The Anterior-Based Muscle-Sparing Approach to Total Hip Arthroplasty

Jeffrey A. Geller
Brian J. McGrory
Editors

MOREMEDIA

Springer

The Anterior-Based Muscle-Sparing Approach to Total Hip Arthroplasty

Jeffrey A. Geller • Brian J. McGrory
Editors

The Anterior-Based Muscle-Sparing Approach to Total Hip Arthroplasty

Springer

Editors
Jeffrey A. Geller
Department of Orthopedic Surgery
New York Presbyterian-Columbia
University Irving Medical Center
New York, NY, USA

Brian J. McGrory
Department of Orthopedic Surgery
Tufts University School of Medicine
and Maine Medical Center
Falmouth, ME, USA

ISBN 978-3-031-02058-2 ISBN 978-3-031-02059-9 (eBook)
https://doi.org/10.1007/978-3-031-02059-9

This Springer imprint is published by the registered company Springer Nature Switzerland AG
The registered company address is: Gewerbestrasse 11, 6330 Cham, Switzerland

I want to dedicate this book to my parents, Herbert Geller (1928–2010) and Elisabeth Geller (1936–), who instilled in me my core values and work ethic, and taught me to never give up. And by the way, go Yankees.

– Jeffrey A. Geller

For my father John P. McGrory (1938–2021) and my brother John J. McGrory (1962–2021), two of the greatest teachers I have ever known.

– Brian J. McGrory

Foreword

Orthopedic surgery is filled with numerous examples of great paradox.

As a collective, we view ourselves as innovators, desire new and improved devices, technology, and protocols. At the same time, the paradox is that these same surgeons are often the most resistant to innovation and improvements in surgical technique.

The Anterior Based Muscle Sparing Approach to Total Hip Arthroplasty is an extremely important and timely contribution to orthopedic practice.

While there have been numerous innovations in our devices and materials, surgeons have traditionally had difficulty learning improved muscle sparing techniques. Younger surgeons often don't realize that total hip replacement started with trochanteric osteotomy for exposure and abductor tensioning; however, just as early in history, Maurius Smith-Peterson developed an extensile direct anterior approach for cup arthroplasty. Various other anterior approaches were used for treatment of hip infection and fracture including the Watson-Jones approach.

So, what is new?

The authors and editors should truly be congratulated for advancing surgical care through a detailed and clearly illustrated text showing the most detailed and descriptive forms of this surgical approach. With the knowledge from this text, surgeons will be safer, more facile, and cause less tissue trauma, while allowing use of the most modern implants and bearing surfaces.

This book is a must have for practicing surgeons, especially those moving to anterior procedures, and certainly for residents and fellows in training. The detail and clarity in technique, as well as beautiful photos, are integral to our learning the ABMS approach.

In addition, those surgeons using this ABMS approach are certain to learn a tip or trick to make routine exposures easier, and complex exposures possible.

Andrew A. Freiberg, MD
Newton-Wellesley Hospital, Newton, MA, USA

Mass General Brigham Health, Boston, MA, USA

Former Chief Medical Officer, Zimmer Biomet, Warsaw, IN, USA

Preface

Total hip arthroplasty (THA) surgery has endured a long journey through history. The earliest experiences started in the 1920s with several different poorly designed implants such as the cup arthroplasty with porcelain, the low-friction arthroplasty using Teflon cups, and the catastrophes of metal-on-metal articulations. These utter failures have humbled us to continue to search for better implant designs and have compelled us to improve and develop the current generation of modern implants which have now been shown to survive beyond 25–30 years.

In addition to the advancements in implant materials over the last few decades, surgical approach has been less recognized but equally impactful in the way modern hip replacement surgery has improved. What started out as a surgical procedure that led to well over a liter of blood loss, a prolonged inpatient hospital stay, a near-guaranteed blood transfusion, a very high rate of complications, and close to a year's worth of recovery, THA has now evolved into a potentially outpatient procedure with a relatively minimal time to recover.

In 2004, one of the co-editors (BJM) served as the chairperson of the American Association of Hip and Knee Surgeons taskforce on minimally invasive (MIS) total joint arthroplasty, just as various different surgical techniques were being first introduced. The group concluded that such surgeries are "of great interest to patients, joint replacement surgeons, and third- party payers" and that "this interest is based on the promise of same or better long-term results with shorter and less painful recovery." As early as 2004, which also happened to coincide with one of Dr. Röttinger's first descriptions of this modification of the Watson-Jones surgical interval, the committee noted that proof for this optimism was not yet available at the time and stated that supportive scientific evidence and rigorous evaluation of such newer techniques were warranted.

The anterior-based muscle sparing (ABMS) approach to the hip is yet another step in the evolution of this truly life-changing intervention of THA. Just consider how surgical approach can dramatically affect a patients' post-operative recovery and ultimate outcome, and how that has changed the expectations of patients today.

This textbook contains an incredible wealth of information and experience, put forth by some of the pioneers who have learned this surgical approach and developed their techniques with little to no formal framework or guidance. Though the ABMS approach has been utilized in different pockets around the world, this work marks the first collection and compendium of information on this surgical approach. The reader will find a wealth of information beginning with Dr. Röttinger's early experience as he began to popularize this unique surgical approach, the versatility of ABMS to be done in either the supine or the lateral position, and how to avoid complications through the "learning curve" and moving on to some of the most advanced means of doing revision surgery through the ABMS approach. This is a comprehensive work of science that should afford even the novice hip surgeon the tools to study and implement this technique into their surgical practice.

Our patients, of course, are the ultimate beneficiary of such a technique. Along with substantial improvements in materials, pre-operative optimization, and perioperative care, THA in the twenty-first century is very promising indeed. A primary goal of publishing this book was to summarize a worldwide experience with the ABMS technique, describe nuances for primary and revision surgeries, and offer technical points, postoperative care, and outcomes data – all in one place. Because of unclear nomenclature used with the ABMS THA approach, it can be vexing to search in the usual literature databases to access all of this information. Previous descriptions of this surgical approach include "Modified Watson-Jones," "Röttinger Approach," "Abductor Sparing Watson-Jones," "Anterolateral MIS," or the "ABLE approach," all of which have been confusing and perhaps implying different treatment of the surrounding musculature while approaching the hip joint.

The name "ABMS" approach was largely defined by one of our co-authors, Dr. Scott Kelley, who recognized that the nomenclature was scattered and not well delineated. Dr. Kelley was an early proponent of the ABMS approach, who was not deterred by early skepticism from leaders in the anterior hip establishment, and his perseverance is a big reason for the growing pool of talented hip surgeons who utilize this surgical approach today.

In summary, this textbook is yet another small step in the continuing improvement of surgical technique and outcome that we, as a specialty, have further propelled during our years of research and practice. Our patients are the true heroes who unknowingly have taught us where to steer, and how to improve, upon reflection of their complications and adverse events, and we are humbled by their strength each and every day.

New York, NY, USA Jeffrey A. Geller
Falmouth, ME, USA Brian J. McGrory

Acknowledgments

This textbook marks the culmination of over 20 years of education and experience in hip surgery. I have been fortunate in my career to train under and work with some amazing individuals through my residency and fellowship. In addition, I have had the pleasure of training some of the brightest residents and fellows, who have taught me and influenced me as much over my career as I have hopefully done for them. With every teaching conference and research meeting, I am astonished at the bright and inquisitive minds that surround me every day.

Additionally, I would like to acknowledge the thousands of patients who have trusted the care of their hips to me over the years. Without their trust and belief, I would never have developed the skill and experience needed to put together a resource such as this work. I would also like to thank Dr. McGrory. He has been a tremendous partner in this project. His hard work and incredible wealth of knowledge have been a major part of the success of this book.

And of course, I could never have had a successful career without the unwavering support of my family. My dearest wife Leigh, who has supported me and my career from the early days of medical school through the rigors of training and practice, she has shouldered the load of our family, and been a beacon of love and strength for the last 25 years. And to my amazing kids, Caroline, Henry, and Susie, who have developed into young adults that I couldn't be more proud of. Through all of the late nights, travel days away, and weekends at meetings, their love and support has always kept me grounded.

Jeffrey A. Geller

I am very grateful to the talented authors, surgeons, and colleagues whose outstanding contributions have made this book possible. I also feel very fortunate for all of the patients that have taught me over the years, because it was their beliefs and support that encouraged me to learn and hone the anterior-based muscle sparing (ABMS) approach in my own practice. Brigham McKenney, PA-C, has worked with me tirelessly in the operating room and deserves great credit in my growth as an ABMS surgeon. Next, I would like to thank my partners at Maine Medical Center (MMC), particularly George Babikian, MD, and Adam Rana, MD. Dr. Babikian was not only the first to employ this approach in Maine but also an indefatigable champion of this variation of anterior total hip arthroplasty (THA). He is a gifted and generous teacher, outstanding leader, and – among many other accomplishments – the force behind, and engineer of, outpatient THA at MMC. Dr. Rana leads the MMC Joint Replacement Center research and outcomes program, and in addition to being an exceptional ABMS surgeon and teacher, he has led the team that has systematically analyzed our institutional data to add gravitas to the evidence-based reasoning for adopting the ABMS approach. I would like to also acknowledge the backing of Smith and Nephew, Inc. (Memphis, TN) for ongoing institutional research support and also their steadfast commitment to ABMS education nationally and internationally (ABLE advanced anterior approach program). Thank you also to Springer Nature, for supporting this book, and Janakiraman Ganesan, for his role as project coordinator. Finally, I sincerely thank Jeffrey Geller, MD, my co-editor in this undertaking. Dr. Geller envisioned this book, kindly invited me to join him in the project, and has been a fantastic partner in bringing it to fruition.

My family has sustained and supported me throughout my career, and for this I am forever grateful. My wife Lori has been my biggest champion; for the last 35 years, she has encouraged me to pursue my dreams and has done all of the heavy lifting for our family as I chased them. Lori and my wonderful sons Conor and Aidan have been a constant inspiration.

Brian J. McGrory

Contents

1 The Idea of "Minimally Invasive Solution" Total Hip Arthroplasty: History and Perspective Behind the Modernization of Surgery Through the Watson-Jones Muscle Interval. 1
Heinz Röttinger

2 Transitioning to the ABMS Approach. 15
Timothy Kahn, Jill Erickson, and Christopher L. Peters

3 Anatomy of the ABMS Approach to the Hip 21
Nicholas C. Danford and Alexander L. Neuwirth

4 ABMS THA in the Lateral Position 31
George Babikian

5 The ABMS Approach to Total Hip Replacement in the Supine Position 43
Mohammad S. Abdelaal and Peter F. Sharkey

6 Outpatient Total Hip Arthroplasty Using an ABMS Approach 55
Timothy C. Keating, Nabil Mehta, Vasili Karas, and Richard A. Berger

7 ABMS Approach for Cementless Total Hip Replacement. 67
Ian Duensing, Max Greenky, and Rhett Hallows

8 Cemented Total Hip Replacement through the ABMS Approach 77
Michael B. Held, Alirio J. deMeireles, Sohil S. Desai, and Roshan P. Shah

9 Implant Selection in ABMS Surgery 95
Brian J. McGrory

10 Tips and Tricks to Overcome the Learning Curve of the ABMS Approach to the Hip. 105
Johannes F. Plate, Nicholas M. Hernandez, and Scott S. Kelley

11 Surgical Navigation in the ABMS Approach to Total Hip Replacement (THR) 119
M. Giraud, J. Aebi, and J. Cabezas-Davalos

12 Comparison of the ABMS Approach to Other Surgical Approaches for Total Hip Replacement 129
Eddie S. Wu, Mohamed F. Albana, and Ronald E. Delanois

13 Periprosthetic Hip Infection Treatment Through the ABMS Approach 139
Michael Müller

14 How to Avoid Complication in the ABMS Total Hip Replacement 145
Roberto Civinini, Andrea Cozzi-Lepri, Matteo Innocenti, Marco Villano, and Massimo Innocenti

15 Revision of the Acetabulum in Total Hip Arthroplasty 159
Matthew M. Levitsky, Michael B. Held, and Roshan P. Shah

16 Femoral Revision via the ABMS Approach 169
Adam Brekke, Ian Duensing, and Scott S. Kelley

17 Total Hip Replacement for Fragility Fractures Using the ABMS Approach in the Older Adult 187
Michael B. Held, Kyle L. McCormick, and Jeffrey A. Geller

18 Outcomes of the ABMS THA 201
Adam J. Rana, Callahan M. Sturgeon, Brian J. McGrory, and George Babikian

19 Rehabilitation for THA Using the ABMS Approach 211
Brian J. McGrory and Kurt K. Jepson

Index 229

Contributors

Mohammad S. Abdelaal Department of Orthopaedic Surgery, Rothman Orthopedics at Thomas Jefferson University, Philadelphia, PA, USA

J. Aebi Traumatologic and Orthopaedic Surgery, clinique du Pont-de-Chaume, Montauban, France

Mohamed F. Albana Department of Orthopaedic Surgery, Inspira Health, Vineland, NJ, USA

George Babikian Department of Orthopedic Surgery, Maine Medical Center, Falmouth, ME, USA

Richard A. Berger Rush University Medical Center, Chicago, IL, USA

Adam Brekke Texas Hip and Knee Center, Fort Worth, TX, USA

J. Cabezas-Davalos Traumatologic and Orthopaedic Surgery, clinique du Pont-de-Chaume, Montauban, France

Roberto Civinini Orthopedic Unit, Department of Health Sciences, University of Florence, Florence, Italy

Andrea Cozzi-Lepri Orthopedic Unit, Department of Health Sciences, University of Florence, Florence, Italy

Nicholas C. Danford Department of Orthopedic Surgery, Columbia University Irving Medical Center, New York, NY, USA

Ronald E. Delanois Rubin Institute for Advanced Orthopedics, Baltimore, MD, USA

Alirio J. deMeireles Columbia University Medical Center, Department of Orthopaedic Surgery, New York, NY, USA

Sohil S. Desai Columbia University Medical Center, Department of Orthopaedic Surgery, New York, NY, USA

Ian Duensing Adult Reconstruction Division, Department of Orthopedics, University of Virginia, Charlottesville, VA, USA

Jill Erickson Department of Orthopedic Surgery, University of Utah, Salt Lake City, UT, USA

Jeffrey A. Geller Department of Orthopedic Surgery, New York Presbyterian-Columbia University Irving Medical Center, New York, NY, USA

M. Giraud Traumatologic and Orthopaedic Surgery, clinique du Pont-de-Chaume, Montauban, France

Max Greenky Syracuse Orthopedic Specialists, Syracuse, NY, USA

Rhett Hallows North Carolina Orthopedic Clinic, Department of Orthopedic Surgery, Duke University, Durham, NC, USA

Michael B. Held New York Presbyterian-Columbia University Irving Medical Center, New York, NY, USA

Nicholas M. Hernandez Department of Orthopaedics and Sports Medicine, University of Washington School of Medicine, Seattle, WA, USA

Matteo Innocenti Orthopedic Unit, Department of Health Sciences, University of Florence, Florence, Italy

Massimo Innocenti Orthopedic Unit, Department of Health Sciences, University of Florence, Florence, Italy

Kurt K. Jepson Jepson Physical Therapy Consults SP, Saco, ME, USA

Timothy Kahn Department of Orthopedic Surgery, University of Utah, Salt Lake City, UT, USA

Vasili Karas Rush University Medical Center, Chicago, IL, USA

Timothy C. Keating Rush University Medical Center, Chicago, IL, USA

Scott S. Kelley North Carolina Orthopaedic Clinic, Duke University, Durham, NC, USA

Matthew M. Levitsky Columbia University Medical Center, Department of Orthopaedic Surgery, New York, NY, USA

Kyle L. McCormick Columbia University Irving Medical Center, New York Presbyterian Hospital, New York, NY, USA

Brian J. McGrory Department of Orthopedic Surgery, Tufts University School of Medicine and Maine Medical Center, Falmouth, ME, USA

Nabil Mehta Rush University Medical Center, Chicago, IL, USA

Michael Müller Charite University Medicine Berlin, Centre for Musculoskeletal Surgery, Department of Orthopaedics, Berlin, Germany

Alexander L. Neuwirth Department of Orthopedic Surgery, Columbia University Irving Medical Center, New York, NY, USA

Christopher L. Peters Department of Orthopedic Surgery, University of Utah, Salt Lake City, UT, USA

Johannes F. Plate Department of Orthopaedic Surgery, University of Pittsburgh, Pittsburgh, PA, USA

Adam J. Rana Department of Orthopedic Surgery, Maine Medical Center, Falmouth, ME, USA

Tufts School of Medicine, Boston, MA, USA

Heinz Röttinger Arthroplasty Department, München Klinik Neuperlach, Munich, Germany

Roshan P. Shah Columbia University Medical Center, Department of Orthopaedic Surgery, New York, NY, USA

Peter F. Sharkey Department of Orthopaedic Surgery, Sidney Kimmel School of Medicine, Rothman Orthopedics at Thomas Jefferson University, Philadelphia, PA, USA

Callahan M. Sturgeon Department of Orthopedic Surgery, Maine Medical Center, Falmouth, ME, USA

Marco Villano Orthopedic Unit, Department of Health Sciences, University of Florence, Florence, Italy

Eddie S. Wu Premier Orthopaedic Associates of Southern New Jersey, Vineland, NJ, USA

1

The Idea of "Minimally Invasive Solution" Total Hip Arthroplasty: History and Perspective Behind the Modernization of Surgery Through the Watson-Jones Muscle Interval

Heinz Röttinger

Learning Points

- Total hip replacement surgery has evolved to become extremely successful through many different surgical approaches.
- The adoption of the anterior-based muscle-sparing (ABMS) approach to hip arthroplasty represents a successful surgical approach with low rate of learning curve and complications.
- Incision size is less important than the muscle interval through which total hip arthroplasty (THA) is performed.

Introduction

In the first years of this century, the ongoing success of total hip arthroplasty (THA) led to questions about potential future challenges. The improvement of implants, instrumentation, and surgical techniques' standardization led to a steady increase in demand and application. There have long been well-founded concerns about whether current health systems and insurers will be able to cope with increasing cost pressures in the future as technology improves and services expand. Consequently, this cost pressure will also reach the medical health providers like hospitals, clinics, doctors, nurses, physiotherapists, and other medical-associated professions and institutes. Medical health providers are also constantly forced to find solutions to save resources while improving medical quality, also in THA.

The following factors could reduce resource consumption in THA: shortened inpatient stay, improved early functional outcome after surgery, overall reduced rehabilitation time and earlier return to the usual daily routine, reduced blood loss during and after surgery, overall reduced painkiller consumption, and improved outcomes. Surgical trauma very much influences all these factors. It was therefore obvious to develop atraumatic surgical techniques that are gentle on the muscles and tissues. This endeavor very quickly led to the usage of the term "minimally invasive solution (MIS)." However, the MIS techniques in THA hardly correlated with the already existing successful ideas of minimally surgical procedures, like arthroscopy and endoscopy.

The concept of "MIS in THA" should constantly be changing toward further improvement. The original intention was to improve the early functional recovery after THA. There was also hope that an excellent early functional recovery could also positively affect both the short- and the long-term outcomes. The conventional surgi-

H. Röttinger (✉)
Arthroplasty Department, München Klinik Neuperlach, Munich, Germany

J. A. Geller, B. J. McGrory (eds.), *The Anterior-Based Muscle-Sparing Approach to Total Hip Arthroplasty*, https://doi.org/10.1007/978-3-031-02059-9_1

cal techniques already achieved impressive long-term results and possessed a very high standardized level of performance. The introduction of a new surgical procedure often compromises the surgeon, accompanied by the increased occurrence of previously unknown problems and complications. The doubtful positive influence of "MIS THA" compared with conventional hip approaches on the long-term results, a heated discussion about the sense and purpose of these efforts, was pre-programmed from day one.

History of Hip Approaches

Some hip approaches are still associated with the names of famous past orthopedic surgeons. Most of these surgeons, however, were not aware of the problem of divergent working directions in connection with hip arthroplasty. They used the muscle intervals to perform operations around the hip joint. The approaches named after these famous surgeons do not refer to the specific surgical technique connected with hip arthroplasty but to the muscular interval used.

The anterolateral approach using the muscular interval between the gluteus medius muscle and the tensor fascia latae muscle was first published by Lewis Albert Sayre (1820–1900). He was appointed to the faculty at the newly founded Bellevue Medical College in New York, where he was the first professor of orthopedic surgery in America [129]. In addition to a lifetime substantial involvement in public health, Lewis Sayre was particularly concerned in the orthopedic surgical field with the treatment of bone infections. He recognized the importance of creating a stable, chronic fistula to treat bone infections, often combined with joint resection in the hip area. He described the muscular interval between the gluteus medius muscle and the tensor fascia latae muscle as a proven surgical option to approach the hip joint.

Today, the muscular interval between the gluteus medius and the tensor fascia latae is usually associated with the name of Reginald Watson-Jones (1902–1972). In his time, Watson-Jones set the basic standards in fracture treatment [117]. The publication regularly used to define the Watson-Jones approach relates to the treatment of femoral neck fractures [116]. Therefore, the fundamental problem of hip arthroplasty, namely, the divergent working directions during implantation of the acetabular and stem components, is not considered in his publication. Only a derivative of the Watson-Jones approach, the Bauer modification or Bauer approach, frees the access direction for stem implantation by releasing the anterior insertion of the gluteus medius muscle tendon at the greater trochanter. In the end, the detached tendon insertions are refixed to the greater trochanter [7].

Carl Hueter used the anterior approach between the sartorius muscle and the tensor fascia latae muscle to visualize and resect the hip joint in case of infections [52]. An early pioneer of hip arthroplasty was Marius Nygaard Smith-Petersen (1886–1953), to whom the anterior approach is attributed chiefly today [48, 103]. He used the muscular interval between the tensor fascia latae muscle and the sartorius muscle to implant artificial hip joints. In his original anterior approach description, Smith-Petersen detached the tensor fascia latae muscle tendon from the anterolateral iliac crest, then sectioned the reflected head of the rectus muscle, and finally released the piriformis muscle to elevate the proximal femur.

The brothers Robert Judet (1909–1980) and Jean Judet (1905–1995) used the same interval between the tensor fascia latae muscle and the musculus sartorius muscle to visualize the acetabulum and the proximal femur in a modified form, no longer requiring any muscle detachment. Later they combined the extension fracture table with this approach, which made the technique much more effortless [57, 58].

The entire pelvi-trochanteric muscle package inserts onto a small bony area in the lateral greater trochanter. This muscle mass covers the approach to the proximal femur for stem preparation like a backdrop. Long before hip arthroplasty, it was a standard procedure of hip arthrodesis to detach the abductors via greater trochanter osteotomy and subsequently to refix the bone part by osteosynthesis [18].

The brilliant pioneer in hip arthroplasty, Sir John Charnley, perfected trochanteric osteotomy and subsequent refixation [20–22]. Uniquely and meticulously, the long-term results of his THA implantations have been recorded. It is still highly recommended today to take a look at his groundbreaking findings and results [123]. William Hamilton Harris presented an extreme extension of the approach involving a trochanteric osteotomy [45, 46]. Another modification of the trochanteric osteotomy is the Dall technique, in which only the anterior proximal portion of the greater trochanter is detached and refixed [25].

The posterior approach is probably the most popular access technique for hip arthroplasty insertion worldwide. This posterior approach knows many variations and modifications, with the most significant differences in the incision and gluteus maximus splitting [37, 50, 75, 89]. The Moore technique, also known as the "Southern approach," is undoubtedly the most popular posterior approach [84].

The direct lateral approach has also been in use for a long time in orthopedics. Bryan McFarland and Geoffrey Osborne initially described the approach technique with a subtotal detachment of the gluteus medius tendon [80]. The direct lateral approach in the modification by Kevin Hardinge became very popular and widespread, detaching the tendon only in the anterior proximal trochanteric portion and sparing the central part of the gluteus medius insertion predominantly dorsal to it [44].

The different surgical approaches for implanting an artificial hip joint have always been the subject of an ongoing, but over the years, increasingly deadlocked discussion without convincing results. The most common techniques were the posterior approach, the direct lateral approach, the anterolateral approach, and especially in France, the anterior approach in Judet's modification. None of these different approaches could establish itself as clearly superior to another. The surgeons trusted the once learned and familiar technique, appreciated its respective advantages, and accepted its disadvantages or understood how to deal with them. The different approaches were taken as approximately equal in their results. But soon after the turn of the millennium, the entrenched discussions about the preferred hip approach were to be over. The presentation of the minimally invasive philosophy in THA, together with its first approaches to solutions, shook up the stable view violently.

The MIS THA Discussion: Stormy Times

Minimally invasive surgical techniques were increasingly used in routine abdominal surgery, thoracic surgery, and neurosurgery. Orthopedics also benefited from the rapid spread of arthroscopy. The arthroscopy on the large joints allowed surgeons to perform sophisticated operations with very little trauma. Following this general trend, attempts were made in hip arthroplasty to reduce the surgical trauma through revised and newly developed instrumentation. Unfortunately, the term "minimally invasive surgery (MIS)" was used confusingly and provocatively broadly at the beginning of this development without consensus regarding its definition. Any effort to deliberately modify the surgical wound and approach to reduce the associated tissue trauma in hip arthroplasty claimed the term "minimally invasive solution" in THA. An incision length of the surgical wound of less than 10 cm was propagated early on as an objective threshold value for the justified claim of "MIS THA," also with an unmodified surgical technique [8, 23, 28, 38, 99].

Some discussants found it helpful to divide the different MIS approaches into two basic categories: firstly, the "minimally incision approaches," defined from the conventional approaches such as posterior, direct lateral, and anterolateral access, usually by shortening the surgical wound alone, and, secondly, the "two-incision approach" [11, 38]. This subdivision gave the two-incision technique a distinguishing feature as a novel MIS THA procedure.

The two-incision technique (2IT) was originally an idea of Dana C. Mears and was intensively promoted by Richard Berger [11–13, 82]. The two-incision technique in particular strongly encouraged the polarization of the entire discussion about MIS hip arthroplasty. The implantation of hip arthroplasty with the two-incision technique was performed via two independent approaches. The cup implantation used a direct anterior approach. The stem implantation needed a separate posterior skin incision. The shaft rasp was moved bluntly through the essentially unprotected gluteal muscle tissue, its bony adaptation only controlled by fluoroscopic guidance. This blind approach to stem implantation left conventionally positioned orthopedic surgeons very uncomfortable and challenged massive opposition. Also, direct transmuscular femoral preparation without sufficient tissue protection was suspect to many practitioners.

The 70th Annual Meeting Proceedings of the American Academy of Orthopaedic Surgeons in New Orleans in 2003 dedicated much discussion to the topic of MIS THA [11, 39, 60 101, 106, 122]. The issue was also high on the agenda at the Annual Meeting of the American Orthopaedic Association in Charleston, 2003 [15]. Clever and forward-looking orthopedic surgeons were already securing patent rights [128]. After a short time, the first books on minimally invasive arthroplasty appeared [31, 51]. Sustained evidence-based results on the supposed benefits of these minimally invasive surgical techniques were initially unavailable or later often could not be reproduced from interested users [2, 121]. Lawrence D. Dorr sums up the critics' point of view in the title of his article: The mini-incision hip: building a ship in a bottle [29].

The April 2005 issue of the renowned *Journal of Bone and Joint Surgery* (Am) (JBJS) brought a bang. Already in the editorial, D.J. Berry dealt with the minimally invasive topic and formulated that minimally invasive total hip arthroplasty has not yet shown any demonstrable advantages [14]. Immediately following in the same issue were presentations of three case histories with catastrophic complications after minimally invasive hip arthroplasty [34]. Case reports of postoperative complications in the exclusive JBJS were very unusual. In the following article on this issue, L. Ogonda et al. published the well-known study, which later served as an essential witness in the argumentation against MIS THA [88]. This scientifically brilliantly prepared article from the team of David Beverland, a fellow of Sir John Charnley, dealt in the prospective randomized study with the posterior approach and the effect of different lengths of the surgical wound (smaller than 10 cm or standard length 16 cm) on the patients' outcome. In 219 unilaterally implanted hip arthroplasties, no differences were found between the two groups regarding blood loss, pain level, and functional outcome 6 weeks postoperatively.

Further publications by the authors reported the results followed a more extended period postoperatively. In gait pattern and movement kinematics, they found no difference between the two groups at any later time point [9, 10, 71].

A new innovative MIS surgical technique was introduced in this heated atmosphere called "Anterolateral Mini-Incision Hip Replacement Surgery: A Modified Watson-Jones Approach" [16]. The tissue- and muscle-sparing approach uses the anterolateral muscle interval between the gluteus medius muscle and tensor fascia latae muscle. During surgery, the patient is fixed in the lateral position, and the surgeon stands in front of the patient. The acetabulum preparation is very unspectacular and provides excellent exposure. For stem implantation, the leg rotates externally and is placed adducted and positioned to the posterior aspect of the patient, making the proximal end of the femur freely accessible [16, 97]. Later, the name "Röttinger approach" became internationally accepted for this approach.

In the following years, the discussion persistently revolved around the evidence of the various MIS THA options. In retrospect, there are two different categories of MIS approaches. On the one hand, all conventional surgical techniques aiming to reduce the size of the surgical wound without actually changing the surgical technique can be grouped. This group concerns the posterior approach, the direct lateral approach, and the anterolateral approach. In contrast, the second category includes the innovative minimally invasive surgical techniques performing the implantation of a hip arthroplasty without muscle transection. This second group consists of the "two-incision technique – 2IT," the "Röttinger approach – ABMS," and the "direct anterior approach – DAA." This anterior approach had been known for decades and was a proven standard approach in France [57, 58]. In the search for improved MIS approach techniques, the DAA experienced continuously growing popularity [60, 61, 79].

Overall, the mere reduction of the surgical wound with an unchanged surgical technique does not lead to convincingly better results. This observation also applies to the immediate postoperative course [3, 66, 67, 88, 92, 95, 100, 120, 125]. There are only very few studies that deviate from this statement and also see advantages, even if only slight, in the immediate postoperative course due to a reduction of the surgical wound [30, 112].

The highly polarized discussion about the two-incision technique (2IT) substantially impacted the overall debate on the MIS THA topic. Initially, reports of encouraging early results of 2IT raised eyebrows [11, 13, 32]. However, criticism of the 2IT existed initially but increased significantly over time. The 2IT proved to be very complicated with a very flat learning curve. Different reports showed an extensive spread in terms of results and approach-connected complications. This procedure was burdened with an increased complication rate in the early learning period and long-term use after the initial learning phase [2, 5, 63]. Richard Berger also gave up his commitment to 2IT very early. Thus, this technique had lost its authoritative protagonist. As a result, 2IT disappeared from the scientific discussion.

An increasing interest in the DAA accompanied this withdrawal of the 2IT. The DAA is a long-established surgical technique that fulfills the requirements of the MIS THA [57, 58, 60, 61, 72, 79]. All minimally invasive approaches have in common to work in a very confined space targeting to cause as minor tissue trauma as possible. After several years of experience with a conventional approach, switching to a minimally invasive approach was a real challenge for many surgeons. Also, the DAA is characterized by an increase in complications in the early learning phase, including periprosthetic fractures [33, 68, 105]. It often affords to cut the ischiofemoral ligament, the piriformis tendon, and the conjoint tendon to elevate the proximal femur [96, 126, 127, 130]. Temporary or permanent damage to the lateral cutaneous femoral nerve is observed postoperatively in up to 37% of cases [91]. In obese patients, the approach is technically very demanding. Other critics of the DAA pronounce the difficulties to extend the approach for managing intraoperative complications and/or in cases of revision surgery, especially on the femoral side [78].

The "Röttinger Approach" in Comparison

Besides the two-incision technique, the Röttinger approach (ABMS – anterior-based muscle-sparing) was a real innovative contribution to the discussion of minimally invasive THA. This approach is very similar to the posterolateral approach, except that all essential steps are performed reciprocally. In the original description, the patient is in a lateral position. The surgeon stands in front of the patient in the ABMS. The leg is positioned dorsally from the patient during the operation, and the individual leg rotations for femoral preparation are in opposite directions in each case [16]. It became apparent that surgeons interested in the THA MIS were almost exclusively concerned with the ABMS or the DAA.

The early discussion comparing ABMS with DAA pointed out that the ABMS is an intermuscular approach, and in contrast, the DAA is an internervous approach. This discussion targets the fact that although the ABMS uses the muscle gap between the tensor fascia latae muscle and gluteus medius muscle, the superior gluteal nerve innervates both muscles. The superior gluteal nerve usually crosses this muscular interval mainly in the proximal past but occasionally with significant variation [1, 54, 56, 107, 111]. In a study of 26 patients, fatty degeneration of the tensor fascia latae muscle was found in 42% of cases [110]. Another study with 70 patients compared the anterolateral approach with the direct lateral approach and the posterior approach regarding different electromyographic changes in the tensor fascia latae muscle, the gluteus medius, and maximus muscles. Most frequently, the ABMS showed a lesion of the inferior branch of the superior gluteal nerve concerning the innervation of the tensor fascia latae muscle in 73% of the cases.

Parts of the gluteus medius muscle were affected in only 9% of cases with the ABMS, whereas the maximus muscle showed no lesions. The direct lateral approach showed partial denervation of the gluteus medius muscle in 81.8% of cases and the tensor fascia latae muscle in 48% of cases. The gluteus maximus was also partially damaged in 29% of cases with the direct lateral approach. With the posterior approach, partial denervation of the gluteus medius was found in 53% of patients and the maximus muscle in 71%. At least partial denervation of the tensor fascia latae also occurred in 14% of cases with the posterior approach [24].

In a prospective randomized controlled trial, 30 patients with THA underwent bilateral surgery, randomizing one side to the direct anterior approach and the opposite side to the ABMS. Prospective comparative clinical outcomes, the incidence of lateral femoral cutaneous nerve damage, and tensor fasciae latae atrophy were assessed. One year postoperatively, no difference was observed in clinical outcome. There was transient damage to the lateral femoral cutaneous nerve with the direct anterior approach in 30% of cases. In magnetic resonance imaging (MRI), 3 months after surgery, there was significantly more atrophy of the tensor fasciae latae in patients with direct anterior approach compared to the (22.8% vs. 17.7%) [131].

A similar study comes to a comparable conclusion. The prospective randomized study with 44 patients compared changes in the tensor fascia latae after ABMS access and direct lateral access by MRI examinations preoperatively, 3 months postoperatively, and 12 months postoperatively. The ABMS group showed more minor and no high-grade signs of degeneration in the tensor fascia latae muscle and the anterior portion of the gluteus medius muscle than the group with the direct lateral approach [86]. Up to 2 years, postoperatively recovery can be observed [109].

In a retrospective study of 164 patients after THA by the use of ABMS, the tensor fasciae latae muscle was evaluated for postoperative atrophy via comparative evaluation of available preoperative and postoperative magnetic resonance imaging. Atrophy of the tensor fasciae latae was noted in 13 cases (8%). In patients with high body mass index, atrophy of the tensor fasciae latae was significantly higher [132].

In contrast, no nerve crosses the muscle gap between the sartorius muscle and tensor fascia latae muscle being an internervous interval. On the other hand, in DAA, muscles regularly inserting dorsally on the greater trochanter, such as the piriformis muscle and the conjoint tendon, need to be detached for elevation to the proximal femur [96, 98, 126, 127, 130]. Thus, the DAA would require similar muscle detachment as the posterior approach but without the possibility to reinsert the detached tendons. In contrast, with the ABMS approach, at least the posterior attachment of the piriformis does not appear to be at risk [98]. The lateral cutaneous femoral nerve damage often observed with the DAA is unknown with the ABMS. Also, the ABMS approach does not experience limitations in patients with increased body mass index [114]. With both DAA and ABMS, there is no increased risk of femoral nerve damage (0.4–0.6%), but in principle, femoral nerve damage has a poor recovery tendency [35].

When changing a proven and long-standing standardized surgical technique to a new procedure, a learning curve and an initially increased incidence of complications are expected [27, 42, 64]. New to the ABMS and DAA, interested surgeons also had to learn these lessons. In this regard, the most common problem when switching to these minimally invasive approach techniques is the initially increased incidence of periprosthetic fracture by preparing the femur and implanting the stem [47, 65, 68, 70]. The cramped conditions and the requirement for muscle-sparing make orthograde alignment of the femur difficult and thereby increase the stress on the medial calcar [33, 73, 105]. By making femoral preparation more challenging to access, DAA and ABMS have contributed to the proliferation of short-stem prostheses [69, 73, 74, 127].

Increased variability in acetabular component placement has also been observed, at least initially [49, 55, 119].

The access-related long-term results after hip arthroplasty are all convincingly good. This statement applies to all surgical approach techniques, both to the minimally invasive approaches such as DAA and ABMS and the conventional approaches such as the anterolateral, the direct lateral, and the posterolateral approaches.

A meta-analysis evaluated 28 studies with 2825 patients (1428 minimally invasive, 1421 conventional approaches). There was no difference in the Harris Hip Score and the radiological evaluation for the different approaches. Overall, the MIS approaches showed less blood loss but also more frequent nerve damage [104]. However, this analysis included both randomized and non-randomized studies. All different minimally invasive surgical techniques built one joint group by data pooling. Also, some of the same cohorts were counted twice via publication in various studies [62].

A further meta-analysis considering 14 randomized studies with 1174 patients found again reduced blood loss for the minimally invasive approaches. Compared with the posterior approach, there was no difference in pain medication, postoperative radiological evaluation, the frequency of complications, and the final functional result [124]. Most probably, the discussion about the efficiency of the individual surgical approaches in THA is not manageable via meta-analyses [83].

Numerous randomized studies are also available. It seems decisive which approaches are compared and the time points of investigations. A prospective randomized study investigated the MIS derivatives from the anterolateral approach, the direct lateral approach, and the posterolateral approach. The research focused on quality of life, patient satisfaction, and possible radiological differences. The overall outcome showed no difference in any approach [41].

A small study of 48 randomized patients compared isokinetic abilities and patient-reported outcome measures (PROMs) after ABMS and after posterolateral approach. There were no differences between 6 months and 12 months after surgery [19]. A similar prospective randomized study with a total of 156 patients cannot attribute a decisive advantage to any group at the same examination intervals [41]. Over a follow-up of 12 months, the ABMS shows no significant difference about movement patterns and electromyographic changes compared with the direct lateral approach [94].

Especially in the long-term results, the minimally invasive approaches do not show any tangible differences compared to the conventional approaches. Still, they prove to be an alternative access option without disadvantages [17, 26, 53, 55, 59, 67, 93, 113]. Also, no increased periprosthetic ossifications are observed with ABMS [81].

Individual studies see differences, especially in comparing the ABMS to the direct lateral approach in long-term results. Comparing these two approaches, the ABMS shows better static and functional results with higher patient satisfaction. Already postoperatively, these patients have less pain, and the total hospital stay was comparatively somewhat shorter [108].

A retrospective study compared ABMS and DAA in a total of 220 patients. In a direct comparison of the two minimally invasive approaches, the ABMS had a shorter and reduced opioid use and a slightly shorter inpatient stay [36].

A prospective randomized study compared 42 patients with the ABMS approach and 41 patients with the direct lateral approach. Reduced blood loss was registered for the ABMS approach. Other observations such as peri- and postoperative complications, postoperative analgesic consumption, and length of hospital stay were overall comparable. The early functional test was slightly improved for the ABMS group but showed no difference after 1 year [76].

In evaluating the approach-comparative studies, the long-term results between the ABMS and DAA compared to the posterior approach showed the most minor difference. In this comparison, however, the ABMS and the DAA have one clear advantage. Overall, these MIS approaches have a lower risk of dislocation in the short, medium, and long term [4, 43, 77, 102].

The better early postoperative outcomes are almost universally seen with the DAA and ABMS minimally invasive approaches compared with the conventional approaches [6, 85, 87, 90, 115, 118, 124]. In a randomized, double-blind study, 120 patients underwent minimally invasive anterolateral and classic anterolateral and minimally invasive posterolateral and classic posterolateral surgery. The study assessed the implant position, leg length differences, and the Harris Hip Score. During the observation period of 6 weeks postoperatively, the ABMS showed significantly better results than the other approaches. However, this difference no longer existed at the control 1 year after surgery. Initially, an increased number of periprosthetic shaft fractures were registered with the ABMS, but in the further course, this complication was no longer observed [40].

The longer the minimally invasive approaches are in clinical use, the less the typically increased complication rates are reported compared to conventional approaches [43, 90, 124].

Conclusion

With the experience of several decades in total hip arthroplasty, the following conclusion can be summarized: DAA, ABMS, and posterior approach achieve comparable results at any time after surgery. The posterior approach has an increased risk of dislocation. Here, the minimally invasive, anterior-based approaches stand out due to their preserved posterior capsule stability. The ABMS and the posterior approach can be extended without problems and suitable for revision surgery. While the posterior approach and most likely also the DAA cut the piriformis muscle and the conjoint tendon, the ABMS often partially or entirely denervates the tensor fascia latae muscle via damage to the superior gluteal nerve. Both the detachment of the small external rotators, including the piriformis muscle, and the weakening of the tensor fascia latae muscle do not affect the functional outcome after THA. However, the abductors appear to be very vulnerable and should be spared as much as possible in their insertion area.

References

1. Apaydin N, Kendir S, Loukas M, Tubbs RS, Bozkurt M. Surgical anatomy of the superior gluteal nerve and landmarks for its localization during minimally invasive approaches to the hip. Clin Anat. 2013;26:614–20.
2. Archibeck MJ, White REJ. Learning curve for the two-incision total hip replacement. Clin Orthop Relat Res. 2004;(429):232–8.
3. Asayama I, Kinsey TL, Mahoney OM. The effect of incision size on clinical outcomes and recovery after total hip arthroplasty with the anterolateral approach. J Arthroplasty. 2004;19:257.
4. Austin MS, Rothman RH. Acetabular orientation: anterolateral approach in the supine position. Clin Orthop Relat Res. 2009;467:112–8.
5. Bal BS, Haltom D, Aleto T, Barrett M. Early complications of primary total hip replacement performed with a two-incision minimally invasive technique. J Bone Joint Surg Am. 2005;87:2432–8.
6. Barrett WP, Turner SE, Leopold JP. Prospective randomized study of direct anterior vs postero-lateral approach for total hip arthroplasty. J Arthroplast. 2013;28:1634–8.
7. Bauer R, Kerschbaumer F, Poisel S, Oberthaler W. The transgluteal approach to the hip joint. Arch Orthop Trauma Surg. 1979;95:47–9.
8. Belsky MR. What's new in orthopaedic surgery. J Am Coll Surg. 2003;197:985–9.
9. Bennett D, Ogonda L, Elliott D, Humphreys L, Beverland DE. Comparison of gait kinematics in patients receiving minimally invasive and traditional hip replacement surgery: a prospective blinded study. Gait Posture. 2006;23:374–82.
10. Bennett D, Ogonda L, Elliott D, Humphreys L, Lawlor M, Beverland D. Comparison of immediate postoperative walking ability in patients receiving minimally invasive and standard-incision hip arthroplasty: a prospective blinded study. J Arthroplast. 2007;22:490–5.
11. Berger RA. The technique and early results of the two-incision minimally invasive total hip arthroplasty. Proceedings of the 31th Open Meeting of the Hip Society. 70th Annual Meeting Proceedings of the American Academy of Orthopaedic Surgeons, New Orleans, p. 40. 2003.
12. Berger RA. Total hip arthroplasty using the minimally invasive two-incision approach. Clin Orthop Relat Res. 2003;417:232–41.
13. Berger RA, Jacobs JJ, Meneghini RM, Della Valle C, Paprosky W, Rosenberg AG. Rapid rehabilita-

tion and recovery with minimally invasive total hip arthroplasty. Clin Orthop Relat Res. 2004;(429): 239–47.

14. Berry DJ. "Minimally invasive" total hip arthroplasty. J Bone Joint Surg Am. 2005;87:699–700.
15. Berry DJ, Berger RA, Callaghan JJ, Dorr LD, Duwelius PJ, Hartzband MA, Lieberman JR, Mears DC. Minimally invasive total hip arthroplasty. Development, early results, and a critical analysis. Presented at the Annual Meeting of the American Orthopaedic Association, Charleston, South Carolina, USA, June 14, 2003. J Bone Joint Surg Am. 2003;85:2235–46.
16. Bertin KC, Röttinger H. Anterolateral mini-incision hip replacement surgery. Clin Orthop Relat Res. 2004;429:248–55.
17. Bonnin MP, Fessy MH, Van Rooij F, Nover L, Artro I, Ait-Si-Selmi T. No differences in midterm sports participation or functional scores after total hip arthroplasty by posterolateral vs anterolateral approach. J Arthroplast. 2020;35:3656–60.
18. Brackett EG. A study of the different approaches to the hip-joint, with special reference to the operations for curved trochanteric osteotomy and for arthrodesis. Boston Med Surg J. 1912;166:235–42.
19. Cankaya D, Inci F, Karakus D, Turker HB, Kahve Y, Neyisci C. Isokinetic performance and function are similar after total hip arthroplasty applied with a posterior or anterolateral approach: a randomised controlled trial. Hip Int. 2021;11207000211012989
20. Charnley J. Total prosthetic replacement of the hip. Reconstr Surg Traumatol. 1969;11:9–19.
21. Charnley J. Low friction arthroplasty of the hip. Berlin, Heidelberg: Springer; 1979.
22. Charnley J, Ferreiraade S. Transplantation of the greater trochanter in arthroplasty of the hip. J Bone Joint Surg Br. 1964;46:191–7.
23. Chimento GFPV, Sharrock N, Kahn B, Cahil J, Sulco TP. Minimally invasive total hip arthroplasty: a prospective randomized study (paper no. 276). 70th Annual Meeting Proceedings of the American Academy of Orthopaedic Surgeons, New Orleans, p. 637. 2003.
24. Chomiak J, Huracek J, Dvorak J, Dungl P, Kubes R, Schwarz O, Munzinger U. Lesion of gluteal nerves and muscles in total hip arthroplasty through 3 surgical approaches. An electromyographically controlled study. Hip Int. 2015;25:176–83.
25. Dall D. Exposure of the hip by anterior osteotomy of the greater trochanter. A modified anterolateral approach. J Bone Joint Surg Br. 1986;68:382–6.
26. Delanois RE, Sultan AA, Albayar AA, Khlopas A, Gwam CU, Sodhi N, Lamaj S, Newman JM, Mont MA. The Röttinger approach for total hip arthroplasty: technique, comparison to the direct lateral approach and review of literature. Ann Transl Med. 2017;5:S31.
27. Den Hartog YM, Mathijssen NMC, Vehmeijer SBW. The less invasive anterior approach for total HIP arthroplasty: a comparison to other approaches and an evaluation of the learning curve - a systematic review. Hip Int. 2016;26:105–20.
28. Dorr LD. Mini-incision for THA: pros, cons and experience to date. Proceedings of the 31th Open Meeting of the Hip Society, New Orleans, p. 18. 2003
29. Dorr LD. The mini-incision hip: building a ship in a bottle. Orthopedics. 2004;27(192):194.
30. Dorr LD, Maheshwari AV, Long WT, Wan Z, Sirianni LE. Early pain relief and function after posterior minimally invasive and conventional total hip arthroplasty. A prospective, randomized, blinded study. J Bone Joint Surg Am. 2007;89:1153–60.
31. Duncan CP, Masri BA. Minimally invasive joint reconstruction. Philadelphia: W. B. Saunders Company; 2004.
32. Duwelius PJ, Burkhart RL, Hayhurst JO, Moller H, Butler JB. Comparison of the 2-incision and mini-incision posterior total hip arthroplasty technique: a retrospective match-pair controlled study. J Arthroplast. 2007;22:48–56.
33. Eto S, Hwang K, Huddleston JI, Amanatullah DF, Maloney WJ, Goodman SB. The direct anterior approach is associated with early revision total hip arthroplasty. J Arthroplast. 2017;32:1001–5.
34. Fehring TK, Mason JB. Catastrophic complications of minimally invasive hip surgery. A series of three cases. J Bone Joint Surg Am. 2005;87:711–4.
35. Fleischman AN, Rothman RH, Parvizi J. Femoral nerve palsy following total hip arthroplasty: incidence and course of recovery. J Arthroplast. 2018;33:1194–9.
36. George NE, Gwam CU, Etcheson JI, Smith SS, Semenistyy AA, Delanois RE. Short-term outcomes of the supine muscle-sparing anterolateral versus direct lateral approach to primary total hip arthroplasty. Hip Int. 2019;29:504–10.
37. Gibson A. Posterior exposure of the hip joint. J Bone Joint Surg Br. 1950;32-b:183–6.
38. Goldstein WM, Branson JJ, Berland KA, Gordon AC. Minimal-incision total hip arthroplasty. J Bone Joint Surg Am. 2003;85-A Suppl 4:33–8.
39. Goldstein WM, Gordon AC, Branson JJ, Berland K. Minimally incision total hip arthgroplasty (scientific exhibition no. SE204). 70th Annual Meeting Proceedings of the American Academy of Orthopaedic Surgeons, New Orleans, pp. 625–3. 2003.
40. Goosen JH, Kollen BJ, Castelein RM, Kuipers BM, Verheyen CC. Minimally invasive versus classic procedures in total hip arthroplasty: a double-blind randomized controlled trial. Clin Orthop Relat Res. 2011;469:200–8.
41. Greidanus NV, Chihab S, Garbuz DS, Masri BA, Tanzer M, Gross AE, Duncan CP. Outcomes of minimally invasive anterolateral THA are not superior to those of minimally invasive direct lateral and posterolateral THA. Clin Orthop Relat Res. 2013;471:463–71.

42. Gustke K. Anterior-based muscle-sparing approach for THA. Semin Arthroplast. 2018;29:137–41.
43. Hansen BJ, Hallows RK, Kelley SS. The Röttinger approach for total hip arthroplasty: technique and review of the literature. Curr Rev Musculoskelet Med. 2011;4:132–8.
44. Hardinge K. The direct lateral approach to the hip. J Bone Joint Surg Br. 1982;64:17–9.
45. Harris WH. A new lateral approach to the hip joint. JBJS. 1967;49:891–8.
46. Harris WH. Extensive exposure of the hip joint. Clin Orthop Relat Res. 1973;91:58–62.
47. Herndon CL, Nowell JA, Sarpong NO, Cooper HJ, Shah RP, Geller JA. Risk factors for periprosthetic femur fracture and influence of femoral fixation using the mini-anterolateral approach in primary total hip arthroplasty. J Arthroplast. 2020;35:774–8.
48. Hernigou P. Smith-Petersen and early development of hip arthroplasty. Int Orthop. 2014;38:193–8.
49. Hjorth MH, Lorenzen ND, Soballe K, Jakobsen SS, Stilling M. Equal primary fixation of resurfacing stem, but inferior cup fixation with anterolateral vs posterior surgical approach. A 2-year blinded randomized radiostereometric and dual-energy X-ray absorptiometry study of metal-on-metal hip resurfacing arthroplasty. J Arthroplast. 2017;32:3412–20.
50. Horwitz T. The posterolateral approach in the surgical management of basilar neck, intertrochanteric and subtrochanteric fractures of the femur; a report of its use in 36 acute fractures. Surg Gynecol Obstet. 1952;95:45–50.
51. Hozack WJ, K M, Nogler M, Bonutti PM, Rachbauer F, Schaffer JL, Donnelly WJ, editors. Minimally invasive total joint arthroplasty. Berlin Heidelberg: Springer; 2004.
52. Hueter C. Hueter-Lossen's Grundriss der Chirurgie. Leipzig: F.C.W. Vogel; 1890.
53. Inaba Y, Kobayashi N, Yukizawa Y, Ishida T, Iwamoto N, Saito T. Little clinical advantage of modified Watson-Jones approach over modified mini-incision direct lateral approach in primary total hip arthroplasty. J Arthroplast. 2011;26:1117–22.
54. Ince A, Kemper M, Waschke J, Hendrich C. Minimally invasive anterolateral approach to the hip: risk to the superior gluteal nerve. Acta Orthop. 2007;78:86–9.
55. Innmann MM, Streit MR, Kolb J, Heiland J, Parsch D, Aldinger PR, Konigshausen M, Gotterbarm T, Merle C. Influence of surgical approach on component positioning in primary total hip arthroplasty. BMC Musculoskelet Disord. 2015;16:180.
56. Jacobs LG, Buxton RA. The course of the superior gluteal nerve in the lateral approach to the hip. J Bone Joint Surg Am. 1989;71:1239–43.
57. Judet J, Judet R. The use of an artificial femoral head for arthroplasty of the hip joint. J Bone Joint Surg Br. 1950;32-b:166–73.
58. Judet R, Judet J. Technique and results with the acrylic femoral head prosthesis. J Bone Joint Surg Br. 1952;34-B 2:173–80.
59. Kagan RP, Greber EM, Richards SM, Erickson JA, Anderson MB, Peters CL. Advantages of an anterior-based muscle-sparing approach in transitioning from a posterior approach for total hip arthroplasty: minimizing the learning curve. J Arthroplast. 2019;34:2962–7.
60. Kennon RE, Keggi JM, Wetmore RS, Zatorski LE, Huo MH, Keggi KJ. Total hip arthroplasty through a minimally invasive anterior surgical approach. J Bone Joint Surg Am. 2003a;85-A Suppl 4:39–48. https://doi.org/10.2106/00004623-200300004-00005.
61. Kennon RE, Keggi JM, Wetmore R, Zatorski LE, Keggi KJ. Total hip arthroplasty using the minimally invasive anterior surgical approach (scientific exhibition no. SE202). 70th Annual Meeting Proceedings of the American Academy of Orthopaedic Surgeons, New Orleans, p. 652. 2003b.
62. Khan RJ. Comments on Smith et al.: minimally invasive versus conventional exposure for total hip arthroplasty: a systematic review and meta-analysis of clinical and radiological outcomes. Int Orthop. 2011;35:299; author reply 301–2.
63. Ki SC, Kim BH, Ryu JH, Yoon DH, Chung YY. Total hip arthroplasty using two-incision technique. Clin Orthop Surg. 2011;3:268–73.
64. Kijima H, Tateda K, Yamada S, Nagoya S, Fujii M, Kosukegawa I, Kawano T, Miyakoshi N, Yamashita T, Shimada Y. Changes in invasiveness and latent infection rate associated with switching the approach in total hip replacement. Clin Med Insights Arthritis Musculoskelet Disord. 2021;14:11795441211031340.
65. Kim Y, Pour AE, Lazennec JY. Low pelvic incidence is a risk factor for intraoperative complications in minimally invasive anterolateral approach for total hip arthroplasty. Hip Int. 2020;1120700020953525
66. Kim YH. Comparison of primary total hip arthroplasties performed with a minimally invasive technique or a standard technique: a prospective and randomized study. J Arthroplast. 2006;21:1092–8.
67. Kohnen C, Van Cauter M, M'bra I, Feyder C, Wallard L, Detrembleur C, et al. Minimal-invasive posterior, anterior and anterolateral approach in hip replacement: is there a difference in functional outcome and restoration of hip biomechanics? SM Orthop Musc Syst. 2017;1(1):1001.
68. Kong X, Grau L, Ong A, Yang C, Chai W. Adopting the direct anterior approach: experience and learning curve in a Chinese patient population. J Orthop Surg Res. 2019;14:218.
69. Kutzner KP, Hechtner M, Pfeil D, Rehbein P, Kovacevic MP, Schneider M, Siebert W, Pfeil J. Incidence of heterotopic ossification in minimally invasive short-stem Tha using the modified anterolateral approach. Hip Int. 2017;27:162–8.
70. Laffosse J-M, Chiron P, Accadbled F, Molinier F, Tricoire J-L, Pget J. Learning curve for a modified Watson-Jones minimally invasive approach

in primary total hip replacement: analysis of complications and early results versus the standard-incision posterior approach. Acta Orthop Belg. 2006;72:693–701.
71. Lawlor M, Humphreys P, Morrow E, Ogonda L, Bennett D, Elliott D, Beverland D. Comparison of early postoperative functional levels following total hip replacement using minimally invasive versus standard incisions. A prospective randomized blinded trial. Clin Rehabil. 2005;19:465–74.
72. Light TR, Keggi KJ. Anterior approach to hip arthroplasty. Clin Orthop Relat Res. 1980;152:255–60.
73. Luger M, Hipmair G, Schopper C, Schauer B, Hochgatterer R, Allerstorfer J, Gotterbarm T, Klasan A. Low rate of early periprosthetic fractures in cementless short-stem total hip arthroplasty using a minimally invasive anterolateral approach. J Orthop Traumatol. 2021;22:19.
74. Malahias MA, Tejaswi P, Chytas D, Kadu V, Karanikas D, Thorey F. The clinical outcome of the Metha short hip stem: a systematic scoping review. Hip Int. 2021;31:24–33.
75. Marcy GH, Fletcher RS. Modification of the posterolateral approach to the hip for insertion of femoral-head prosthesis. J Bone Joint Surg Am. 1954;36-a:142–3.
76. Martin R, Clayson PE, Troussel S, Fraser BP, Docquier PL. Anterolateral minimally invasive total hip arthroplasty: a prospective randomized controlled study with a follow-up of 1 year. J Arthroplast. 2011;26:1362–72.
77. Martz P, Bourredjem A, Laroche D, Arcens M, Labattut L, Binquet C, Maillefert J-F, Baulot E, Ornetti P. Röttinger approach with dual-mobility cup to improve functional recovery in hip osteoarthritis patients: biomechanical and clinical follow-up. Int Orthop. 2017;41:461–7.
78. Mast NH, Laude F. Revision total hip arthroplasty performed through the Hueter interval. JBJS. 2011;93:143–8.
79. Matta JM, Shahrdar C, Ferguson T. Single-incision anterior approach for total hip arthroplasty on an orthopaedic table. Clin Orthop Relat Res. 2005;441:115–24.
80. Mcfarland B, Osborne G. Approach to the hip: a suggested improvement on Kocher's method. J Bone Joint Surg Br. 1954;36B:364–7.
81. Mcgrory AC, Mcgrory BJ, Rana A, Babikian G. Incidence of heterotopic ossification in anterior based muscle sparing total hip arthroplasty: a retrospective radiographic review. PRO. 2019;1:11–5.
82. Mears DC. Development of a two-incision minimally invasive total hip replacement. J Bone Joint Surg. 2003;85:2238.
83. Migliorini F, Biagini M, Rath B, Meisen N, Tingart M, Eschweiler J. Total hip arthroplasty: minimally invasive surgery or not? Meta-analysis of clinical trials. Int Orthop. 2019;43:1573–82.
84. Moore AT. The self-locking metal hip prosthesis. J Bone Joint Surg Am. 1957;39-a:811–27.
85. Mouilhade F, Matsoukis J, Oger P, Mandereau C, Brzakala V, Dujardin F. Component positioning in primary total hip replacement: a prospective comparative study of two anterolateral approaches, minimally invasive versus gluteus medius hemimyotomy. Orthop Traumatol Surg Res. 2011;97:14–21.
86. Muller M, Tohtz S, Dewey M, Springer I, Perka C. Evidence of reduced muscle trauma through a minimally invasive anterolateral approach by means of MRI. Clin Orthop Relat Res. 2010;468:3192–200.
87. Nishimura M, Takahira N, Fukushima K, Uchiyama K, Moriya M, Yamamoto T. Comparison of gait motion including postoperative trunk deflection between direct lateral and anterolateral approaches in supine total hip arthroplasty. J Arthroplast. 2016;31:1603–8.
88. Ogonda L, Wilson R, Archbold P, Lawlor M, Humphreys P, O'brien S, Beverland D. A minimal-incision technique in total hip arthroplasty does not improve early postoperative outcomes. A prospective, randomized, controlled trial. J Bone Joint Surg Am. 2005;87:701–10.
89. Osborne RP. The approach to the hip-joint: a critical review and a suggested new route. Br J Surg. 1930;18:49–52.
90. Ostojić M, Kordić D, Moro G, Ostojić Z. Anterolateral minimally invasive hip approach offered faster rehabilitation with lower complication rates compared to the minimally invasive posterior hip approach-a University clinic case control study of 120 cases. Arch Orthop Trauma Surg. 2021;142(5):747–54. https://doi.org/10.1007/s00402-020-03719-6. Epub 2021 Jan 2. PMID: 33386978.
91. Patton RS, Runner RP, Lyons RJ, Bradbury TL. Clinical outcomes of patients with lateral femoral cutaneous nerve injury after direct anterior total hip arthroplasty. J Arthroplast. 2018;33:2919–2926.e1.
92. Peck CN, Foster A, Mclauchlan GJ. Reducing incision length or intensifying rehabilitation: what makes the difference to length of stay in total hip replacement in a UK setting? Int Orthop. 2006;30:395–8.
93. Pongcharoen B, Chaichubut K. Limping following primary total hip replacement: comparison of 3 surgical approaches. JBJS Open Access. 2019;4:e0043.
94. Pospischill M, Kranzl A, Attwenger B, Knahr K. Minimally invasive compared with traditional transgluteal approach for total hip arthroplasty: a comparative gait analysis. J Bone Joint Surg Am. 2010;92:328–37.
95. Repantis T, Bouras T, Korovessis P. Comparison of minimally invasive approach versus conventional anterolateral approach for total hip arthroplasty: a randomized controlled trial. Eur J Orthop Surg Traumatol. 2015;25:111–6.
96. Roche JJ, Jones CD, Khan RJ, Yates PJ. The surgical anatomy of the piriformis tendon, with particular

reference to total hip replacement: a cadaver study. Bone Joint J. 2013;95-B:764–9.
97. Röttinger H. Minimally invasive anterolateral surgical approach for total hip arthroplasty: early clinical results. Hip Int. 2006;16(Suppl 4):42–7.
98. Sasaki M, Nagoya S, Kaya M, Okazaki S, Tateda K, Kosukegawa I, Yamashita T. Relationship between the hip joint capsule and piriformis tendon in a simulation of the modified Watson-Jones anterolateral approach in THA cadaver study. Clin Anat. 2013;26:610–3.
99. Sherry E, Egan M, Henderson A, Warnke PH. Minimally invasive techniques for total hip arthroplasty. J Bone Joint Surg Am. 2002;84A:1481.
100. Shitama T, Kiyama T, Naito M, Shiramizu K, Huang G. Which is more invasive-mini versus standard incisions in total hip arthroplasty? Int Orthop. 2009;33:1543–7.
101. Sivananthan DHS, Sivananthan S, Egan M, Warnke PH, Sherry E. Minimally invasive surgery for the hip replacement using the NILNAV hip system (poster no. P512). 70th Annual Meeting Proceedings of the American Academy of Orthopaedic Surge, New Orleans, p. 533. 2003.
102. Skoldenberg O, Ekman A, Salemyr M, Boden H. Reduced dislocation rate after hip arthroplasty for femoral neck fractures when changing from posterolateral to anterolateral approach. Acta Orthop. 2010;81:583–7.
103. Smith-Petersen MN. Evolution of mould arthroplasty of the hip joint. J Bone Joint Surg Br. 1948;30b:59–75.
104. Smith TO, Blake V, Hing CB. Minimally invasive versus conventional exposure for total hip arthroplasty: a systematic review and meta-analysis of clinical and radiological outcomes. Int Orthop. 2011;35:173–84.
105. Spaans AJ, Van Den Hout JA, Bolder SB. High complication rate in the early experience of minimally invasive total hip arthroplasty by the direct anterior approach. Acta Orthop. 2012;83:342–6.
106. Swanson TV, Hanna RS. Advantages of cementless THA using mini-incision surgical technique (poster no. 043). 70th Annual Meeting Proceedings of the American Academy of Orthopaedic Surgeons, New Orleans, pp. 369–70. 2003.
107. Toms A, Duncan CP. The limited incision, anterolateral, intermuscular technique for total hip arthroplasty. Instr Course Lect. 2006;55:199–203.
108. Tudor A, Ruzic L, Vuckovic M, Prpic T, Rakovac I, Madjarevic T, Legovic D, Santic V, Mihelic R, Sestan B. Functional recovery after muscle sparing total hip arthroplasty in comparison to classic lateral approach – a three years follow-up study. J Orthop Sci. 2016;21:184–90.
109. Uemura K, Takao M, Sakai T, Nishii T, Sugano N. Volume increases of the gluteus maximus, gluteus medius, and thigh muscles after hip arthroplasty. J Arthroplast. 2016;31:906–912.e1.
110. Unis DB, Hawkins EJ, Alapatt MF, Benitez CL. Postoperative changes in the tensor fascia lata muscle after using the modified anterolateral approach for total hip arthroplasty. J Arthroplast. 2013;28:663–5.
111. Van Oldenrijk J, Hoogland PV, Tuijthof GJ, Corveleijn R, Noordenbos TW, Schafroth MU. Soft tissue damage after minimally invasive THA. Acta Orthop. 2010;81:696–702.
112. Varela-Egocheaga JR, Suárez-Suárez MA, Fernández-Villán M, González-Sastre V, Varela-Gómez JR, Murcia-Mazón A. Minimally invasive hip surgery: the approach did not make the difference. Eur J Orthop Surg Traumatol. 2013;23:47–52.
113. Vasarhelyi EM, Williams HA, Howard JL, Petis S, Barfett J, Lanting BA. The effect of total hip arthroplasty surgical technique on postoperative muscle atrophy. Orthopedics. 2020;43:361–6.
114. Von Roth P, Olivier M, Preininger B, Perka C, Hube R. BMI and gender do not influence surgical accuracy during minimally invasive total hip arthroplasty. Hip Int. 2011;21:688–93.
115. Walde TA, Blattgerste D, Sehmisch S, Kuttler W, Walde H-J, Köster G. Early results and patient satisfaction after total hip arthroplasty using a minimally invasive anterolateral approach. Hip Int. 2009;19:367–71.
116. Watson-Jones R. Fractures of the neck of the femur. Br J Surg. 1936;23:787–808.
117. Watson-Jones R. The classic: "Fractures and Joint Injuries" by Sir Reginald Watson-Jones, taken from "Fractures and Joint Injuries," by R. Watson-Jones, Vol. II, 4th ed., Baltimore, Williams and Wilkins Company, 1955. Clin Orthop Relat Res. 1974;(105):4–10.
118. Weber T, Al-Munajjed AA, Verkerke GJ, Dendorfer S, Renkawitz T. Influence of minimally invasive total hip replacement on hip reaction forces and their orientations. J Orthop Res. 2014;32:1680–7.
119. Woerner M, Sendtner E, Springorum R, Craiovan B, Worlicek M, Renkawitz T, Grifka J, Weber M. Visual intraoperative estimation of cup and stem position is not reliable in minimally invasive hip arthroplasty. Acta Orthop. 2016;87:225–30.
120. Woolson ST. In the absence of evidence–why bother? A literature review of minimally invasive total hip replacement surgery. Instr Course Lect. 2006;55:189–93.
121. Woolson ST, Mow CS, Syquia JF, Lannin JV, Schurman DJ. Comparison of primary total hip replacements performed with a standard incision or a mini-incision. J Bone Joint Surg Am. 2004;86:1353–8.
122. Wright JM, Crockett HC, Sulco TP, Lyman S, Madson M. Mini incision for total hip arthroplasty - a prospective, controlled investigation with 5 year follow-up (paper no. 277). 70th Annual Meeting Proceedings of the American Academy of Orthopaedic Surgeons, New Orleans, p. 636. 2003.

123. Wroblewsky BM, Siney PD, Fleming PA. Charnley low-friction torque arthroplasty of the hip. Practice and results. Springer International Publishing Switzerland; 2016.
124. Xu CP, Li X, Song JQ, Cui Z, Yu B. Mini-incision versus standard incision total hip arthroplasty regarding surgical outcomes: a systematic review and meta-analysis of randomized controlled trials. PLoS One. 2013;8:e80021.
125. Yang B, Li H, He X, Wang G, Xu S. Minimally invasive surgical approaches and traditional total hip arthroplasty: a meta-analysis of radiological and complications outcomes. PLoS One. 2012;7:e37947.
126. Yao R, Howard JL, Lanting BA. Conjoint tendon release in direct anterior total hip arthroplasty: no impact on patient outcomes. Orthopedics. 2017;40:e971–4.
127. Yao R, Lanting B, Howard J. Conjoint tendon release in direct anterior total hip arthroplasty: does it matter? Orthop Proc. 2016;98-B:103.
128. Yoon TR. Two-incision minimally invasive total hip arthroplasty. *United States Patent Application Publication,* Pub. No.: Us 2005/0096748A1, Appl. No.: Filed: 10/700,008. 2003.
129. Zampini JM, Sherk HH. Lewis A. Sayre: the first Professor of Orthopaedic Surgery in America. Clin Orthop Relat Res. 2008;466:2263–7.
130. Zhao G, Zhu R, Jiang S, Xu C, Xu N, Wang Y. Soft tissue restrictors of femoral elevation in direct anterior approach-an anatomic study. J Orthop Surg Res. 2018;13:308.
131. Takada R, Jinno T, Miyatake K, Hirao M, Kimura A, Koga D, et al. Direct anterior versus anterolateral approach in one-stage supine total hip arthroplasty. Focused on nerve injury: a prospective, randomized, controlled trial. J Orthop Sci. 2018;23(5):783–7.
132. Takada R, Jinno T, Miyatake K, Hirao M, Yoshii T, Okawa A. Incidence of tensor fascia lata muscle atrophy after using the modified Watson-Jones anterolateral approach in total hip arthroplasty. Eur J Orthop Surg Traumatol. 2021;31(3):533–40.

2 Transitioning to the ABMS Approach

Timothy Kahn, Jill Erickson, and Christopher L. Peters

Learning Points

- Transitioning to the anterior-based muscle-sparing (ABMS) approach is facilitated by performing cadaveric procedures, observing/training with surgeons experienced in the technique, or participating in courses.
- The ABMS approach is attractive due to lateral or supine patient positioning, direct visualization for component placement, and leg freedom for range of motion and stability testing.
- Early results with the ABMS show only a minimal learning curve effect.
- The ABMS approach facilitates early functional recovery and minimizes dislocation risk.

Introduction

Anterior surgical approaches for total hip arthroplasty (THA) have become increasingly common over the past several years [1, 2], with a recent survey of AAHKS members demonstrating that over 50% of arthroplasty surgeons now primarily use an anterior-based approach for THA [3]. However, for many surgeons who did not train on an anterior approach, the adoption of a new anterior surgical approach can come with a significant learning curve. This has been well studied in surgeons transitioning to the direct anterior approach for THA, where it has been demonstrated that 40–300 cases are necessary to decrease surgical time and the initial high rate of complications [4–7].

The anterior-based muscle-sparing (ABMS) approach was described in the modern era by Röttinger et al. in 2004 and has been adopted by a growing number of surgeons as their preferred surgical approach for THA [8–15]. Utilizing the plane between tensor fascia latae (TFL) and the abductor musculature, the procedure may be performed with the patient in the lateral decubitus position (or supine position on a standard operating room table) with a peg board (Figs. 2.1 and 2.2) that allows for external rotation and adduction of the limb to expose the proximal femur [13]. There are several advantages of the approach, including ease of acetabular and femoral exposure, utilization of a more lateral skin incision away from the inguinal folds and lateral femoral cutaneous nerve, and ability to physically assess limb length at the level of the knees [11]. Furthermore, surgeon familiarity with the lateral decubitus position, the most common position for posterior or lateral based approaches, and the ability to keep the operated lower extremity free may ameliorate some of the difficulties associated with transitioning to an anterior-based approach [16].

In contrast to the relatively larger learning curve associated with the direct anterior approach,

T. Kahn · J. Erickson · C. L. Peters (✉)
Department of Orthopedic Surgery, University of Utah, Salt Lake City, UT, USA
e-mail: Jill.erickson@hsc.utah.edu; Chris.Peters@hsc.utah.edu

J. A. Geller, B. J. McGrory (eds.), *The Anterior-Based Muscle-Sparing Approach to Total Hip Arthroplasty*, https://doi.org/10.1007/978-3-031-02059-9_2

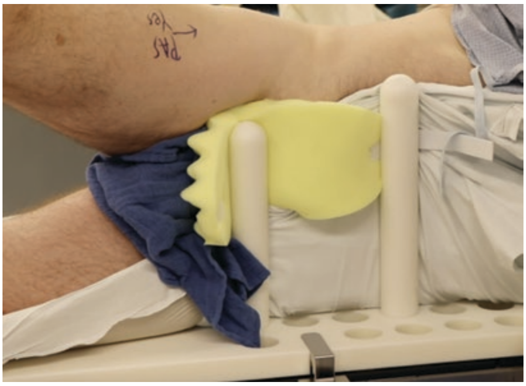


Fig. 2.1 A photograph illustrating patient positioning (right hip) in the lateral position on the ABMS peg board, with inferior peg being shorter and at the level of the pubic symphysis. The taller the peg, the more superior it is to stabilize abdomen. Posterior pegs, not shown, stabilize just inferior to the sacrum and low back

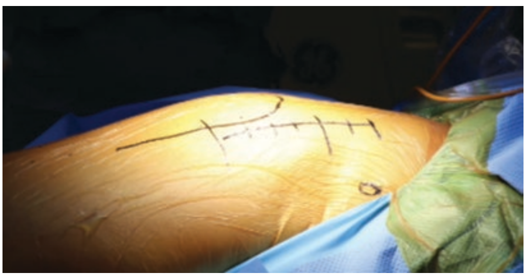


Fig. 2.2 A photograph illustrating incision planning of the right hip with the lateral femur drawn with greater trochanter and femoral shaft, incision planned for about 1 cm anterior to the anterior femoral border. ASIS is in the field and marked (circle). This is a right THR, with the patient's foot oriented toward the left side of the picture and the head oriented to the right

several studies have demonstrated minimal changes in short-term outcomes for surgeons transitioning to the ABMS approach [16–19]. Mandereau et al. described their single surgeon series of 103 THA procedures through an ABMS approach [17]. They reported that the senior author had performed 30 ABMS THA procedures prior to the 103 patients included in the study. Although the authors reported experiencing a learning curve associated with the procedure and attributed a femoral perforation due to such, they did not perform any direct analysis of the learning curve. Overall, they demonstrated excellent outcomes and minimal major complications (one case of recurrent instability which resolved with nonoperative management). Postoperative computed tomography analysis was done that demonstrated reliable cup placement within safe zones, though with substantial variation in femoral version.

A prospective randomized study by Martin et al. in 2011 compared 42 patients treated with THA via an ABMS approach to 41 patients treated with a Hardinge direct lateral approach (the standard approach of the senior surgeon) [18]. They reported that the senior surgeon had completed five cadaveric courses prior to the start of the study, though was not performing ABMS THA prior to the start of the study. Despite a 20% increase in operative time, the outcomes were not significantly different, and operative blood loss was significantly less. Although they reported subjectively having a learning curve associated with the procedure, there were no changes in outcomes or complication rates over the study to suggest such. However, it is not unreasonable to consider that they may have performed an insufficient number of cases to fully observe improvement within a learning curve.

In another study by D'Arrigo et al., 60 patients were randomized to undergo either a direct anterior, an ABMS, or a minimally invasive direct lateral approach for THA [19]. All these approaches were being performed for the first time by an experienced surgeon (who traditionally performed standard direct lateral approaches) in order to gauge the learning curve effect with these procedures. They reported that there was no difference in patient-reported outcomes, though all of the procedures had less average blood loss than the traditional direct lateral approach and early functional scores were better for both direct anterior and ABMS approaches. There was also a lower rate of complications in the ABMS group.

In a previous retrospective study at our institution by Kagan et al., the first 100 hips (96 patients) treated with an ABMS THA were compared to a previous cohort of THA procedures (91 procedures, 89 patients) done via a minimally invasive posterolateral approach during the previous year [16]. This design allowed for observation of the learning curve during the first 100 cases when compared to a traditional posterior approach performed by an experienced surgeon. Importantly, no significant changes were made to the perioperative protocol during the study period. There were no differences in patient-reported outcomes, estimated blood loss, surgical time, or complication rate. There was a slightly shorter length of stay in the ABMS group (1.53 vs 1.85 days, $p = 0.001$), though given the decreasing average length of stay over the past several years [20], this may represent confounding factors. Postoperative standing radiographs were analyzed to compare cup version and inclination; the ABMS group had slightly more abduction in the cups (45° vs 40°, $p = 0.001$) and greater anteversion (depending on the measurement method utilized).

Additionally, in the study by Kagan et al., there was no evidence of a significant learning curve [16]. All postoperative complications were evenly distributed, without grouping around the initial period. Patients were also stratified based on chronology of cases (cases 1–20, 21–40, etc.), and there was found to be no difference in outcome scores or operative time between these groups. These findings suggest that the ABMS approach may have a less substantial learning curve when compared to other anterior approaches, though such a direct comparison was not made in this study.

Therefore, THA done via the ABMS approach has been shown to have very similar outcomes to more traditional lateral and posterolateral approaches, even during the transition period after adopting the technique. This may be due to the familiarity with keeping the operated limb free and using an assistant to manipulate the limb for exposure, as well as keeping the patient in the standard lateral decubitus position. The approach allows for excellent acetabular exposure with a very intuitive view for cup placement and access to anatomic landmarks. Furthermore, femoral exposure is relatively easily achieved without the use of a mechanical femoral lifting hook, as is commonly used with direct anterior approaches. However, as with any anterior approach, femoral exposure can require patience in progressively releasing posterior capsular tissue off the trochanter, a technique which is assuredly improved with surgical experience.

Key Steps in Transitioning to the ABMS Approach

We began using the ABMS approach in 2015 based primarily on patient demand for anterior-based approaches and the potential for reduced dislocation rate associated with the posterior approach. Although some studies show low posterior dislocation rates, the question of dealing with chronic hip instability after a posterior approach was especially challenging. In order to minimize early complications during the so-called learning curve of a new approach, a structured plan was developed to become facile with the ABMS approach. First a visitation was arranged with Scott Kelley, M.D. (a recognized expert in the ABMS approach), and his colleague, Rhett Hallows, M.D., at Duke University. We spent 2 days as a scrubbed observer on 6–8 THA. Second, extensive cadaver work was performed at our institution with our team members to become familiar with the work-flow. Third, Dr. Hallows was kind enough to travel and assist in the first three cases at our home institution. Thereafter, our surgical team became increasingly comfortable with the approach, and we continue to utilize the ABMS approach in the majority of primary THA cases.

When transitioning from the posterior approach, common questions arise and are addressed below. The patient is positioned laterally on a specialized peg board to allow for external rotation of the lower extremity into a sterile bag, with the distal pegs placed at approximately the level of the pubic symphysis anteriorly and inferior sacrum posteriorly (Fig. 2.1). The skin incision is typically 8–12 cm and is located about 1 cm anterior to the anterior greater trochanter (Fig. 2.2). A line drawn from the anterior superior iliac spine (ASIS) to the tip of the greater trochanter helps delineate the approximate midpoint of the incision. Our technique is not to use fluoroscopy for this nor for the remaining portion of the procedure. Identification of the TFL is next, and it is important to stay posterior to the muscle belly or fibers of the muscle. After careful incision of the fascia latae, the anterior edge of the gluteus medius is identified, and blunt dissection under the gluteus and on top of the hip capsule allows insertion of cobra retractors on the superior and anterior hip capsule. The anterior capsulotomy is straightforward, and superior and inferior capsular release is key for excellent exposure of the acetabulum and femur.

The in situ femoral neck cut is performed in two steps, alleviating the need to dislocate the hip. First with the leg in slight external rotation and adduction over a sterile bump (Fig. 2.3), a reciprocating saw is used to make an oblique subcapital neck cut with superior and inferior cobra retractors placed in the joint. The leg is then manipulated into extension, adduction, and external rotation to deliver the neck into the field, sliding on the oblique neck osteotomy. The second neck cut then is performed at a level consistent with preoperative templating with a reciprocating saw. The "saddle" and lesser trochanter can facilitate the neck cut a proper length.

Acetabular exposure is achieved with the femur retracted posteriorly with leg in extension and an anterior cobra retractor (Fig. 2.4). Because the surgeon stands on the anterior aspect of the patient, acetabular visualization and preparation are straightforward. Socket positioning is intuitive with full visualization of the anterior and posterior walls which facilitates optimum cup placement. Our preference is to utilize a porous-coated, limited hole acetabular component, and screws are rarely utilized as a good press fit is usually achieved with impaction.

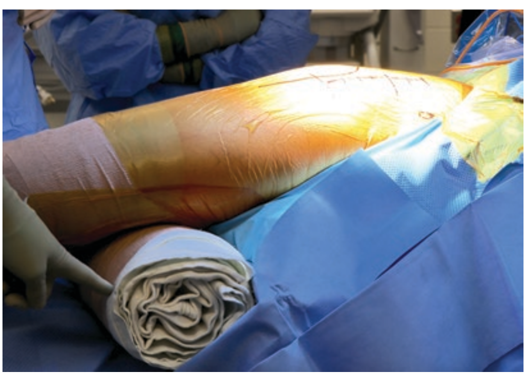


Fig. 2.3 A photograph illustrating the sterile bath blankets rolled into a bolster that allows abduction of the hip as proximal as possible for approach, in situ neck cut, delivery of femur for the final neck cut, and acetabular preparation

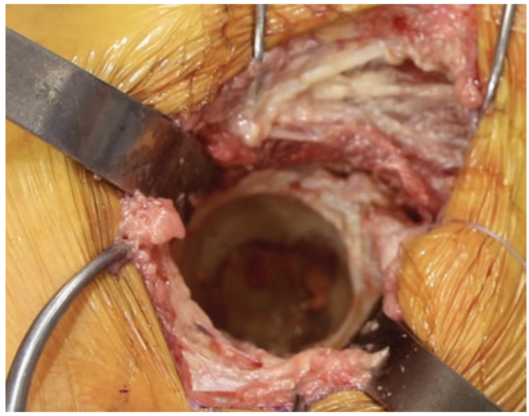


Fig. 2.4 A photograph illustrating acetabular exposure with one-point, cobra-retracting femur posteriorly, and similar retractor anteriorly (cadaver right hip)

Femoral preparation then begins with bump removed, leg placed into extension, adduction, and external rotation by a trained assistant on the posterior aspect of the operating table. The leg is placed into a sterile bag or drape during this maneuver (Fig. 2.5). A pointed long bent Hohmann- or Wagner-like retractor is then placed through the posterior capsule at the midpoint of the femoral neck to visualize the posterior capsular reflection on the posterior greater trochanter. Using electrocautery the posterior capsule is released from the inside of the posterior greater trochanter as the leg is brought into more extension, adduction, and external rotation. Full visualization of the femoral neck is achieved with posterior retractor over the top of the greater trochanter and a spoon-like elevator under the calcar. As experience is gained, the femoral release becomes a "dance" or interplay between the surgeon and assistant who is manipulating the leg to ensure safe tension is placed on retractors. This interplay minimizes the risk of femur or trochanteric fracture. The release is complete when the lower leg is able to be adducted and externally rotated to a final position with the foot directly underneath the knee or up to 10–15° further

Fig. 2.5 A photograph illustrating left operative leg being extended, adducted, and externally rotated into sterile bag off posterior edge of peg board for femoral exposure and preparation by the trained assistant. The assistant's right leg is providing pressure to patient's lateral lower leg/ankle for adequate external rotation

under the table than "vertical" to ensure adequate visualization of the femoral neck.

Femoral broaching is straightforward as the cut femoral neck is fully visualized and broaching occurs in a natural plane of motion (Fig. 2.6). The canal is probed with a thin curved rasp to identify the path of the canal. Double offset broach handles help minimize any damage to the gluteus medius muscle. We are able to use a variety of femoral stems depending on bone quality and femoral morphology. One advantage of the ABMS approach is that it is largely stem agnostic. We have had excellent results with tapered wedge stems, proximal filling stems, Wagner cone, and cemented stems. In elderly osteoporotic bone, conversion to a cemented stem system is particularly straightforward and minimizes periprosthetic fracture risk.

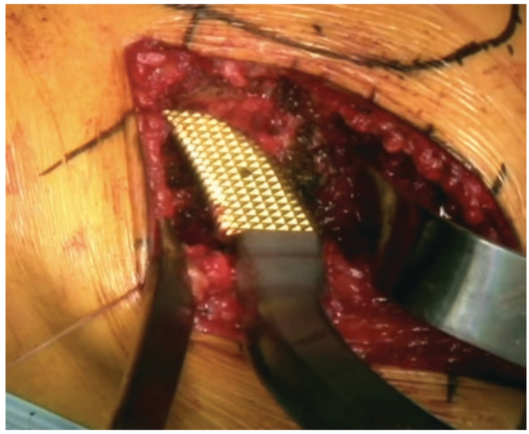


Fig. 2.6 A photograph illustrating bent-angled retractor (right/superior) the protecting gluteus medius muscle and spoon-like retractor (inferior/left) on the femoral calcar of the right hip for femoral broaching

After broaching or final stem insertion, trial reduction is accomplished with the leg in extension, facilitated by gentle traction, and internal rotation with surgeon guidance in the surgical field. We obtain an intraoperative digital pelvis radiograph to assess limb length and final component placement. A digital picture archiving and communication system (PACS) allows for easy comparison to a preoperative template. During this time the wound is soaked with a dilute betadine or chlorhexidine-based solution. After the final reduction, the capsule is closed (another nice feature that reduces dead space), and the fascia and skin are closed with surgeon preference material. We allow immediate weight bearing and do not use any dislocation precautions.

Conclusion

In conclusion, THA performed via an ABMS approach demonstrates comparable postoperative outcomes and possibly improved early functional recovery compared to traditional lateral and posterior approaches. The learning curve has been demonstrated to be minimal with the approach, with no studies demonstrating a significant increase in approach-related complications during the transition period. As with any transition to a new surgical technique, adequate preparation through performing cadaveric procedures, observing/training with surgeons experienced in the technique, or participating in courses is highly encouraged.

References

1. Flevas DA, Tsantes AG, Mavrogenis AF. Direct anterior approach total hip arthroplasty revisited. JBJS Rev. 2020;8(4):e0144.
2. Angerame MR, Fehring TK, Masonis JL, Mason JB, Odum SM, Springer BD. Early failure of primary total hip arthroplasty: is surgical approach a risk factor? J Arthroplast. 2018;33(6):1780–5.
3. Patel NN, Shah JA, Erens GA. Current trends in clinical practice for the direct anterior approach total hip arthroplasty. J Arthroplast. 2019;34(9):1987–1993.e1983.
4. Brun OL, Månsson L, Nordsletten L. The direct anterior minimal invasive approach in total hip replacement: a prospective departmental study on the learning curve. Hip Int. 2018;28(2):156–60.
5. Schwartz BE, Sisko ZW, Mayekar EM, Wang OJ, Gordon AC. Transitioning to the direct anterior approach in total hip arthroplasty: is it safe in the current health care climate? J Arthroplast. 2016;31(12):2819–24.
6. Masonis J, Thompson C, Odum S. Safe and accurate: learning the direct anterior total hip arthroplasty. Orthopedics. 2008;31(12 Suppl 2).
7. Spaans AJ, van den Hout JA, Bolder SB. High complication rate in the early experience of minimally invasive total hip arthroplasty by the direct anterior approach. Acta Orthop. 2012;83(4):342–6.
8. Bertin KC, Röttinger H. Anterolateral mini-incision hip replacement surgery: a modified Watson-Jones approach. Clin Orthop Relat Res. 2004;429:248–55.
9. Civinini R, Cozzi Lepri A, Carulli C, Matassi F, Villano M, Innocenti M. The anterior-based muscle-sparing approach to the hip: the “other” anterior approach to the hip. Int Orthop. 2019;43(1):47–53.
10. George NE, Gwam CU, Etcheson JI, Smith SS, Semenistyy AA, Delanois RE. Short-term outcomes of the supine muscle-sparing anterolateral versus direct lateral approach to primary total hip arthroplasty. Hip Int. 2019;29(5):504–10.
11. Hansen BJ, Hallows RK, Kelley SS. The Röttinger approach for total hip arthroplasty: technique and review of the literature. Curr Rev Musculoskelet Med. 2011;4(3):132–8.
12. Herndon CL, Drummond N, Sarpong NO, Cooper HJ, Shah RP, Geller JA. Direct anterior versus mini-anterolateral approach for primary total hip arthroplasty: early postoperative outcomes and complications. Arthroplast Today. 2020;6(2):257–61.
13. Lepri AC, Villano M, Matassi F, Carulli C, Innocenti M, Civinini R. “Anterolateral” approach to the hip: a systematic review of the correct definition of terms. Hip Int. 2020;30(2_suppl):13–9.
14. Ostojić M, Kordić D, Moro G, Ostojić Z. Anterolateral minimally invasive hip approach offered faster rehabilitation with lower complication rates compared to the minimally invasive posterior hip approach-a University clinic case control study of 120 cases. Arch Orthop Trauma Surg. 2021.
15. Van Driessche S, Billuart F, Martinez L, et al. Short-term comparison of postural effects of three minimally invasive hip approaches in primary total hip arthroplasty: direct anterior, posterolateral and Röttinger. Orthop Traumatol Surg Res. 2016;102(6):729–34.
16. Kagan RP, Greber EM, Richards SM, Erickson JA, Anderson MB, Peters CL. Advantages of an anterior-based muscle-sparing approach in transitioning from a posterior approach for total hip arthroplasty: minimizing the learning curve. J Arthroplast. 2019;34(12):2962–7.
17. Mandereau C, Brzakala V, Matsoukis J. Functional recovery, complications and CT positioning of total hip replacement performed through a Röttinger anterolateral mini-incision. Review of a continuous series of 103 cases. Orthop Traumatol Surg Res. 2012;98(1):8–16.
18. Martin R, Clayson PE, Troussel S, Fraser BP, Docquier PL. Anterolateral minimally invasive total hip arthroplasty: a prospective randomized controlled study with a follow-up of 1 year. J Arthroplast. 2011;26(8):1362–72.
19. D’Arrigo C, Speranza A, Monaco E, Carcangiu A, Ferretti A. Learning curve in tissue sparing total hip replacement: comparison between different approaches. J Orthop Traumatol. 2009;10(1):47–54.
20. Petersen PB, Jørgensen CC, Kehlet H. Temporal trends in length of stay and readmissions after fast-track hip and knee arthroplasty. Dan Med J. 2019;66(7):A5553.

3 Anatomy of the ABMS Approach to the Hip

Nicholas C. Danford and Alexander L. Neuwirth

Learning Points

- Intimate knowledge of the anatomical landmarks is crucial to avoid surgical complications when performing anterior-based muscle-sparing (ABMS) total hip replacement (THR).
- The muscular interval for the ABMS approach is between the gluteus medius and minimus and the tensor fascia latae muscle groups.
- The ABMS approach is not an inter-nervous plane, but an intra-nervous plane.
- Avoidance of vital arterial and neurologic structures is fairly straightforward with this approach and may help improve the learning curve.

Introduction

The anterior-based muscle-sparing (ABMS) approach to the hip joint is defined by the plane anterior to the gluteus medius (GMed) and posterior to the tensor fascia latae (TFL). With the ABMS approach, the abductor musculature of the hip joint is not disrupted, and the posterior hip capsule is not violated. This chapter describes the surgical anatomy of the ABMS approach to the hip with emphasis on anatomical descriptions that promote a better understanding of surgical technique.

History of the Anterior-Based Muscle-Sparing Approach

The American orthopedic surgeon Lewis Sayre (1894) and the British orthopedic surgeon Reginald Watson-Jones (1936) are credited with describing the interval used in the ABMS approach to the hip [1]. In the twenty-first century, Heinz Röttinger popularized the approach as a potential means of mitigating the problems of prosthetic dislocation that were associated with the posterior approach and abductor muscle weakness associated with the lateral approach [1].

Surface Anatomy

The anterior superior iliac spine (ASIS) and the greater trochanter are the two most important surface landmarks to identify as the incision is marked in relation to these bony prominences. The ASIS is the most distal bony point that can be identified as the surgeon palpates along the iliac crest. The greater trochanter may be palpated

N. C. Danford (✉) · A. L. Neuwirth
Department of Orthopedic Surgery, Columbia University Irving Medical Center, New York, NY, USA
e-mail: ncd2117@cumc.columbia.edu; aln2137@cumc.columbia.edu

J. A. Geller, B. J. McGrory (eds.), *The Anterior-Based Muscle-Sparing Approach to Total Hip Arthroplasty*, https://doi.org/10.1007/978-3-031-02059-9_3

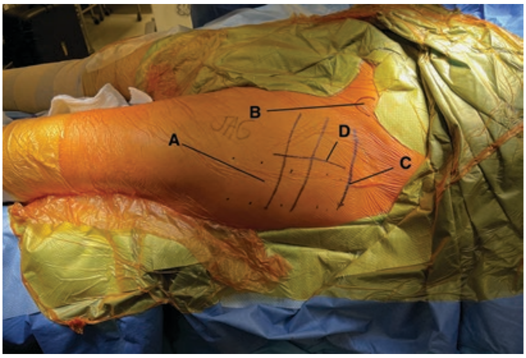


Fig. 3.1 Applied surface anatomy of the anterior-based muscle-sparing approach to the hip. (A) The shaft of the femur is demarcated by the dotted lines. (B) The anterior superior iliac spine is bounded by a curved marking. (C) The tip of the greater trochanter is palpated at the proximal aspect of the femur. (D) The incision is placed slightly anterior to the anterior aspect of the femur, beginning proximally at or just distal to the level of the greater trochanter

lateral and distal to the ASIS. The femoral shaft is palpated along the lateral aspect of the thigh (Fig. 3.1).

Bony Anatomy

The hip joint connects the axial skeleton to the appendicular skeleton. Proximally, it consists of the acetabulum, which is formed by a union of three bones: the ilium, the ischium, and the pubis. While separate at birth and during development, by adulthood the ilium, ischium, and pubis unite to form what is termed the innominate bone.

The ilium makes a sweeping arc from anterior to posterior, allowing it to contain visceral contents of the lower abdomen and pelvis while maximizing efficiency during gait. The bony landmarks of the ilium that assist the surgeon performing the ABMS approach to the hip joint are the iliac crest, which is palpated for assistance in identifying the anterior superior iliac spine; the anterior superior iliac spine, which guides placement of the most proximal point of the incision; and the anterosuperior acetabular rim, upon which a Hohmann retractor is placed during acetabular exposure and which is used to guide for version during cup placement.

Just superior to the acetabulum, the iliopectineal eminence forms the border between the ilium and the pubis. The pubis unites the two hemipelvises at the pubic symphysis, which is the midline of the body in the coronal plane. Palpation of this point aids the surgeon in identifying the central point for fluoroscopic imaging of the pelvis during total hip arthroplasty. The third bone that makes up the bony pelvis is the ischium. The ischium forms the posterior inferior third of the acetabulum, and more posteriorly it forms the lesser sciatic notch.

An understanding of the surrounding extra-articular bony structure of the acetabulum is necessary for total hip arthroplasty as it allows for accurate acetabular component implantation as well as safe and stable placement of screws through the acetabular prosthetic component. Robert Judet and Emile Letournel popularized the two-column model of acetabular anatomy, which has driven our understanding of implant placement around the acetabulum [2]. Their model describes an anterior and posterior column that together form an inverted "Y" around the acetabulum. These strong columns accept weight transfer from the lower extremities. With regard to fixation of the acetabular component during total hip arthroplasty, the two-column concept is important because placement of screws into the posterior-superior acetabulum is safest through the robust osseous fixation pathway of the posterior column (Fig. 3.2). Placement of screws elsewhere may have the potential to put surrounding neurovascular structures at risk [3].

Distally, the hip joint is made up of the proximal portion of the femur: the femoral head, the femoral neck, and the trochanteric region. The femoral head is covered in cartilage which is undergirded by strong subchondral bone. On average its diameter is 53 mm in men and 49 mm in women [4]. The neck of the femur is anteverted on average 15° from the coronal plane (a line connecting the posterior aspect of the femoral condyles is most commonly used as a reference for the coronal plane). Understanding the significance of femoral neck anteversion has led to numerous theories, the most plausible of which is that it supports vertical forces that are on average

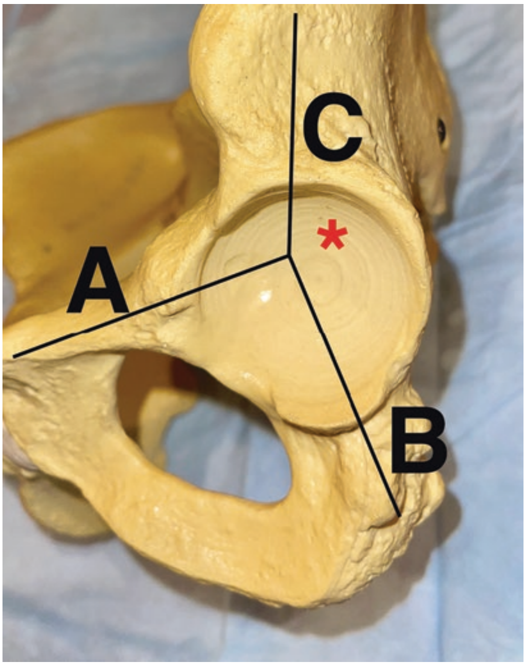


Fig. 3.2 The pelvis model demonstrates the two-column model of acetabular bony anatomy, with the anterior column (A) and posterior column (B) meeting to form the base of an inverted "Y" (C). The asterisk marks the posterosuperior quadrant of the acetabulum, where screw fixation is safest

more anterior in the acetabulum [5]. While the theoretical goal of total hip arthroplasty is to match a patient's native version, it is achieved inconsistently in practice because of variations in patient anatomy and difficulty of obtaining a precise version upon component placement [6–8].

The saddle or saddle point is a key feature of the femoral neck. It is defined as the lowest (most distal) aspect of the superior portion of the femoral neck as it slopes from superior medial to inferior lateral [9]. It is used as a landmark for the superior start point of the femoral neck cut.

The trochanteric region features two bony prominences. The first prominence is the greater trochanter on the lateral aspect of the proximal femur. The second is the lesser trochanter on the posteromedial aspect. These bony prominences serve as attachments for important muscles that are discussed in the next section. From an osteological perspective, the femoral offset, defined as the distance from the center of the femoral head to the axis of the femoral shaft, which runs through the middle of the trochanteric region, plays a role in function after total hip arthroplasty. Increased offset is associated with increased abductor strength and hip range of motion post-operatively. The average femoral offset in one study was 3.9 cm [10]. Femoral offset has also been associated with implant-bone interface stress and polyethylene wear [11, 12]. The femoral head center has been found to shift medially and caudally during aging, which also influences femoral offset and perhaps will influence implant design in the future [13].

Musculature

The principle muscular components that the surgeon performing the ABMS approach must know are (1) the abductors (gluteus medius (GMed) and gluteus minimus (GMin)), (2) the tensor fascia latae (TFL), (3) the rectus femoris, (4) the vastus lateralis, (5) the short external rotators of the hip (piriformis, superior and inferior gemelli, obturator internus, and quadratus femoris), (6) the iliopsoas, and (7) the iliocapsularis.

Abductors The abductors of the hip joint are the GMed and GMin. Both the GMed and GMin insert on the greater trochanter. Knowledge of this insertion point facilitates identification of the ABMS interval as the tendinous insertions of the GMed and GMin can be palpated here to identify the proper surgical interval [1]. The GMed tendon inserts lateral as well as posterior on the greater trochanter [14]. The GMin tendon also inserts onto the greater trochanter. The GMin muscle fascicles are confluent with both the GMin tendon and the hip joint capsule, with an average of 5 of 69 muscle fascicles inserting onto the capsule [14]. These fascicles can remain with the capsule upon capsular exposure [15]. If they do, the retractor should be repositioned so that the capsule and minimus are separated.

Tensor Fascia Latae (TFL) Together with the abductor muscles, the TFL forms the interval of the anterior-based muscle sparing approach to the hip (Fig. 3.3). The TFL is frequently categorized as an abductor muscle. However, its function is more likely related to hip stability and balance of the extremity during standing and walking [16, 17]. It also plays a role in flexing and internally rotating the hip. The TFL originates on and just lateral to the anterior superior iliac spine and becomes confluent with the fascia latae to form the iliotibial tract. The iliotibial tract then inserts onto Gerdy's tubercle of the proximal tibia [4, 6, 7]. The transition from TFL muscle to fascia occurs just distal to the greater trochanter [16, 18].

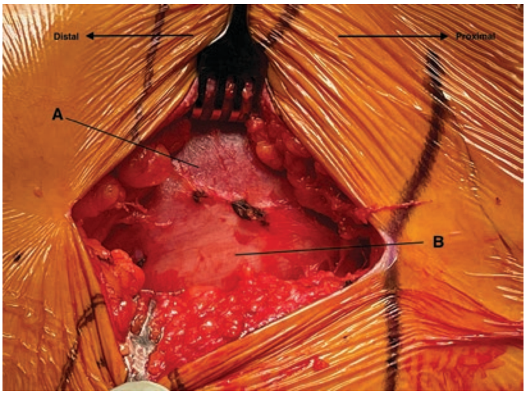


Fig. 3.3 (A) The tensor fascia latae and (B) the abductor musculature of the gluteus medius and minimus form the interval of the anterior-based muscle-sparing approach to the hip

Rectus Femoris The rectus femoris is a principal extensor of the knee via the quadriceps tendon. The rectus femoris also contributes to flexion of the hip. The origin of the rectus femoris is defined by two heads: the direct head, which inserts onto the anterior inferior iliac spine, and the indirect or reflected head, because it does not form a straight line with the rest of the muscle but rather turns from its origin on the superior aspect of the acetabulum to meet the muscle. The indirect head has a larger footprint than the direct head [19]. Similar to the GMin, the rectus femoris also has fibers that are confluent with the capsule of the hip joint [15]. It defines the medial border of deep interval of the ABMS approach and is retracted medially during a total hip arthroplasty performed through the approach (Fig. 3.4).

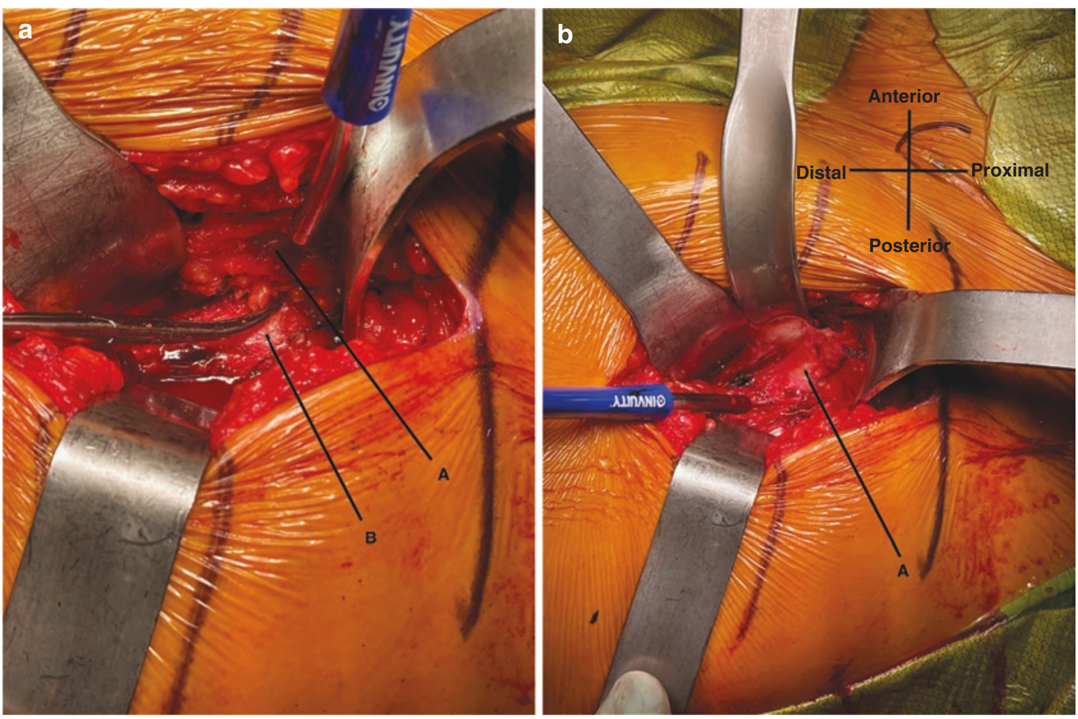


Fig. 3.4 (**a**) The rectus femoris (A) is retracted medially to expose the hip joint capsule (B). This image shows the rectus before it is retracted further to fully expose the capsule. (**b**) The rectus femoris is no longer in the image, having been retracted medially to expose the anterior capsule fully (A)

Vastus Lateralis The vastus lateralis has a broad origin defined by the intertrochanteric line and the anterior and inferior boarders of the greater trochanter, a bony area known as the vastus ridge [20]. With the rectus femoris and the rest of the anterior compartment muscles (vastus medialis, vastus intermedius), it forms the quadriceps tendon which extends the knee. Its significance in the ABMS approach is that it helps define the distal extent of the capsulotomy. Fibers of the vastus lateralis will appear as the surgeon exposes the capsule and works distally during the capsulotomy. The muscle itself is not violated during the approach.

Iliopsoas The iliopsoas is a flexor of the hip joint that consists of two muscle bellies whose fibers become confluent as they pass deep to the inguinal ligament to exit the pelvis. The first muscle is the iliacus, which originates from the broad inner surface of the ilium known as the iliac fossa. The second muscle is the psoas, which originates from the transverse processes of the lumbar vertebrae. The common tendon inserts distally onto the lesser trochanter. The muscle is important during the ABMS approach to the hip because it cushions the femoral nerve during acetabular exposure. Anatomic studies have shown the muscle to be surprisingly thin at this point, which may contribute to femoral nerve palsy associated with anterior-based total hip arthroplasty [21].

Short External Rotators The short external rotators of the hip that the surgeon performing the ABMS must know are the superior gemellus, obturator internus, inferior gemellus, piriformis, and obturator externus. The superior gemellus, the obturator internus, and the inferior gemellus become confluent to form a conjoint tendon. The tendinous attachments of these muscles insert on the greater trochanter, with the conjoint tendon the most anterior. The tendon of the piriformis inserts just posterior to the conjoint, with the tendon of the obturator externus inserting posterior to the piriformis tendon [22].

Iliocapsularis The iliocapsularis muscle is intimate with the hip capsule, originating from it just distal to the reflected head of the rectus femoris and running laterally to the rectus femoris before inserting onto the distal capsule just proximal to the vastus lateralis [22]. Its true function is unknown, but it may play a role in joint stabilization, especially in dysplastic hips [23].

Neurovascular Anatomy

Nerves

The surgeon performing the ABMS approach to the hip joint must have detailed knowledge of three nerves, the first of which is the superior gluteal nerve. The ABMS approach to the hip uses an intermuscular plane that is also an intranervous (NOT inter-nervous) plane, as the TFL and the GMed and GMin are all innervated by the superior gluteal nerve (SGN). The superior gluteal nerve originates from sacral nerve roots L4 through S1, exits the sciatic notch superior to the piriformis muscle, and gives off terminal branches to the GMed, GMin, and TFL. Because the superior gluteal nerve most innervates these muscles more proximal than the extent of surgical dissection, it is left intact and not visualized during the ABMS for total hip arthroplasty [24]. Terminal branches of the SGN entering the TFL may be encountered at the proximal dissection when the surgery is performed with the patient in the lateral decubitus position and should be pushed proximally rather than transected. Dissection through the gluteus medius more than 5–8 cm proximal to its insertion on the greater trochanter puts the superior gluteal nerve at risk of transection [24, 25].

The second nerve is the femoral nerve, which is the most lateral structure in the neurovascular bundle made up of the femoral nerve and the common femoral artery and vein. The femoral nerve supplies sensation to the anterior and medial thigh and to the medial leg and ankle via its terminal branch, the saphenous nerve. It innervates the powerful anterior compartment muscles of the thigh. Because it runs superficial to the iliopsoas, which is retracted medially by a Hohmann-type retractor during acetabular exposure, prolonged compression can cause femoral neuropraxia or neurotmesis [26]. Compression is exacerbated by the location of the nerve within the femoral triangle, an unyielding space defined by inguinal ligament, the sartorius muscle laterally, and the adductor longus medially (Fig. 3.5). Additionally, the femoral nerve ramifies almost immediately after exiting the pelvis, leaving branches to the sartorius and rectus susceptible to pressure from retractors [21].

The lateral femoral cutaneous nerve (LFCN) is the third nerve the surgeon performing the ABMS must know. The LFCN originates from the L2 to L3 nerve roots and supplies sensation to the anterolateral thigh. It runs from posterior to anterior lateral to the psoas muscle, then along the surface of the iliacus muscle before exiting the pelvis either medial (62% of the time), directly over (27%), or lateral (11%) to the anterior superior iliac spine [27]. After exiting the pelvis, its course varies between what Rudin et al. term an anterior dominant course, defined by the nerve running along the lateral aspect of the sartorius; a posterior dominant course, defined by the nerve crossing the medial border of the TFL with variable smaller branches also running anteriorly; and finally a fan pattern, defined by multiple branches of equal caliber spreading out medially and laterally as they move distally [27]. The nerve is at risk during the ABMS approach to the hip, although the risk of post-operative LFCN palsy is low, with one prospective study reporting no LFCN injury using the approach [28].

Vessels

The superior gluteal artery is a branch of the internal iliac artery that exits the pelvis through the greater sciatic notch, superior to the piriformis muscle. It divides after exiting the pelvis, with one superior branch supplying the gluteus maximus (GMax) and one branch running in the plane that separates the GMed from GMin. A lower radicle of this branch comes to within

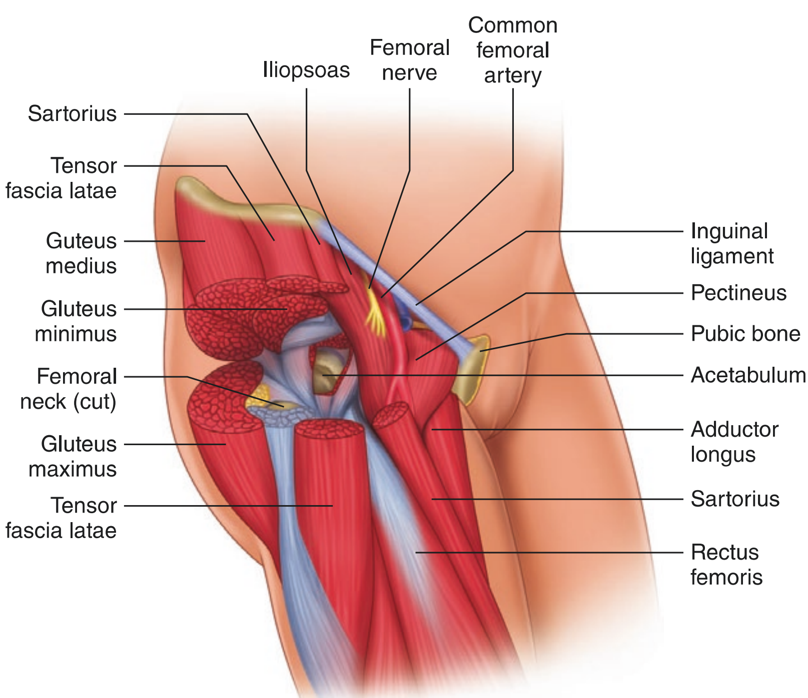


Fig. 3.5 Applied anatomy of the anterior-based muscle-sparing approach to the hip, showing the right hip. The acetabulum is shown in relation to the surrounding musculature and neurovascular structures. The femoral nerve is susceptible to compression during exposure of the acetabulum, as it can be compressed within the triangle bounded by the sartorius, inguinal ligament, and adductor muscles

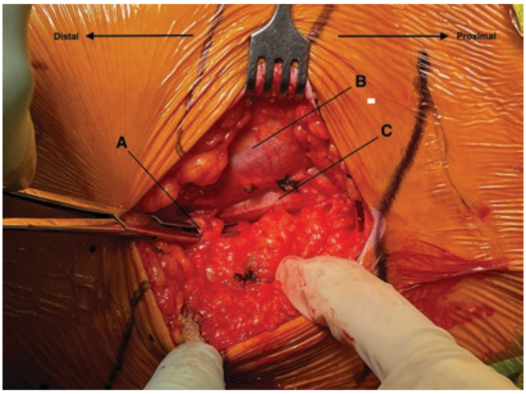


Fig. 3.6 The superior gluteal artery branches into perforating vessels (A) that course orthogonally to the interval between the tensor fascia latae (B) and the abductor musculature (C)

5.5 cm from the most lateral point of the greater trochanter [29]. Terminal branches of superior gluteal artery perforate through the interval of the ABMS approach, between the TFL and the GMed. These arterial branches are typically visible to the surgeon and may provide surgical orientation during the surgical approach, especially to surgeons earlier in their learning curve (Fig. 3.6).

The deep femoral artery, or profunda femoris, and its branch the lateral femoral circumflex artery (LFCA) are rare but still potential sources of danger during the ABMS approach to the hip. The external iliac artery becomes the common femoral artery when it passes over the inguinal ligament. The common femoral artery divides into the deep and superficial femoral arteries 5 cm distal to the inguinal ligament. The LFCA branches off the deep femoral artery soon after the bifurcation of the common femoral artery. Its origin is on average 10.6 cm distal and 6.6 cm medial to the anterior superior iliac spine [30]. It runs laterally from its branch point, deep to the sartorius and rectus femoris before giving off three branches, the superior LFCA, the middle LFCA, and the inferior LFCA. Each of these branches may be encountered in the deep interval between the abductors and rectus femoris and, if encountered, should be promptly ligated. Importantly, each branch may itself divide further, meaning any number of perforating arteries may be found in this interval [30]. The superior LFCA eventually anastomoses with the inferior branch of the superior gluteal artery.

The surgeon performing the ABMS approach to the hip should also understand the course of the obturator artery, which exits the obturator foramen and courses closest to the acetabulum at the anterior and slightly inferior aspect, where it is at risk of iatrogenic injury [31].

The Hip Joint: Capsuloligamentous Structures

The soft tissue structures of the hip joint are the capsule including the synovial membrane, the capsular ligaments, the acetabular labrum, the transverse acetabular ligament, and the ligamentum teres. The hip capsule stabilizes the joint. It protects the relatively avascular intracapsular space and creates a favorable biochemical environment for cartilage, the tissue without which painless joint motion would be impossible. The capsule consists of thick tissue that is lined by a membrane called the synovium. Synovium secretes and maintains fluid that facilitates the smooth gliding motion of the proximal femur against the acetabulum. Interspersed among synovial cells are collagen fibers and other proteins typical of connective tissue such as collagen [32].

The capsule attaches circumferentially around the acetabulum, mostly to the bone with the exception of inferiorly where it attaches to the transverse acetabular ligament. On the femur it attaches anteriorly where the femoral neck meets the trochanteric line. Posteriorly it does not cover the entire femoral neck, attaching slightly proximal to the end of the neck in this area so that the distal third of the femoral neck is extra-articular [20]. The capsule is thickest in the anterosuperior region. In a non-diseased state, the thickness is 3.5–4.2 mm, and in a pathological state, its thickness increases to 6 mm [33].

Three ligaments can be distinguished from the capsule, although they are confluent with the capsule and are often described as thickenings of it. The first is the iliofemoral ligament, which runs from the anterior inferior iliac spine and inserts onto the distal aspect of the anterior capsule in a pattern that resembles the two limbs of the letter "Y." It is also called the ligament of Bigelow. The second is the pubofemoral ligament, which runs from the medial acetabulum to the medial femoral neck, adjacent to the iliofemoral ligament. The tendon of the iliopsoas courses between these two ligaments, where the capsule is thinnest [20]. The third ligament is the ischiofemoral ligament, which runs with the posterior capsule from the ischium to the posterior femoral neck. Taken together, these ligaments stabilize the hip against potentially detrimental motions such as eccentric loading of the femoral head on the edge of the acetabulum [34].

The labrum is a soft tissue structure that extends from the bony acetabulum and provides lubrication and stability to the femoral head within the acetabulum by cupping and/or deepening the socket in which the femoral head rests, thereby anchoring it in the acetabulum. It contributes less to rotational constraint compared to the iliofemoral ligament and capsule as a whole [35]. The surgeon performing total hip arthroplasty must excise the acetabular labrum thoroughly enough to visualize the bony rim of the acetabulum so that the acetabular component may be positioned properly. Because the bony acetabulum does not form a complete circle, the inferior aspect which contains a fat pat is stabilized by a separate soft tissue structure, the transverse acetabular ligament. Its purpose is to further stabilize the hip joint and provide an attachment site for the joint capsule, which may help the joint strike a balance between allowing adequate range of motion and maintaining a stable joint for weight bearing. Investigators have attempted to use orientation of the transverse acetabular ligament to the labrum measured on magnetic resonance imaging to guide proper cup orientation [36]. The transverse acetabular ligament may also help guide cup orientation intra-operatively for other approaches to the joint, such as the posterior approach [37]. However, acetabular component position with the ABMS approach is judged using assessment of cup position in the acetabulum using alternative landmarks such as the anterior and posterior walls and, crucially, intra-operative fluoroscopy.

The ligamentum teres connects the proximal and central portion of the femoral head to the acetabulum. Like the rest of the capsuloligamentous structures that exist in and/or define the borders of the hip joint, the ligamentum teres contributes to the stability of the femoral head within the acetabulum. Besides acting as a stabilizing force, in many circumstances, the ligamentum teres contains arterial supply that is critical for maintaining the biology of the femoral head. Additionally, the presence of nerves within the ligamentum teres suggests that it may play a role in proprioception and/or pain response [38].

Conclusion

The anatomy of the hip joint consists of bone, muscle, nerve, blood vessels, and capsuloligamentous structures that together dictate what can and cannot be accomplished during the ABMS approach to the hip. The surgeon undertaking this approach must have a firm grasp of the surrounding anatomy to perform total hip arthroplasty through the ABMS approach safely and expeditiously.

References

1. Bertin KC, Röttinger H. Anterolateral mini-incision hip replacement surgery: a modified Watson-Jones approach. Clin Orthop Relat Res. 2004;429:248–55. https://doi.org/10.1097/01.blo.0000150294.81825.8c.
2. Judet R, Judet J, Letournel E. Fractures of the acetabulum: classification and surgical approaches for open reduction: Preliminary Report. J Bone Joint Surg Am. 1964;46(8):1615–75.
3. Wasielewski C, Cooperstein LA, Kruger MP. Acetabular anatomy and the transacetabular fixation of screws in total hip arthroplasty. J Bone Joint Surg Am. 1990;72(4):501–8.
4. Girard J. Femoral head diameter considerations for primary total hip arthroplasty. Orthop Traumatol Surg Res. 2015;101(1 Suppl):S25–9. https://doi.org/10.1016/j.otsr.2014.07.026.
5. Tayton E. Femoral anteversion. J Bone Joint Surg Br. 2007;89-B(10):1283–8. https://doi.org/10.1302/0301-620X.89B10.19435.

6. Dorr LD, Malik A, Dastane M, Wan Z. Combined anteversion technique for total hip arthroplasty. Clin Orthop. 2009;467(1):119–27. https://doi.org/10.1007/s11999-008-0598-4.
7. Emerson RH. Increased anteversion of press-fit femoral stems compared with anatomic femur. Clin Orthop. 2012;470(2):477–81. https://doi.org/10.1007/s11999-011-1993-9.
8. Patel AB, Wagle RR, Usrey MM, Thompson MT, Incavo SJ, Noble PC. Guidelines for implant placement to minimize impingement during activities of daily living after total hip arthroplasty. J Arthroplast. 2010;25(8):1275–1281.e1. https://doi.org/10.1016/j.arth.2009.10.007.
9. Sugano N, Noble PC, Kamaric E. Predicting the position of the femoral head center. J Arthroplast. 1999;14(1):102–7. https://doi.org/10.1016/S0883-5403(99)90210-3.
10. McGrory B, Morrey B, Cahalan T, An K, Cabanela M. Effect of femoral offset on range of motion and abductor muscle strength after total hip arthroplasty. J Bone Joint Surg Br. 1995;77-B(6):865–9. https://doi.org/10.1302/0301-620X.77B6.7593096.
11. Sakalkale DP, Sharkey PF, Eng K, Hozack WJ, Rothman RH. Effect of femoral component offset on polyethylene wear in total hip arthroplasty. Clin Orthop Relat Res. 2001;388:125–34.
12. Ramaniraka NA, Rakotomanana LR, Rubin PJ, Leyvraz PF. Noncemented total hip arthroplasty: influence of extramedullary parameters on initial implant stability and on bone-implant interface stresses. Orthop Proc. 2002;84-B(Supp_I):24-b. https://doi.org/10.1302/0301-620X.84BSUPP_I.0840024b.
13. Boymans TAEJ, Veldman HD, Noble PC, Heyligers IC, Grimm B. The femoral head center shifts in a mediocaudal direction during aging. J Arthroplast. 2017;32(2):581–6. https://doi.org/10.1016/j.arth.2016.07.011.
14. Flack NAMS, Nicholson HD, Woodley SJ. The anatomy of the hip abductor muscles. Clin Anat. 2014;27(2):241–53. https://doi.org/10.1002/ca.22248.
15. Walters BL, Cooper JH, Rodriguez JA. New findings in hip capsular anatomy: dimensions of capsular thickness and pericapsular contributions. Arthroscopy. 2014;30(10):1235–45. https://doi.org/10.1016/j.arthro.2014.05.012.
16. Flack NAMS, Nicholson HD, Woodley SJ. A review of the anatomy of the hip abductor muscles, gluteus medius, gluteus minimus, and tensor fascia lata. Clin Anat N Y N. 2012;25(6):697–708. https://doi.org/10.1002/ca.22004.
17. Gottschalk F, Kourosh S, Leveau B. The functional anatomy of tensor fasciae latae and gluteus medius and minimus. J Anat. 1989;166:179–89.
18. Al-Hayani A. The functional anatomy of hip abductors. Folia Morphol (Warsz). 2009;68(2):98–103.
19. Ryan JM, Harris JD, Graham WC, Virk SS, Ellis TJ. Origin of the direct and reflected head of the rectus femoris: an anatomic study. Arthroscopy. 2014;30(7):796–802. https://doi.org/10.1016/j.arthro.2014.03.003.
20. Iannotti JP. Pelvis, hip, and thigh. In: Netter collection of medical illustrations: musculoskeletal system, part II - spine and lower limb. Philadelpha: Elsevier Saunders; p. 49–127.
21. Simmons C, Izant TH, Rothman RH, Booth RE, Balderston RA. Femoral neuropathy following total hip arthroplasty. Anatomic study, case reports, and literature review. J Arthroplast. 1991;6 Suppl:S57–66.
22. Rodriguez JA, Kamara E, Cooper HJ. Applied anatomy of the direct anterior approach for femoral mobilization. JBJS Essent Surg Tech. 2017;7(2):e18. https://doi.org/10.2106/JBJS.ST.16.00099.
23. Babst D, Steppacher SD, Ganz R, Siebenrock KA, Tannast M. The iliocapsularis muscle: an important stabilizer in the dysplastic hip. Clin Orthop. 2011;469(6):1728–34. https://doi.org/10.1007/s11999-010-1705-x.
24. Hoppenfeld S, de Boer P, Buckley R. Chapter 8: The hip. In: Surgical exposures in orthopaedics: the anatomic approach. 5th ed. New York: Walters Kluwe; 2016. p. 403–64.
25. Jacobs LG, Buxton RA. The course of the superior gluteal nerve in the lateral approach to the hip. JBJS. 1989;71(8):1239–43.
26. Fleischman AN, Rothman RH, Parvizi J. Femoral nerve palsy following total hip arthroplasty: incidence and course of recovery. J Arthroplast. 2018;33(4):1194–9. https://doi.org/10.1016/j.arth.2017.10.050.
27. Rudin D, Manestar M, Ullrich O, Erhardt J, Grob K. The anatomical course of the lateral femoral cutaneous nerve with special attention to the anterior approach to the hip joint. JBJS. 2016;98(7):561–7. https://doi.org/10.2106/JBJS.15.01022.
28. Takada R, Jinno T, Miyatake K, et al. Direct anterior versus anterolateral approach in one-stage supine total hip arthroplasty. Focused on nerve injury: a prospective, randomized, controlled trial. J Orthop Sci. 2018;23(5):783–7. https://doi.org/10.1016/j.jos.2018.05.005.
29. Li B, Zhang B, Ding Z, Liu Y, Dai M. Anterolateral intermuscular approach for type A2 intertrochanteric fractures: a cadaveric study. Int Surg. 2015;100(2):314–9. https://doi.org/10.9738/INTSURG-D-14-00188.1.
30. Totlis T, Paparoidamis G, Terzidis I, Piagkou M, Tsiridis E, Natsis K. Surgical anatomy of the lateral circumflex femoral artery branches: contribution to the blood loss control during hip arthroplasty. Ann Anat. 2020;232:151566. https://doi.org/10.1016/j.aanat.2020.151566.

31. Kawasaki Y, Egawa H, Hamada D, Takao S, Nakano S, Yasui N. Location of intrapelvic vessels around the acetabulum assessed by three-dimensional computed tomographic angiography: prevention of vascular-related complications in total hip arthroplasty. J Orthop Sci. 2012;17(4):397–406. https://doi.org/10.1007/s00776-012-0227-7.
32. Mescher A. Chapter 8: Bone. In: Junqueira's basic histology: text and atlas. 15th ed. United States: McGraw Hill; 2018.
33. Weidner J, Büchler L, Beck M. Hip capsule dimensions in patients with femoroacetabular impingement: a pilot study. Clin Orthop. 2012;470(12):3306–12. https://doi.org/10.1007/s11999-012-2485-2.
34. Karunaseelan KJ, Dandridge O, Muirhead-Allwood SK, van Arkel RJ, Jeffers JRT. Capsular ligaments provide a passive stabilizing force to protect the hip against edge loading. Bone Joint Res. 2021;10(9):594–601. https://doi.org/10.1302/2046-3758.109.BJR-2020-0536.R1.
35. Ng KCG, Jeffers JRT, Beaulé PE. Hip joint capsular anatomy, mechanics, and surgical management. J Bone Joint Surg Am. 2019;101(23):2141–51. https://doi.org/10.2106/JBJS.19.00346.
36. Archbold HAP, Slomczykowski M, Crone M, Eckman K, Jaramaz B, Beverland DE. The relationship of the orientation of the transverse acetabular ligament and acetabular labrum to the suggested safe zones of cup positioning in total hip arthroplasty. Hip Int. 2008;18(1):1–6. https://doi.org/10.5301/hip.2008.1755.
37. Archbold HAP, Mockford B, Molloy D, McConway J, Ogonda L, Beverland D. The transverse acetabular ligament: an aid to orientation of the acetabular component during primary total hip replacement: a preliminary study of 1000 cases investigating postoperative stability. J Bone Joint Surg Br. 2006;88(7):883–6. https://doi.org/10.1302/0301-620X.88B7.17577.
38. Perumal V, Woodley SJ, Nicholson HD. Neurovascular structures of the ligament of the head of femur. J Anat. 2019;234(6):778–86. https://doi.org/10.1111/joa.12979.

ABMS THA in the Lateral Position

4

George Babikian

Learning Points

- A step-by-step approach for performing total hip arthroplasty (THA) using the ABMS approach with the patient in the lateral position is presented from a very experienced surgeon.
- A trained assistant and operating room bed modification are critical to the success of this technique.
- By following the sequence laid out here, the learning curve to adopt this anterior THA approach will be shortened.

Introduction

This chapter will be a step-by-step description of how I perform the ABMS approach with the patient in the lateral position. In discussing with other practitioners, it is clear that there are many individual variations in technique that maintain the principles of minimal soft tissue trauma while allowing for accurate and stable implant placement. These variations are typically the location of the incision and its length, removing or preserving the anterior hip capsule, and treatment of the reflected head of the rectus. I will describe my technique that has evolved over 15 years and 7500 hips. It has served my patients well and has been adopted at my institution with success, as reflected in the results reported in Chap. 18. While this chapter is not the only way to perform a ABMS THA in the lateral position, this will serve as a good starting point for one to slowly evolve their own variations.

There are two special, but very important, requirements for this surgical approach. Because the leg will be continually moved to create access to, sequentially, the interval between the gluteus medius (GMed) and tensor fascia latae (TFL), the acetabulum, and the femur, a dedicated, skilled, and engaged assistant is critical. I believe the biggest part of the "learning curve" is developing the relationship with an assistant that allows each of us to understand the challenges of each step in the process and how to help overcome them. The second requirement is an operating room (OR) bed modification. Access to the femur is obtained with the assistant placing the leg in a maximally extended, externally rotated, and adducted position. This position is allowed by using an OR bed that has a posterior "cut out" distal to the gluteal fold. For us, this is a polyethylene peg board that is attached to our usual OR bed with the foot of the bed flexed down and out of the way (Fig. 4.1). These attachments can be purchased for a nominal fee. There are also beds that have two independent "feet," the posterior of which can be dropped with the patient positioned so that the gluteal fold is level with the break in the bed.

G. Babikian (✉)
Department of Orthopedic Surgery, Maine Medical Center, Falmouth, ME, USA
e-mail: BABIKG1@mmc.org

J. A. Geller, B. J. McGrory (eds.), *The Anterior-Based Muscle-Sparing Approach to Total Hip Arthroplasty*, https://doi.org/10.1007/978-3-031-02059-9_4

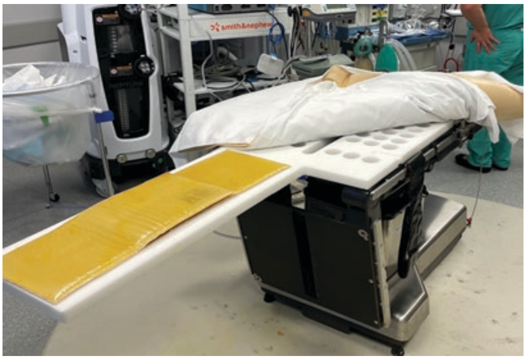


Fig. 4.1 A pegboard on bed with "beanbag" on top for more secure positioning

Anesthesia

We use general anesthesia with infiltration at the end of the procedure. Current regimen is best described as multimodal pain management with general anesthesia and neuromuscular blockade to maximize the ease of surgical exposure.

It has been our observation that with a general anesthetic and full paralysis, less tension in the muscles allows for more gentle retraction and less muscle injury. This is also obviously possible with a regional anesthetic, but in our experience not as reliably so, with occasional residual muscle tension in the proximal leg.

Positioning

We place a beanbag on top of the pegboard to further secure the patient and to minimize pressure points at the pegs. Patient is placed in the lateral position with the operative hip up, the gluteal fold at the level of the posterior cut out in the table, and on top of the beanbag and table extension (Fig. 4.2). Pelvis is leveled and the short peg placed in the most distal anterior hole. The most distal posterior hole is then filled with a medium-length peg. Proximal anterior peg is then placed or skipped if abdomen is protuberant. Proximal posterior peg is the last to be placed, and this can be medium or long. The beanbag is then manually compressed by me from the foot of the bed to make sure of a level pelvis, and the bag is well below the anterior-superior iliac spine (ASIS). It is then deflated for stability. Position is now stable and will allow free motion of the leg without restriction by the bed. I place the bed in 10 degrees of Trendelenburg for what I consider ease of access and possibly blood loss reduction by improving venous return.

Fig. 4.2 Positioning with gluteal fold at break in bed

The patient's leg is next washed with a betadine scrub followed by drying and application of alcohol-based prep (Duraprep). The circulating nurse holds the leg, while U drape is positioned tight in the groin but below the ASIS. A cross drape is then placed transversely above the iliac crest. A stockinette is rolled up the leg to the proximal thigh and secured with Coban. An aperture drape is placed over the leg and positioned proximally to allow access to the ASIS and more proximal pelvis posteriorly. Steri-Drape is then applied laterally and then medially in the groin to complete the draping. The aperture drape may have a leg bag incorporated into it; if not, a mayo stand cover may be attached to the drape and the assistants' chest to accomplish the same thing, a sterile place to put the adducted, extended, and externally rotated leg while accessing the femur.

Incision

The mapping of the location for the incision will help ensure optimum placement over the anterior edge of the GMed. A spot 1 cm proximal and 1 cm posterior to the ASIS is marked (Fig. 4.3). With the leg in 20 degrees of abduction and slightly externally rotated, a 20-gauge spinal needle is used to locate the top of the greater trochanter. This spot is marked. The anterior border of the femur is then located with the spinal needle in two places distally on the proximal femur. Draw a straight line parallel to the anterior femur on its anterior third from top of the trochanter 2 inches distally. Connect the point determined proximally near the ASIS to the end of this line. The resultant line will be approximately 5 inches in length and positioned slightly anterior to the anterior edge of the GMed. The length and position of this line will also give some information regarding access and muscle trajectory. If the line is significantly shorter than 5″ (4″ or less), access will be more challenging. A longitudinal line implies a valgus femoral neck and perhaps easier access and a more transverse line implies a varus neck and perhaps more difficult access. These are clues, not rules, but may be important in choosing the

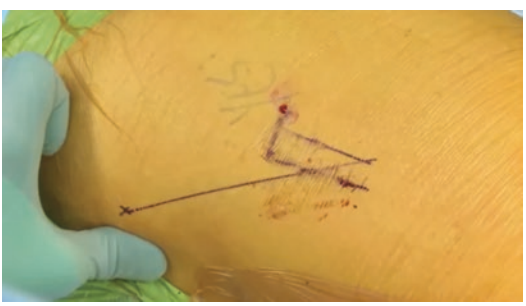


Fig. 4.3 Incision mapped, the thumb is on ASIS, and the proximal femur marked out as a rectangle

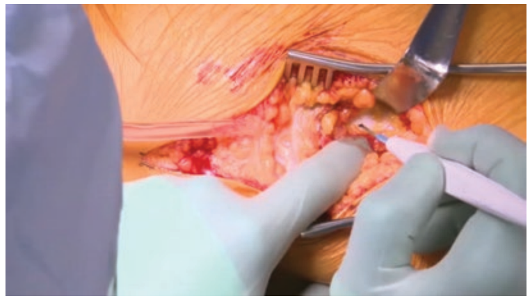


Fig. 4.4 Incision to fascia latae over trochanter, ready to incise fascia

cases to initially choose when adopting this approach.

Incision is made sharply along the above resultant line through the skin. Using electrocautery, the subcutaneous fat is incised to fascia. I attempt to leave fat attached to fascia without stripping. By feeling for the trochanter distally, the fat can be incised accurately to bring the incision down on the anterior trochanter about 2 inches from its most proximal extent. Fascia is incised distally at the junction of the lateral and anterior edge of the trochanter (Fig. 4.4). This is a small opening at first; if beneath the fascia, fat is observed. This is the proper position, and the fascial incision can be carefully extended proximally.

After opening distal to proximal approximately 2–3 inches, it will be possible to locate the GMed and TFL beneath a variable thick layer of investing fascia.

The interval is easiest to find by locating the anterior distal border of the medius as it enters the trochanter and using careful dissection following this muscle both proximally and posteriorly to define the space between the GMed and TFL and the medius/minimus and the anterior hip capsule.

The fascial incision laterally can be extended proximally as the interval is progressively defined. Care should be taken to leave a small cuff of fascia on the TFL for later closure. There will be a leash of vessels midway up the interval entering the medius from below, these need to be ligated. More proximally, the nerve to the TFL, a branch of the superior gluteal nerve, should be preserved by sweeping it anteriorly toward the TFL (Fig. 4.5).

A retractor then can be placed over the femoral neck under the minimus and on top of the hip capsule (Fig. 4.6). The second assistant may be tempted to pull too hard on this retractor to see over the wound, discouraging this as muscle damage may result. There will be a variable amount of fat on the anterior capsule. A second retractor is placed along the inferior femoral neck just proximal to the lesser trochanter. This position can be found by following the intermedius muscle along the intertrochanteric line. There will be a soft spot at the inferior extent of this muscle that allows for easy placement of this retractor. The interval can now be extended proximally as needed with sharp and blunt dissection between the muscles, leaving the fascia of the TFL intact. Fascial incision can be extended distally to free the TFL and further open the interval as needed for access.

The fat over the anterior capsule is then removed to help define the extent of capsulotomy and the location of the reflected head of the rectus, which will be evident under the fat pad (Fig. 4.7). Capsulotomy can then be executed to the edge of the acetabulum without injuring the reflected head.

Capsulotomy will be Z configuration, starting at the tip of the greater trochanter and roughly following the femoral neck to the superior acetabulum, taking care not to extend past the edge and injure the reflected head of the rectus femoris muscle. Next, a limb is created from the tip of trochanter along proximal edge of the vastus intermedius along the intertrochanteric line (Fig. 4.8). This should not be extended too far medially, again to protect rectus. Extension of this limb will be done later from inside the capsule. Retractor is now replaced inside this inferior anterior limb on the femoral neck. Next, the

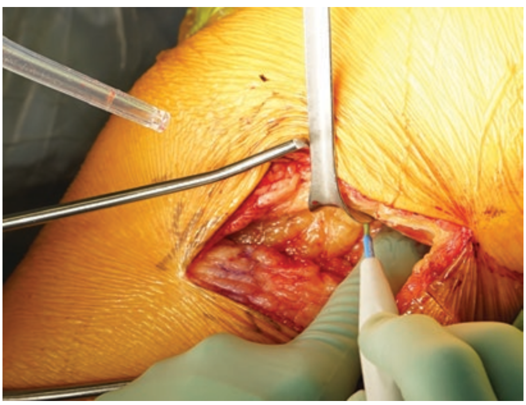


Fig. 4.5 The fascia incised, medius under Richardson retractor, and finger on greater trochanter pulling TFL anteriorly

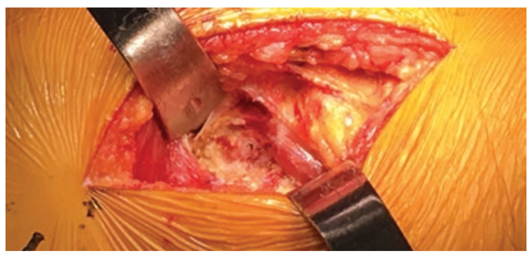


Fig. 4.7 Fat pad removed from the top of capsule to help define the extent of capsulotomy

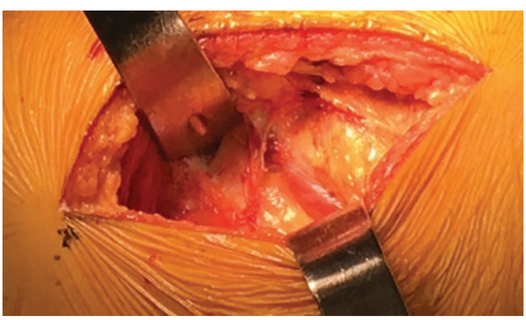


Fig. 4.6 Retractors above and below femoral neck on top of capsule, under medius and minimus

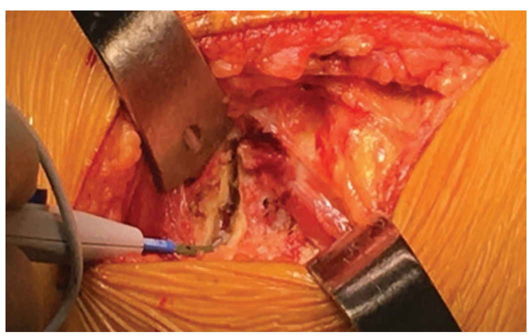


Fig. 4.8 The first limb of capsulotomy, roughly along femoral neck axis

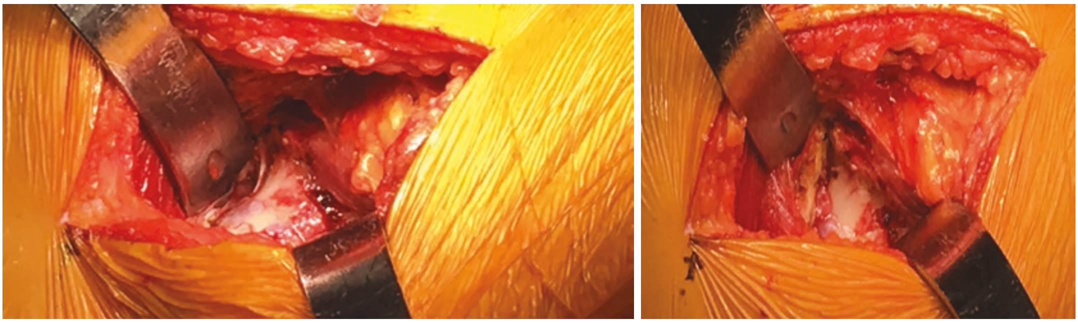


Fig. 4.9 The second limb of capsulotomy along intertrochanteric line completed and inferior retractor placed inside capsule inferiorly

limb is developed along superior rim of acetabulum creating a posterior flap. Retractor is placed inside this limb along superior femoral head neck posteriorly allowing a clear look at the proximal femoral neck and distal femoral head inferior to the acetabular rim (Fig. 4.9).

From here the leg is rotated into a relaxed Fig. 4.4 position, gently flexed, externally rotated, and abducted. Retractors inside the capsule may need to be repositioned, again inside the capsule at the posterior superior and inferior anterior femoral head to give more proximal exposure (Fig. 4.10).

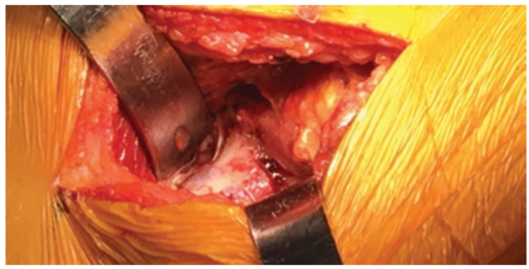


Fig. 4.10 The third and final limb of capsulotomy complete along superior acetabulum, retractors in place, leg in relaxed Fig. 4.4 position

Once positioned, the initial femoral cut is made. This is done as proximal as possible, near the edge of the acetabulum, at an angle of 30°–45° to the floor. It is important to make sure the oscillating blade is between the retractors, as this will protect the muscles from the edges of the blade. I find it necessary to hold the saw upside down to get the clearance needed to make the cut as proximal and as angled as necessary (Fig. 4.11). The angle is to allow the femur to slide up the inclined plane created with angled cut in the next step. Making the cut as proximal as possible provides a later advantage, the high cut makes for a larger neck fragment removed, which makes more space to remove the femoral head segment, which is smaller given the more proximal cut. Overall, these details are “worth it.”

A straight 1-inch osteotome is then placed in the oblique osteotomy to act as a skid, the posterior femoral neck retractor removed, and the inferior retractor repositioned on the neck. The assistant adducts, extends, and externally rotates the leg into the leg bag while placing a proximal and laterally directed force on the femur. This should allow the femur to slide “up” the osteotomy, relaxing the medius and minimus by shortening the distance to trochanter (Fig. 4.12).

The posterior retractor is now replaced under the minimus/medius and over the trochanter on top of the capsule. The saddle is now located with dissection along the lateral intertrochanteric line, locating the spot where the trochanter reflects up from the neck. This spot will be the target for the lateral exit of the definitive femoral neck osteotomy. The trajectory of the osteotomy from this spot will be based on the intertrochanteric line and the intermedius muscle. For a higher cut one angle away proximally from the intertrochanteric line, a shorter cut will follow the line. The femur is held with the shaft parallel to the floor and the tibia perpendicular to the floor. The neck cut is then made perpendicular to the floor, which will also be square to the femur, allowing a guide later to the trajectory of the femoral implant (Fig. 4.13).

Fig. 4.11 Oscillating saw upside down cutting femoral neck at an angle, taking care to keep oscillations between the retractors

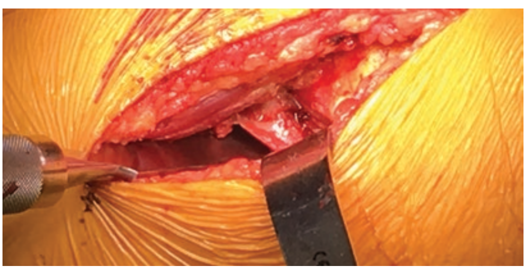


Fig. 4.12 Osteotome in femoral neck cut to act as inclined plane for femur to slide up into the wound, relaxing medius and minimus

Neck fragment is then removed and observed (Fig. 4.14). I remove the neck fragment with a meniscal clamp; it is often advantageous to start the freeing of the neck fragment with a straight osteotome placed in the osteotomy. The shape of the distal cut will advise the length of the neck cut, round higher and oval lower.

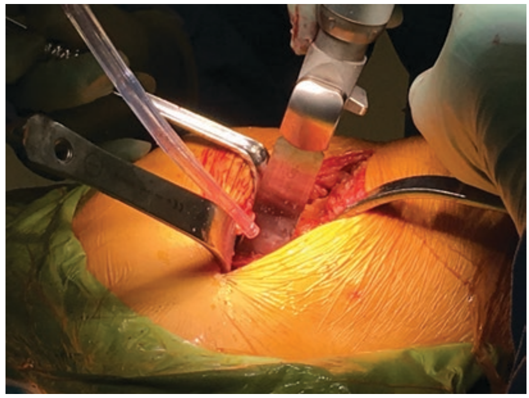


Fig. 4.13 Femoral neck cut being made, again, taking care to keep oscillations between the retractors

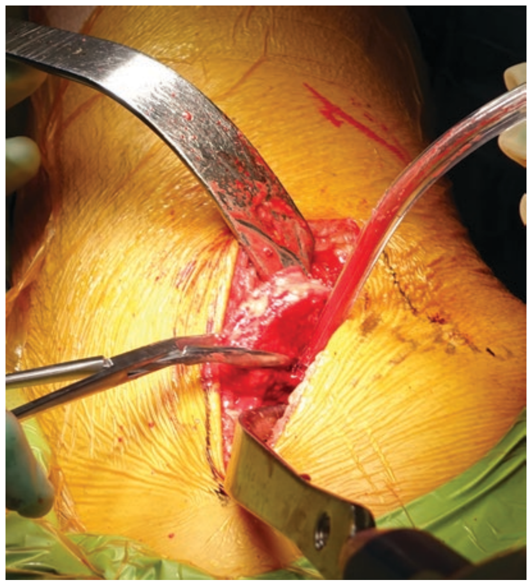


Fig. 4.14 Neck fragment being removed

After removal of the neck fragment, it is often necessary to reposition the anterior inferior retractor more distally. The assistant then maximally adducts, externally rotates, and extends the leg, with the lower leg in the leg bag, to facilitate the capsular release; this position places the tissue to be released under tension and makes obvious the stepwise effects of the release.

The capsular release is performed along the medial and posterior border of the greater trochanter (Fig. 4.15). The trochanter is located

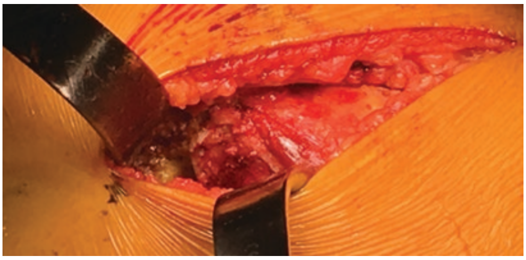


Fig. 4.15 Release performed. Note avascular area behind femoral neck cut. This is the medial greater trochanter with capsule released

posterior to the lateral neck and is covered in capsule at this stage. Using electrocautery, a longitudinal incision from distal to proximal along the trochanter will free the capsule from the trochanteric bone and allow proximal and lateral migration of the femur into the wound, further relaxing the GMed and GMin. When in the right spot, the tip of the electrocautery will be on bone, and the plane will open as avascular with some fat under the incised capsule. This release can be taken to the tip of the trochanter.

If further mobilization of the femur is required, release can be performed in the piriformis fossa, again with a degree of mobilization of the femur proximal and lateral. The last release can be along the posterior neck, but this rarely provides much mobilization. I judge the amount of release to do by access; as soon as access is adequate to allow accurate broaching of the femur, no further release is done.

The femoral head is now removed. Leg is returned to a neutrally abducted position, and a two-prong retractor placed on the cut surface of the femoral head to rotate the cut surface just past parallel to the face of the acetabulum with a small amount of head projecting past the anterior wall. The first attempt is made by grabbing the head with a meniscal clamp and pulling the head out under the femur, over the anterior acetabulum. If unsuccessful, I place a T handle awl parallel to the cut surface and remove the head with a force directed to pull the head under the femur anteriorly over the anterior wall. It may rarely be necessary to section the ligamentum teres to allow removal. In rare cases it may be necessary to section the femoral head just proximal to the T handle awl and remove the head in two pieces. This is done by using the awl as a handle, rotating the head out of the socket maximally, placing single-prong retractors front and back on the head, and cutting using an oscillating saw between the retractors. The cut can be completed with an osteotome, and the more distal fragment removed. The smaller proximal fragment with its attached ligament can be left in the acetabulum until the acetabulum is prepared for reaming and access is easier. With femoral head removed, it is easy to locate the lesser trochanter by palpation along the posterior neck to further confirm the length of neck cut.

Retractors are now placed around the acetabulum; the first is a Mueller-type two-prong retractor along the posterior inferior acetabulum. This can be placed with the femur in a neutral position, with the assistant placing an upward, laterally directed force from under the femur to create space. With a finger between the prongs of the retractor, palpating the acetabulum, the retractor can be drawn up the posterior wall until it comes over the edge of the wall in position at 8 o'clock for left and 4 o'clock for right hips. This retractor is given to the second assistant, with the purpose of retracting the femur both posteriorly and inferiorly. This retractor should not be pulled on with any force until all acetabular retractors are placed, as at this stage it is very close perpendicularly to the muscle direction and will cut muscle with excessive force.

A second retractor, Hohmann type with a straight tip, is now placed over the anterior acetabular rim beneath the rectus at 3 or 9 o'clock depending on the laterality. A third single-prong retractor is placed superiorly under medius/minimus. This retractor gently changes the direction of the medius, allowing more force to be placed on the posterior acetabular retractor without muscle damage.

With retractors in place, the acetabulum is prepared for reaming (Fig. 4.16). First, overhanging anterior and superior capsule can be mobilized with an incision (using electrocautery) tangential to the superior acetabulum which carried a very short distance onto the ilium. This will

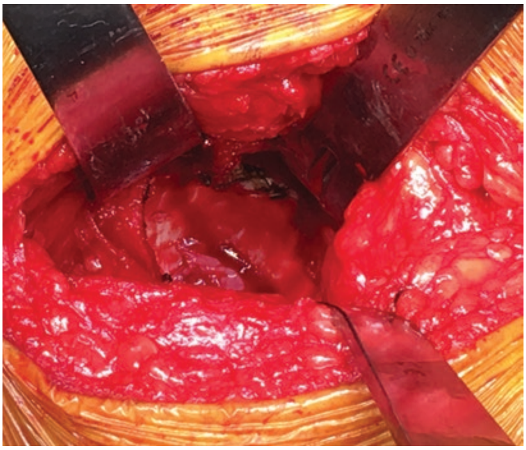


Fig. 4.16 Acetabular retractors in place

Fig. 4.17 Reamer going into acetabulum using retractors as "skids" to clear the muscle

open the interval to the acetabulum. Overhanging capsule can be removed. Labrum is removed now, as are osteophytes, particularly anteriorly if they block access.

Reaming is begun with a reamer 2 mm under the template that fits the acetabulum well. Reamer is introduced by abducting the femur to open the wound medial lateral. Once through the muscle plane, the leg is returned to neutral and the reamer placed into the acetabulum. Throughout, the retractors act as "skids" to protect the muscle behind them (Fig. 4.17). Difficulty introducing the reamer is often due to inadequate retraction on the posterior acetabular retractor, usually without enough distally directed force. If still tight, consider the release of capsule along the medial femoral neck. If still tight consider further neck resection if the remaining bone allows. Taking a millimeter or two of bone can make things much easier in patients with tight access. Reaming is started in a central, medializing direction to avoid being pushed superiorly. The second reamer, at templated dimension, can be angled toward anatomic abduction, but not overly so. Removing the reamer from the acetabulum is accomplished by dissociating the reamer head from the shaft, removing the reamer head with a tonsil clamp.

Ream to standard fit without excessive deepening.

I place the acetabular component by rotating it into place, entering the wound retroverted and vertical, once below the muscles bringing the face parallel to the acetabulum, tucking the inferior edge under the transverse acetabular ligament, then using the superior anterior corner of the acetabulum as a fulcrum, and rotating the component into excessive anteversion until the implant slides fully into the acetabulum. The component is then rotated back to the proper anteversion, slightly below the anterior acetabular rim. Local and external landmarks are used to guide accurate placement (Fig. 4.18). Impaction follows, testing stability thereafter. Screw utilization is optional. Liner is then impacted (Fig. 4.19). It is not necessary to use large femoral heads as stability will be excellent with 32 mm heads. I do go to 36 mm heads at 58 mm and above.

The use of an elevated rim anteriorly is at user discretion.

Fig. 4.18 Acetabular component in position for impaction

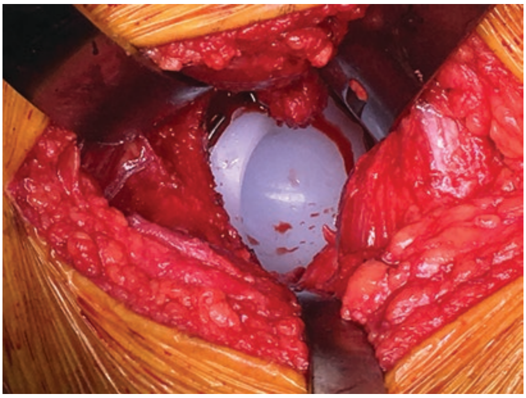


Fig. 4.19 Acetabular component insertion completed

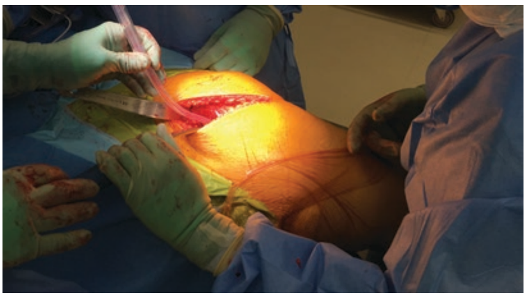


Fig. 4.20 Leg positioned for femoral exposure, extended, externally rotated, and adducted by assistant. Retractors behind the tip of greater trochanter and on calcar

Attention is now turned to the femur. Leg is returned to the bag, and assistant positions the leg in adduction, external rotation, and extension. Single-prong retractor is placed under the medius/minimus over the trochanter. This will be held by the second assistant, with instruction not to pull "too hard." The second retractor, two-prong, is placed on calcar proximal to the lesser trochanter (Fig. 4.20). Access should be such that trajectory of broach is not changed by contact with retractors or soft tissue. If this is not the case, and all releases done, access can be improved with lengthening of the fascial incision distally parallel to the femoral shaft. This will allow the TFL to fall forward and lessen the need to retract a large, rigid medius.

Broaching is conducted in standard fashion, remembering that with a neck cut perpendicular to the axis of the femur (as obtained above), placing broach parallel to the cut will give an implant in line with the femoral axis (Fig. 4.21). Starting point is lateral and with reference to the piriformis fossa, which lies directly over the femoral canal.

Femur is sequentially broached to size, and access should be such that any implant can be used. Take care not to enlarge or deform the machining of the metaphysis by taking care in removing and placing the sequential broaches (Fig. 4.22). Proximal femur machining should near-perfectly match the implant, with no gaps anterior or medial.

Upon reaching the final broach, trial reduction is performed. I trial-reduce a size shorter than the template, as I am confident of stability, and reduction can be a significant effort with a slightly long construct, particularly if minimal releases have been performed or larger heads are being used.

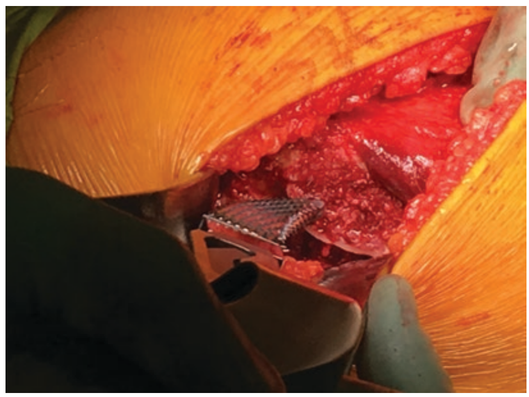


Fig. 4.21 Starter broach

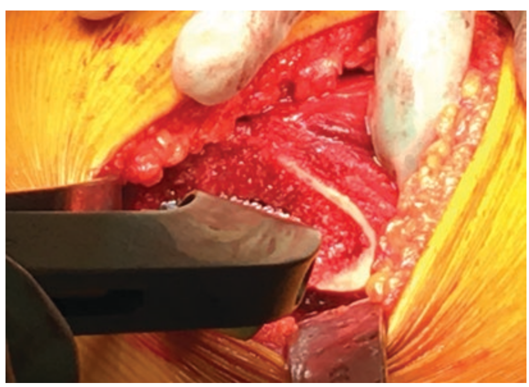


Fig. 4.22 Take care to be precise in "machining" the femur with the broaches. Note the fit of the broach

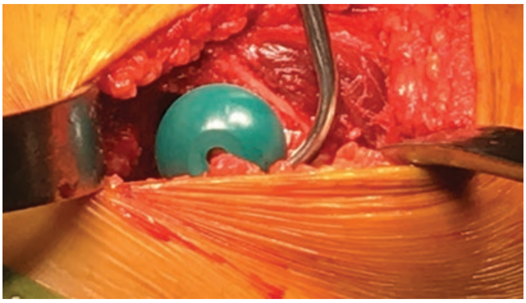


Fig. 4.23 This is a left hip before reducing the femoral head into the acetabulum

Once reduced, these long constructs can be even more difficult to dislocate, so I avoid trialing long. Reduction is accomplished by placing a bone hook on the femoral neck, bringing the leg into slight abduction and lifting the femoral head posterior and lateral over the anterior acetabulum and capsule into the capsular osteotomy (Fig. 4.23). Longitudinal traction at this point will reduce the hip. Do not drag or push the femoral head over the anterior acetabulum as the rotational force on the femoral head (and hence broach) is significant and may cause the broach to rotate, perhaps cracking the calcar. Lifting the femur will remove this risk.

Multiple reads are available to judge length and offset. First is the difficulty of reduction. If difficult (requiring significant longitudinal traction) and there is no longitudinal translation with a distally directed pull once reduced, the hip is too tight, it either is too long, has too much offset, or a combination of both.

If reduction is difficult but a millimeter or two of translation with distal pull, the cup may be slightly under anteverted or horizontal. Check tightness of fascia latae for further confirmation. range of motion (ROM) is tested for stability and tightness, particularly in quadriceps in extension. Hip is then dislocated with bone hook (Fig. 4.24) to lift femoral head out of acetabulum after placing distraction force in slight abduction.

Leg is returned to the bag and femoral access position (Fig. 4.25). Retractors are replaced behind trochanter and on calcar.

Broach is again tested for stability and, if stable, removed and replaced with permanent implant (Fig. 4.26). If not stable, further broaching is performed to implant stability, and permanent implant placed. Length adjustments are made prior to final implant (calcar planning, sizing up, etc.).

Trial reduction can again be performed, or if previous trial is adequate, permanent head/neck

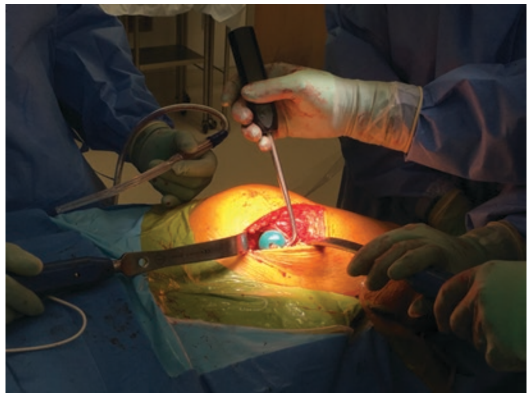


Fig. 4.24 Dislocation with bone hook

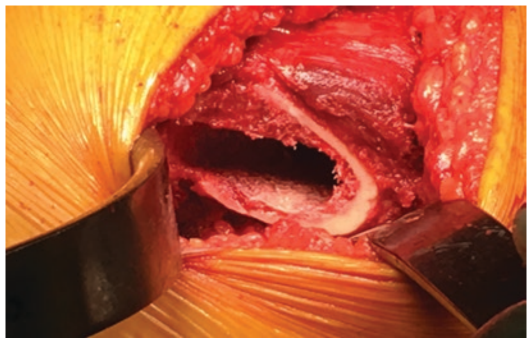


Fig. 4.25 Metaphyseal envelope for femoral stem

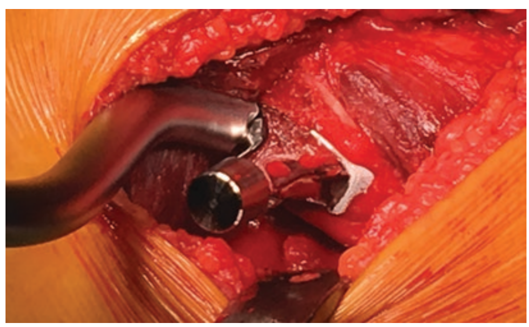


Fig. 4.26 Femoral stem in place, good cancellous bone to the implant

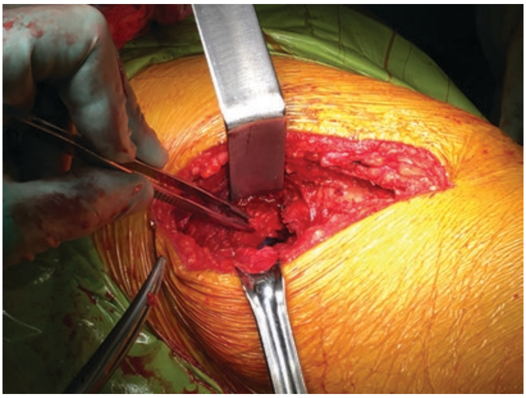


Fig. 4.27 Capsule ready for closure

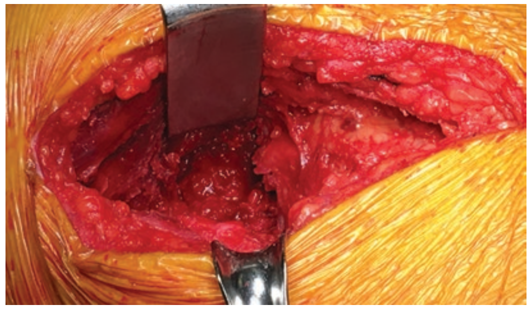


Fig. 4.28 Capsule closed

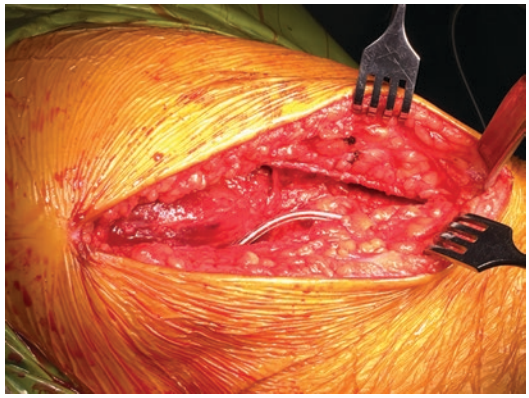


Fig. 4.29 The beginning of closure. We no longer use drains

placed and reduced using same sequence as above. Test ROM and tensions a final time.

Closure (Fig. 4.27) is accomplished by placing two stitches in the hip capsule at the corners of the capsulotomy, loosely closing it (Fig. 4.28).

Local anesthesia is then infiltrated into the capsule and subcutaneous tissues. Fascia latae (with the fat still attached to it) is closed with a running 0 Vicryl or by the method of choice (Fig. 4.29).

Subcutaneous tissue is approximated to minimize dead space, and the skin closed with a running subcuticular suture and glue. Dressing is applied and patient awakened.

Conclusion

Following these steps is a good way to begin the process of becoming facile with the ABMS approach to total hip replacement (THR). This sequence is the product of 16 years of evolution and small modifications to improve outcomes and has been very successful for me and my partners.

Your own modifications will surely follow, but by paying attention to the sequence laid out here, the learning curve will be shortened.

5 The ABMS Approach to Total Hip Replacement in the Supine Position

Mohammad S. Abdelaal and Peter F. Sharkey

Learning Points

- The anterior-based muscle-sparing (ABMS) total hip replacement (THR) is a safe and effective means of performing hip arthroplasty.
- With proper planning, the surgery can be performed expeditiously in the supine position.
- Direct assessment of stability and leg lengths can be done very easily via ABMS in the supine position and does not require any special operating room (OR) table.
- Fluoroscopy can be utilized in the supine position, which can be a major benefit for implant confirmation prior to leaving the OR.
- ABMS in the supine position has shown a shorter learning curve than the direct anterior approach to THR.

M. S. Abdelaal
Department of Orthopaedic Surgery, Rothman Orthopedics at Thomas Jefferson University, Philadelphia, PA, USA
e-mail: mohammad.abdelaal@rothmanortho.com

P. F. Sharkey (✉)
Department of Orthopaedic Surgery, Sidney Kimmel School of Medicine, Rothman Orthopedics at Thomas Jefferson University, Philadelphia, PA, USA
e-mail: Peter.Sharkey@rothmanortho.com

Introduction

Total hip arthroplasty (THA) has evolved over the past 50 years to become one of the most consequential quality of life improving interventions performed today [1, 2]. With innovations in implant manufacturing including cementless components, highly cross-linked polyethylene, and enhanced ceramic head quality, the need for revision THA has significantly declined [3]. These recent advances have highlighted the importance of the nuances of the procedure including the surgical approach. Variations in surgical approach as a means of improving early function and reducing postoperative pain in THA have attracted a lot of interest [4]. Traditionally, long-established approaches for THA including the posterior (Moore or Southern) and lateral (Hardinge) have routinely led to excellent clinical and functional outcomes when performed by an experienced surgeon [5]. However, the increasing demand for THA has created a debate focused on the speed of recovery and rating the quality of outcome based on incremental measures dependent on variables including surgical approach [6]. Since THA is already almost 99% successful, procedural changes might risk downside consequences with less chance of surgical improvement. Therefore, surgeons must be judicious in case they consider switching their surgical techniques to avoid complications.

J. A. Geller, B. J. McGrory (eds.), *The Anterior-Based Muscle-Sparing Approach to Total Hip Arthroplasty*, https://doi.org/10.1007/978-3-031-02059-9_5

Over the last decade, there has been an increasing interest in minimally invasive approaches to THA with a surge in published literature regarding favorable outcomes of these soft tissue-preserving procedures. Much focus was directed to anterior-based approaches and in specific direct anterior approach (DAA) with recent reports showing that about 20% of surgeons in the American Association of Hip and Knee Surgeons currently perform THA through DAA [7]. However, the steep learning curve of DAA with increased reported complication during the learning curve has led to continuous evaluation of other anterior-based approaches [8].

The anterior-based muscle-sparing (ABMS) approach was popularized by Bertin and Röttinger in 2004 as an innovative approach of THA in the modern era [9]. Multiple reports described the approach in different terms, including the modified anterolateral or modified Watson-Jones approach [10, 11]. The ABMS is performed via exposure of the hip joint through an interval between the tensor fascia latae (TFL) and gluteus medius (GMed) muscles. Studies published on ABMS surgery have reported enhanced recoveries, less tendency to postoperative limp, excellent long-term results, reduced hospital stay, and low complication rates when compared to THA performed through other approaches [10, 12].

While ABMS THA was originally described while patient is in lateral decubitus position, it can be also performed with the patient in the supine position without the need for any specialized tables [13]. Of note, this interval was described with the patient in a supine position in a 1966 manuscript describing the McKee-Farrar hip prosthesis [14]. Similarly, other exposures for THA, such as direct lateral (Hardinge) and transtrochanteric, allow for patient positioning options. The advantages and disadvantages of both positioning techniques are dissimilar. With the patient in the supine position, the surgeon can more easily determine implant position, stability of the articulation, and equalization of leg lengths [15].

This chapter will describe the ABMS approach to THA performed with the patient supine on the operating bed. The operative experience and technique will be explained to explore the potential advantages of this approach as a safe alternative for primary THA.

Advantages

Proponents of this technique note that excellent exposure of the hip can be obtained without release of muscle attachments. Additionally, the exposure allows for clear identification of the abductor muscles and with optimal technique; injury to these muscles can be avoided. Additionally, if the procedure is more challenging than expected, the ABMS exposure can easily be expanded by releasing a portion of the abductors, essentially converting to a Hardinge approach. Multiple studies reported on the favorable outcomes of the ABMS approach. In two studies done by Martin et al. [11] and Martez et al. [16], there was less operative bleeding, smaller incisions, and slightly longer OR times with ABMS compared to other approaches. Faster recovery in the postoperative period and lower level of muscle creatine kinase on postoperative day 1 were reported by Inaba et al. [17], which reflects the limited surgical trauma caused by the ABMS approach. This early recovery and improvement in functional outcomes suggest that muscle splitting or tenotomies have a greater effect on the sensomotor capacity of the joint. This is similar to the hypothesis described by Zati et al. [18] and He et al. [19], who stated that muscle afferent is more important than the hip capsule receptors for preserving joint proprioception and strengthening static and dynamic antigravitational reaction. Hence sparing muscle severing can lead to shortening of the rehabilitation period and improving the functional outcome scores. Further advantage of ABMS includes the control of limb length discrepancy with 96% of the cases within the range of 6 mm of LLD [13]. The supine position and draping both legs sterile allows for a precise and convenient evaluation of leg length with trial components both with knee extended and, when in doubt, with the knee flexed.

Disadvantages

Critics of ABMS THA often cite that while being an intramuscular approach, it is not performed through an intranervous plane. The ABMS exposure between the TFL and GMed muscles has the potential to disrupt innervation by the superior gluteal nerve to the TFL. Ince et al. described a distal intermuscular branch between the GMed and TFL which creates a loop with the upper branches of the superior gluteal nerve within the TFL itself. The consequences of TFL denervation are also undetermined. This occurrence has been described by most authors as inconsequential. At a median follow-up of 9.3 months, Unis et al. found 74% of patients exhibited either atrophy or hypertrophy of the TFL and 42% exhibited fat replacement on MRI [20]. Chulsomlee et al. used a hand-held dynamometer to measure hip abduction and flexion muscle strength after ABMS for THA after femoral neck fracture. They found that 89% of patients had gluteus minimus (GMin) injury on average without GMed muscle injury [21]. Other potential complications may be related to the learning curve. Laffosse [22] et al. showed several cases of intraoperative fractures of the greater trochanter during the early learning stage. Civinini [13] et al. reported 0.6% greater trochanter fracture and 0.6% femoral nerve palsy in their cohort of 343 THA patients operated through ABMS in the supine position.

Surgical Technique

To achieve facile surgical exposure, precise preoperative positioning is critical.

Patient Positioning and Draping The patient is placed in the supine position on a standard operating room table. The surgical extremity is positioned hanging over the edge of the table about an inch while positioning the greater trochanter at the table hinge for maximum leg excursion and manipulation (Fig. 5.1). The table can be tilted toward the non-surgical side approximately 20°, allowing adequate femoral extension which is critical for broaching, reaming, and canal access (Fig. 5.2). This maneuver also allows for better illumination by the operating room (OR) lights. To stabilize the patient, a ridged support is placed against the iliac crest on the non-surgical side (Fig. 5.3). The surgical limb is prepped, and both legs are draped sterile using a custom drape (Kimberly Clark, Irving, TX, USA) that would allow both legs to be draped-free and to be mobile during the surgical procedure (Fig. 5.4).

Fig. 5.1 A patient in the supine position

Fig. 5.2 The operative table is tilted 20° toward the contralateral side

Fig. 5.3 A ridged support is placed against the contralateral (left, in this case) pelvis

Fig. 5.4 Sterile draping of both legs

Alternatively, a bilateral total knee replacement drape may also be utilized, with a larger window cut away for full visualization of the surgical field on the operative extremity.

Anatomical Landmark and Incision A 5- to 8-inches (7–13 cm) incision is made along the anterior border of the greater trochanter. The incision extends from a point one finger breath proximal to a point four finger breaths distal to the tip of the greater trochanter (Fig. 5.5). Early in the learning curve, this incision may be larger to facilitate exposure. The iliotibial tract is exposed and then incised longitudinally in line with the skin incision (Fig. 5.6). The neck is reached through bluntly developing the interval between the TFL and the anterior border of the GMed, with no muscle splitting or detachment. Care should be taken to ligate some small crossing vascular structures at the midpoint of this interval. To expose the capsule, the fat pad can be swept off bluntly or dissected off the anterior portion of the joint capsule, and an anteriorly curved Hohmann retractor is placed anterior to the acetabulum, under the rectus and psoas tendon. Then two curved Hohmann retractors are placed under

Fig. 5.5 Landmarks for incision (GT = greater trochanter)

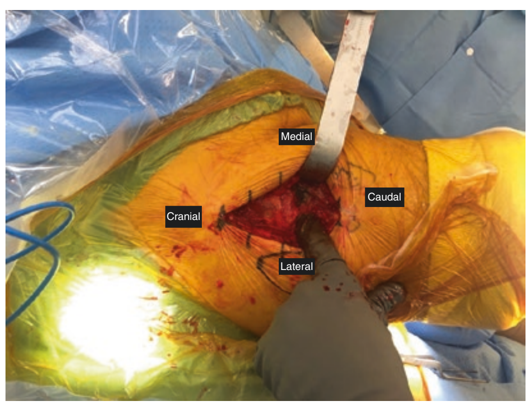


Fig. 5.6 Iliotibial tract incision and retraction of the rectus and psoas tendons

the superior and inferior aspects of the capsule (Fig. 5.7). Care should be taken to not recklessly spread the interval too far proximally, as there may be branches of the superior gluteal nerve innervating the TFL.

Capsulotomy and Femoral Neck Osteotomy An H-shaped anterior capsulectomy is performed, and the edges are tagged with Vicryl sutures for later repair. The femoral neck is osteotomized in situ without dislocation using an oscillating saw (Fig. 5.8). This technique reduces the risk of superior gluteal nerve injury which may be caused by stretching the fibers of the GMed muscle during dislocation. The head and neck are then elevated with a broad osteotome

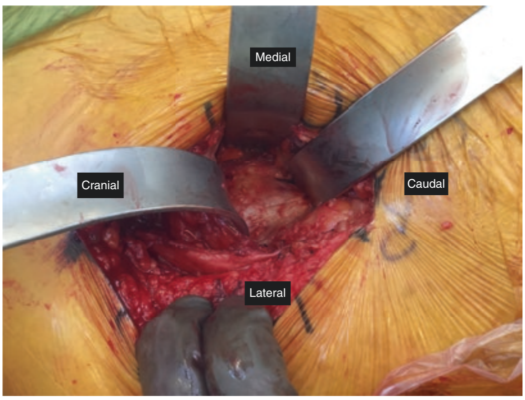


Fig. 5.7 Exposure of the capsule through the interval between the gluteus medius (GMed) muscle, posteriorly, and tensor fascia latae (TFL), anteriorly

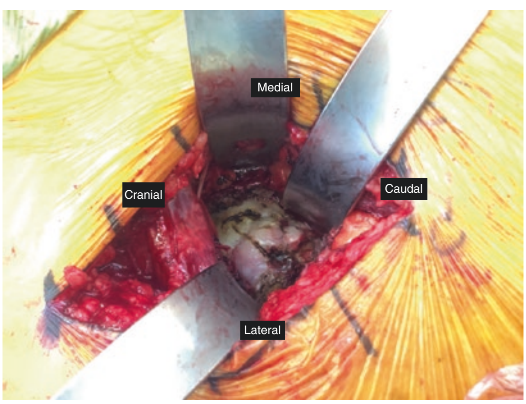


Fig. 5.8 After capsulotomy, the femoral head and neck are exposed

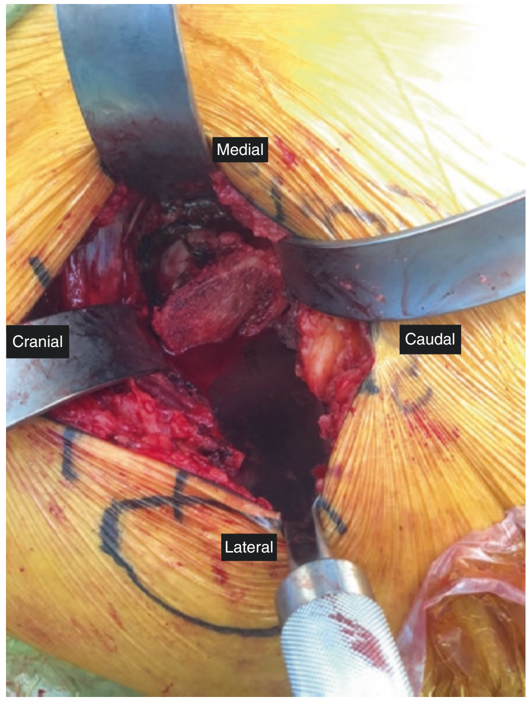


Fig. 5.9 Elevation of the osteotomized head and neck with an osteotome

(Fig. 5.9). After insertion of a corkscrew, the neck is easily rotated anteriorly, and the posterior capsule is released from the neck using a Bovie cautery. The resected head and neck are readily removed without the need for a "napkin ring" resection.

In the early stages of the learning curve, this cut can be marked out with the assistance of fluoroscopy. It should be directed perpendicular to the axis of the neck and originate at the saddle of the neck where it meets the greater trochanter. The geometry of the neck cut is an important factor in determining the ease of the rest of the procedure. If too long, there will be difficulty gaining access to the acetabulum. In addition, preparation of the femur will be difficult if the neck cut is too long and leaves too much of the saddle intact, likely forcing the broach and stem into excessive varus. After gaining more experience, the length of the cut can be assessed by palpating the lesser trochanter around the posterior aspect of the neck, after the cut, and confirming proper length.

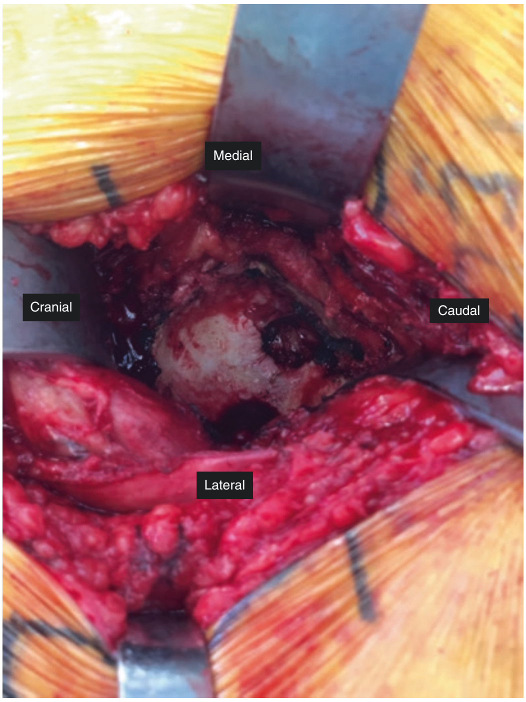


Fig. 5.10 Exposure of the acetabulum

Acetabular Exposure and Preparation Excellent exposure of the acetabulum makes socket preparation relatively simple (Fig. 5.10). Three modified Hohmann retractors are used to expose the acetabulum. The first is a double-footed retractor (or Mueller-type retractor) placed posteriorly to push the femur backward (3 o'clock for a left THR and 9 o'clock for a right THR). The second retractor is placed anteriorly (opposite locations on the clock to the prior positions) to retract the anterior capsule and the muscles. This retractor should be placed with care so as not to injure any of the structures in the femoral triangle. We typically gently place the retractor directly over the anterior lip of the acetabulum with a finger palpating the area and walking the retractor tip into just the right spot. The last retractor is placed below the transverse acetabular ligament, if necessary, in patients with a greater soft tissue envelope. The labrum and pulvinar can now be visualized and excised. With direct visualization of the cotyloid fossa, the initial reamer is placed to achieve appropriate medialization down to the medial wall. Progressive reaming is then performed until reaching the appropriate size for the cup. Extra caution is necessary at this step, as the pelvis position might be changed with challenging dislocation maneuvers. Since the patient is supine, determining the desired cup anteversion and inclination can be achieved by careful inspection of the cup insertion handle after the implant has been firmly seated in the acetabulum (Fig. 5.11). We typically orient the cup in line with the patients' normal anatomy, including abduction angle and anteversion angle. Once again, early in the learning process, this position can be confirmed with fluoroscopy. In this particular case, a modular dual-mobility component was inserted because of prior spinal fusion (Fig. 5.12). Acetabular screws can be placed per the surgeons' preference, and the liner is impacted into place.

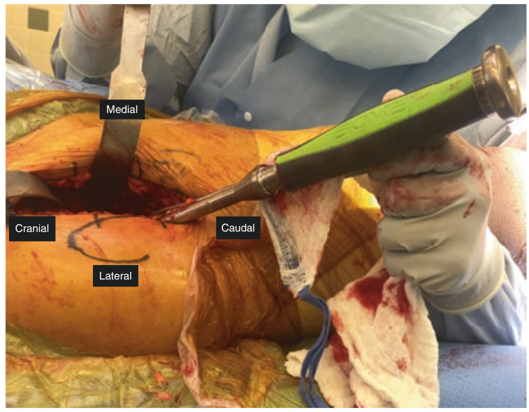


Fig. 5.11 Cup insertion handle helps evaluate the correct cup anteversion and inclination

Femoral Preparation To expose the femur, the surgical limb is placed under the contralateral leg in a Fig. 5.4 position (abduction and external rotation of the femur, with flexion of the knee) (Fig. 5.13). Further dropping of the leg of the table may also improve proximal femoral exposure. This can be done while leaving the "well leg" on a padded mayo stand.

An advantage of the supine position is the ability to reference the handle to the table surface for anteversion and the body midline for inclination angle. Double-footed retractors are placed

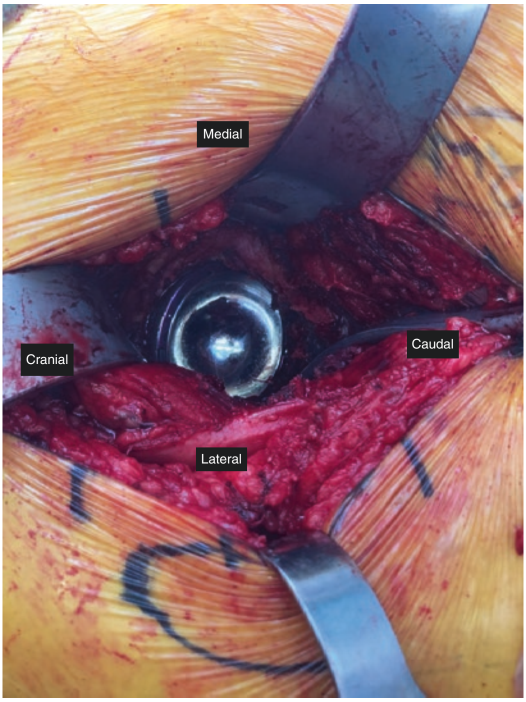


Fig. 5.12 Acetabular component (modular dual mobility) position

Fig. 5.13 To expose the proximal femur, the surgical limb is placed in a Fig. 5.4 position with the lower leg under the extended contralateral limb

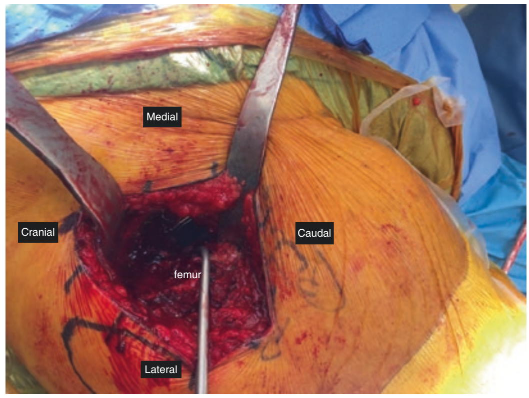


Fig. 5.14 Retractors for the gluteus medius (GMed) muscle and the posterior femur. Bone hook is used to bring the femur forward

on the posterior femur to retract the GMed muscle. An essential step of the procedure is to perform release of the superior and lateral hip capsule from the femur using an electrocautery device. This is best performed while distracting the femur toward the anterior aspect of the wound using a bone hook (Fig. 5.14). This capsule release brings the femur more anterior, allows for a generous femoral exposure, and helps avoid fracturing of the tip of the greater trochanter.

Care should be taken to thoroughly remove the lateral cortical bone in the saddle of the lateral femoral neck. Some surgeons may rasp that area or burr it down, but it is an essential step to avoid varus stem placement and undersizing of the component. Similarly, though any implant can be used with this surgical approach, the surgeon may struggle without adequate soft tissue releases. This may be done in a step-wise fashion, with the superior and lateral capsule released first. This is not generally enough of a release to fully "deliver" the proximal femur out of the deeper part of the wound. We typically continue to partially release the obturator internus/conjoint tendon and possibly part of the piriformis tendon from the piriformis fossa toward the posterior aspect of the greater trochanter. This allows the femur to "rotate" out of the wound and leads to a straight, unencumbered access to the proximal femur (Fig. 5.15). It is typically not necessary to release any muscles beyond those listed above.

We open up the canal with a box osteotome and then establish the direction of the diaphysis

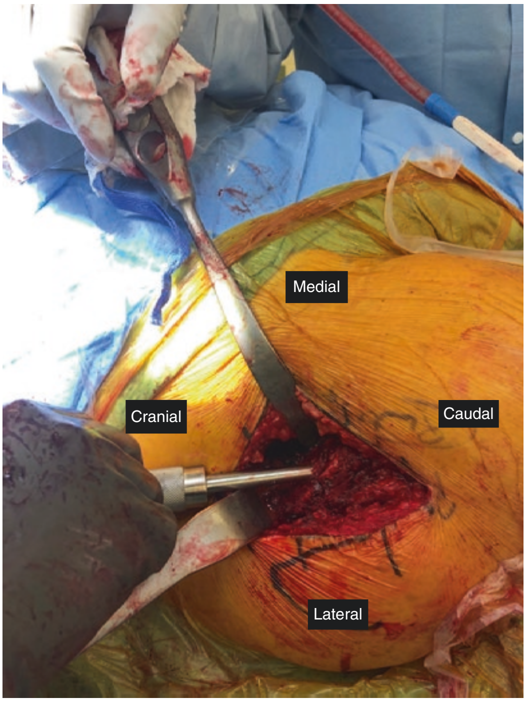


Fig. 5.15 Femoral canal preparation

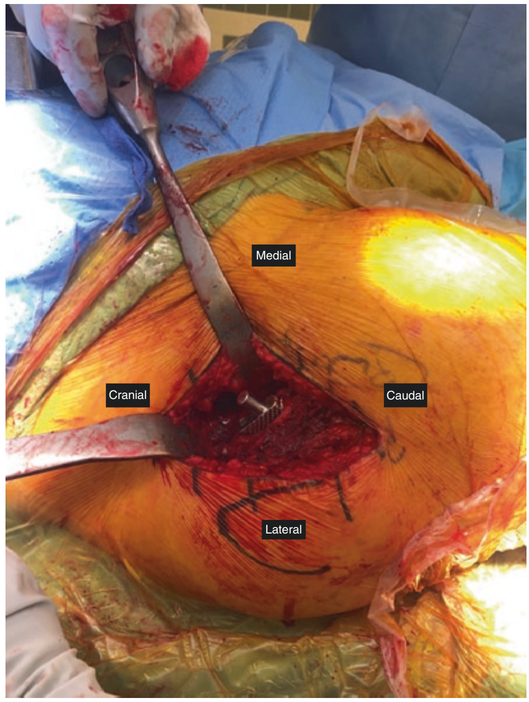


Fig. 5.16 Femur canal broaching

using a straight awl. Once we have identified the angle and direction of the canal, we can start broaching, usually with a small starting broach. We use this same starting broach to “lateralize” any remaining cortical bone by the saddle. Broaching, or reaming if appropriate, is then done in the standard fashion until the final size is reached, and at this point, we can trial the construct. Furthermore, any calcar fracture is readily identified at this point, and the trunnion can be thoroughly cleaned and dried prior to the final assembly (Figs. 5.16 and 5.17). After reduction with the trial components, the supine position allows the leg length equalization to be checked with simple observation (Fig. 5.18). Hip stability and impingement are checked in flexion and extension (Fig. 5.19). As previously mentioned and similar to proponents of the DAA surgical approach, fluoroscopy is easily incorporated into this ABMS approach done in the supine position. With trial components in place, the cup position and angles can be confirmed (if not already done), stem sizing can be judged, leg length can

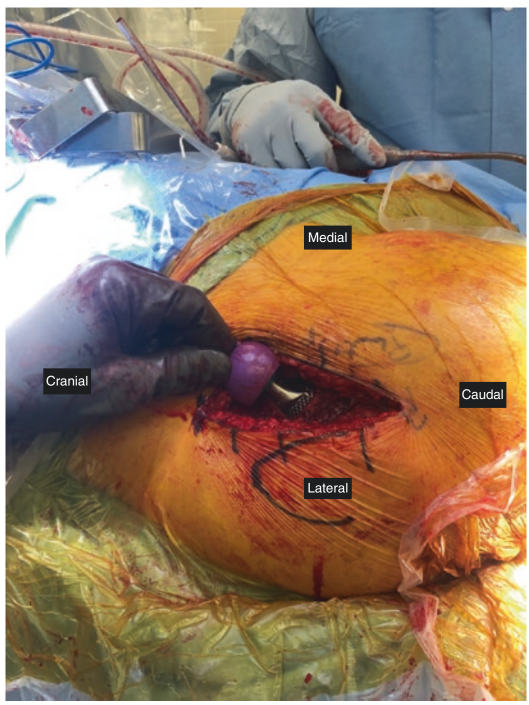


Fig. 5.17 Assembling of components for trial reduction

Fig. 5.18 Evaluation for leg length equalization

Fig. 5.19 Checking of hip stability in flexion and internal and external rotation

be assessed both clinically and fluoroscopically, and further refinements such as femoral offset and stability can easily be checked. This can be an important "quality" check before leaving the OR. Later in the learning curve, less radiographic checking can be done, but the editors find it reassuring to see the exact position of the components prior to leaving the OR. Then, the trial femoral

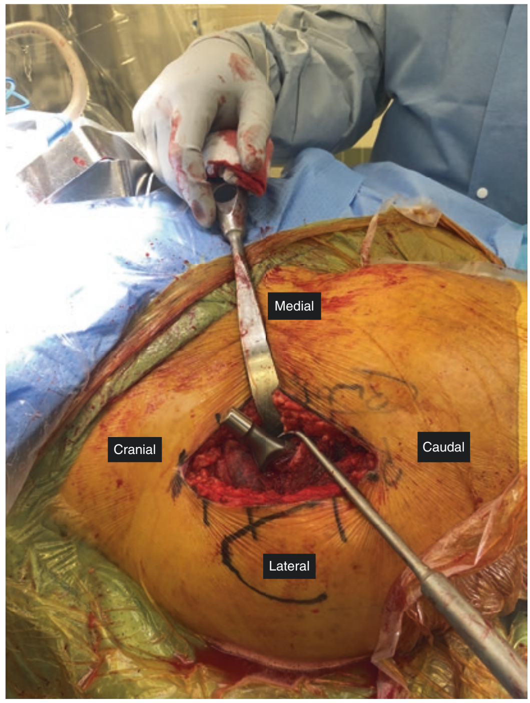


Fig. 5.20 Final stem insertion

component is removed, and the final stem inserted (Fig. 5.20).

Closure of the fascia allows perfect restoration of the intermuscular space and preservation of the abductors with minimal iatrogenic damage (Fig. 5.21). This is typically done with a running barbed suture in the deeper layers and subcutaneous running suture with commercially available skin glue mesh for a water-tight seal.

Conclusion

Thorough understanding of bony and neurovascular anatomy is essential for performing an adequate exposure of the acetabulum and femur using the AMBS approach for THA. This approach utilizes the intermuscular interval between TFL and the GMed and avoids detachment of muscles from their insertion. This approach provides an excellent view of the acetabulum, and the usual landmarks (upper wall, lower back, anterior, and posterior) are easily accessible. By preserving the abductor and short

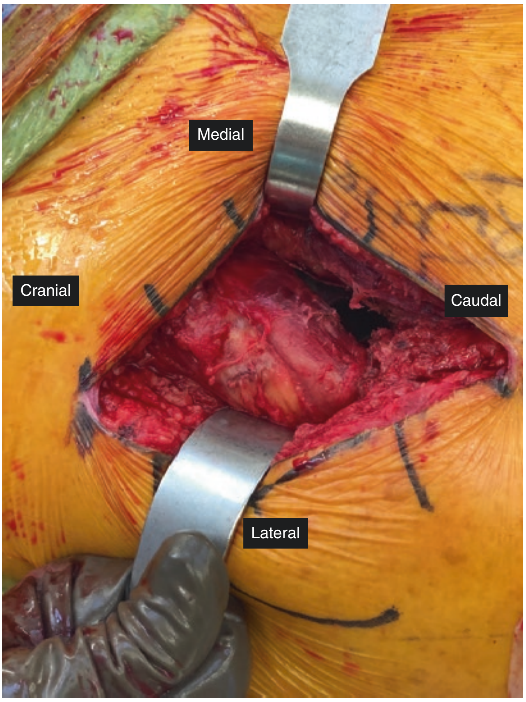


Fig. 5.21 After closure of the soft tissue and gluteus medius (GMed) muscle preserved

external rotator muscle attachments to the femur, faster postoperative recovery can be expected. However, a learning curve might be needed to achieve full competency.

References

1. Learmonth ID, Young C, Rorabeck C. The operation of the century: total hip replacement. Lancet (London, England). 2007;370:1508–19. https://doi.org/10.1016/S0140-6736(07)60457-7.
2. Abdelaal MS, Restrepo C, Sharkey PF. Global perspectives on arthroplasty of hip and knee joints. Orthop Clin North Am. 2020;51:169–76. https://doi.org/10.1016/j.ocl.2019.11.003.
3. Katz JN, Wright EA, Wright J, Malchau H, Mahomed NN, Stedman M, et al. Twelve-year risk of revision after primary total hip replacement in the U.S. medicare population. J Bone Joint Surg Am. 2012;94:1825–32. https://doi.org/10.2106/JBJS.K.00569.
4. Trousdale WH, Taunton MJ, Mabry TM, Abdel MP, Trousdale RT. Patient perceptions of the direct anterior hip arthroplasty. J Arthroplast. 2017;32:1164–70. https://doi.org/10.1016/j.arth.2016.10.006.
5. Cheng TE, Wallis JA, Taylor NF, Holden CT, Marks P, Smith CL, et al. A prospective randomized clinical trial in total hip arthroplasty-comparing early results between the direct anterior approach and the posterior approach. J Arthroplast. 2017;32:883–90. https://doi.org/10.1016/j.arth.2016.08.027.
6. Schwartz AJ, Bozic KJ, Etzioni DA. Value-based total hip and knee arthroplasty: a framework for understanding the literature. J Am Acad Orthop Surg. 2019;27:1–11. https://doi.org/10.5435/JAAOS-D-17-00709.
7. Patel NN, Shah JA, Erens GA. Current trends in clinical practice for the direct anterior approach total hip arthroplasty. J Arthroplast. 2019;34:1987–1993.e3. https://doi.org/10.1016/j.arth.2019.04.025.
8. Brun O-CL, Månsson L, Nordsletten L. The direct anterior minimal invasive approach in total hip replacement: a prospective departmental study on the learning curve. Hip Int. 2018;28:156–60. https://doi.org/10.5301/hipint.5000542.
9. Bertin KC, Röttinger H. Anterolateral mini-incision hip replacement surgery: a modified Watson-Jones approach. Clin Orthop Relat Res. 2004;(429):248–55.
10. Hansen BJ, Hallows RK, Kelley SS. The Röttinger approach for total hip arthroplasty: technique and review of the literature. Curr Rev Musculoskelet Med. 2011;4:132–8. https://doi.org/10.1007/s12178-011-9093-8.
11. Martin R, Clayson PE, Troussel S, Fraser BP, Docquier P-L. Anterolateral minimally invasive total hip arthroplasty: a prospective randomized controlled study with a follow-up of 1 year. J Arthroplast. 2011;26:1362–72. https://doi.org/10.1016/j.arth.2010.11.016.
12. Mandereau C, Brzakala V, Matsoukis J. Functional recovery, complications and CT positioning of total hip replacement performed through a Röttinger anterolateral mini-incision. Review of a continuous series of 103 cases. Orthop Traumatol Surg Res. 2012;98:8–16. https://doi.org/10.1016/j.otsr.2011.10.005.
13. Civinini R, Cozzi Lepri A, Carulli C, Matassi F, Villano M, Innocenti M. The anterior-based muscle-sparing approach to the hip: the "other" anterior approach to the hip. Int Orthop. 2019;43:47–53. https://doi.org/10.1007/s00264-018-4190-6.
14. McKee GK, Watson-Farrar J. Replacement of arthritic hips by the McKee-Farrar prosthesis. J Bone Joint Surg Br. 1966;48(2):245–59. PMID: 5937593.
15. Wodowski AJ, Throckmorton TW, Mihalko WM, Toy PC. Anterior supine intermuscular total hip arthroplasty at an ambulatory surgery center versus hospitalization: cost and adverse events. Orthop Clin North Am. 2021;52:209–14. https://doi.org/10.1016/j.ocl.2021.03.011.
16. Martz P, Bourredjem A, Laroche D, Arcens M, Labattut L, Binquet C, et al. Röttinger approach with dual-mobility cup to improve functional recovery in hip osteoarthritis patients: biomechanical and clinical follow-up. Int Orthop. 2017;41:461–7. https://doi.org/10.1007/s00264-016-3245-9.
17. Inaba Y, Kobayashi N, Yukizawa Y, Ishida T, Iwamoto N, Saito T. Little clinical advantage of modified Watson-Jones approach over modified mini-incision

direct lateral approach in primary total hip arthroplasty. J Arthroplast. 2011;26:1117–22. https://doi.org/10.1016/j.arth.2011.04.002.

18. Zati A, Degli Esposti S, Spagnoletti C, Martucci E, Bilotta TW. Does total hip arthroplasty mean sensorial and proprioceptive lesion? A clinical study. Chir Organi Mov. 1997;82:239–47.
19. He XH, Tay SS, Ling EA. Sensory nerve endings in monkey hip joint capsule: a morphological investigation. Clin Anat. 1998;11:81–5. https://doi.org/10.1002/(SICI)1098-2353(1998)11:2<81::AID--CA2>3.0.CO;2-V.
20. Unis DB, Hawkins EJ, Alapatt MF, Benitez CL. Postoperative changes in the tensor fascia lata muscle after using the modified anterolateral approach for total hip arthroplasty. J Arthroplast. 2013;28:663–5. https://doi.org/10.1016/j.arth.2012.06.032.
21. Chulsomlee K, Sa-ngasoongsong P, Kulachote N, Sirisreetreerux N, Tuntiyatorn P, Vasaruchapong S, et al. Hip muscle power recovery after hip replacement using anterior-based muscle-sparing approach in elderly femoral neck fracture: a prospective study in 40 patients. Orthop Res Rev. 2018;10:31–9. https://doi.org/10.2147/ORR.S153451.
22. Laffosse J-M, Accadbled F, Molinier F, Chiron P, Hocine B, Puget J. Anterolateral mini-invasive versus posterior mini-invasive approach for primary total hip replacement. Comparison of exposure and implant positioning. Arch Orthop Trauma Surg. 2008;128:363–9. https://doi.org/10.1007/s00402-007-0385-9.

6 Outpatient Total Hip Arthroplasty Using an ABMS Approach

Timothy C. Keating, Nabil Mehta, Vasili Karas, and Richard A. Berger

Learning Points

- The anterior-based muscle-sparing (ABMS) approach to the hip was developed in conjunction with the nation's first outpatient total joint program at the authors' institution in the early 2000s.
- This approach is ideal for outpatient surgery and rapid rehabilitation because it is muscle-sparing, requires no postoperative precautions, and is easily extensile in the event of an intraoperative complication.
- In the preoperative period, patient selection, optimization, and education are a labor-intensive but imperative aspect of a successful outpatient program.
- Perioperative protocols and multimodal approaches to pain control require a synergistic relationship between the surgeon, anesthesiologist, and patient.
- Patients who leave the hospital or ambulatory surgery center the same day of surgery require very close follow-up to monitor for early complications and to answer new questions that arise about early postoperative care.

Supplementary Information The online version contains supplementary material available at [https://doi.org/10.1007/978-3-031-02059-9_6].

T. C. Keating (✉) · N. Mehta · V. Karas
R. A. Berger
Rush University Medical Center, Chicago, IL, USA
e-mail: vasili.karas@rushortho.com

Introduction

Total hip arthroplasty (THA) is a reliable and durable treatment option for end-stage degenerative disease of the hip. Successful THA occurs when the four goals of pain relief, functional outcome, patient satisfaction, and a durable reconstruction are achieved [1]. Once expected to involve a prolonged inpatient hospital admission, THA patients now enjoy a shorter hospital stay, nearing an average of one night postoperatively in the United States [2]. In the late 1980s, the average length of stay following THA was 21.5 days [3] and decreased to about 5 days by year 2000 [4]. Shortly thereafter in 2003, the first report of minimally invasive total hip arthroplasty routinely done on an outpatient basis was published at Rush University Medical Center in Chicago, Illinois [5]. The development and implementation of minimally invasive surgical techniques, comprehensive clinical care pathways, and methods for increased patient engagement have increased the likelihood for successful total hip arthroplasty and enabled short-stay and outpatient surgical care [6, 7].

Interest in outpatient total hip arthroplasty has increased drastically over the last two decades, with outpatient procedures increasing 45% between 2012 and 2015 alone [8] and the number

J. A. Geller, B. J. McGrory (eds.), *The Anterior-Based Muscle-Sparing Approach to Total Hip Arthroplasty*, https://doi.org/10.1007/978-3-031-02059-9_6

of ambulatory surgery centers (ASCs) offering total joint procedures increasing 700% between 2013 and 2017 [9]. While total hip arthroplasty performed on an inpatient basis is expected to increase 3% over the next 10 years, outpatient total joint arthroplasty is projected to increase 77% [8]. There are numerous drivers of rapid expansion of outpatient surgery including advancements in surgical technique and perioperative technology. Another driver of outpatient surgery is the potential for increased patient satisfaction, itself a tenet of successful THA. Compared to the inpatient patient experience, patients undergoing THA at a free-standing ambulatory surgery center (ASC) report a better understanding of their postoperative medication plan, preparedness to care for themselves after discharge, and satisfaction with nursing staff [10]. Early apprehension regarding the safety of decreasing inpatient stay length after THA has been largely alleviated by studying patients undergoing fast-track and outpatient THA [11–14]. Comparing sites of outpatient surgery, THA done at a free-standing ambulatory surgery center (ASC) versus in a hospital as part of an outpatient surgery program has been found to have comparable, if not sometimes lower rates of complications, readmissions, and total cost [15–17].

Reducing the cost of the THA care episode is another powerful driver of expanding outpatient surgical services. Outpatient THA has consistently shown to be a cost-effective option for degenerative joint disease of the hip, especially when compared to traditional inpatient services, at an average cost savings of around $1000 per patient [18–20]. In 2020, THA was removed from the Centers for Medicare and Medicaid Services (CMS) inpatient-only list and in 2021 appeared on the ASC Payment System final ruling [21]. The acceptance of THA as an outpatient procedure able to be performed in the ASC will likely contribute to its rapid expansion in eligible patients. Additionally in 2020, the SARS-CoV-2 (COVID-19) pandemic provided an unexpected and unprecedented acceleration of outpatient total joint arthroplasty with the temporary cessation of inpatient surgery in many countries around the world but especially in the United States. Care pathways for outpatient surgery developed during the pandemic may continue to be utilized as an efficient way to perform THA as surgeons around the world resume elective surgery and tackle the backlog of postponed cases [22].

A successful outpatient surgery program demands a comprehensive approach to the entire patient care pathway. We have found that outpatient THA is more successful when there is the synergistic combination of minimally invasive surgery, pain control, rehabilitation, and patient education [23]. When planning for minimally invasive surgery, a surgeon must first choose a surgical approach. The ideal surgical approach for THA is extensile, allows the use of any femoral component design, spares soft tissues, allows for an anatomic closure, depends minimally on intraoperative radiography, requires no complex equipment, allows for easy stability testing, uses an incision location that heals uneventfully, and can be performed on nearly all patients [24]. In an academic institution setting, routinely utilizing an approach that facilitates resident and fellow instruction is crucial as well.

In 2003 the senior author began to perform outpatient THA through an abductor-sparing, Watson-Jones interval in select patients, building on lessons learned from the two-incision approach and experience in other approaches such as the Smith-Petersen approach. The abductor-sparing Watson-Jones approach was found to be more efficient and easier to teach. This combined with the excellent stability as well as the rapid resumption of activities for the patient allowed this approach to become the only approach done by the senior surgeon for all cases. This approach is possible with minimal muscle or tendon transection in almost all patients once through the learning curve [25]. This approach, referred to here as the anterior-based muscle-sparing (ABMS) approach to THA, was described around the same time by Röttinger and has been widely adopted since then with increasing interest in recent years [26–30]. Surgeons transitioning from a traditional posterior approach have found ABMS THA to provide the benefits of anterior approaches to the hip while offering a quick learning curve given the familiarity of operating and placing components in the lateral decubitus position [31]. Most importantly, the muscle-sparing nature of ABMS allows for rapid functional recovery and high patient satisfaction. In addition to a muscle-sparing approach for THA, a successful outpatient total joint program spans the preoperative, immediate perioperative, and postoperative periods. The following sections highlight the rationale and details of a sample protocol in chronological order of such a program.

Preoperative

Appropriate patient selection for outpatient total joint arthroplasty has been studied by multiple authors. Outpatient total knee arthroplasty (TKA) was initially performed on highly selected patients [32, 33]. Patients eligible for the first published study of outpatient TKA had less than three major medical comorbidities; had no history of myocardial infarction, pulmonary emboli, or anticoagulant medication; had a body mass index (BMI) of less than 40 kg/m^2; and were the first case of the day [32]. In this study, 48/50 participants (96%) were discharged home the day of surgery. Less stringent requirements for undergoing outpatient TKA were later studied in a group of patients who were all-comers for TKA and needed only preoperative medical clearance from an internist for TKA in general and for their surgery to be complete by noon [34]. In this unselected group, 104/111 patients (94%) were successfully discharged home, although they did demonstrate a higher readmission rate (3.6%) than previous studies. In an unselected TKA cohort, patients readmitted after outpatient TKA were correlated to higher BMI, age, and medical comorbidities, suggesting that some level of patient screening may prevent frequent readmission [34].

The Medicare limited data set was examined to determine the risk factors for readmission following short-stay and outpatient TKA [35]. These authors found a higher readmission risk in patients with a higher Charlson comorbidity index (CCI) and especially the presence of a heart failure diagnosis, suggesting that these factors should preclude outpatient total joint surgery [35]. While the CCI and American Society of Anesthesiology (ASA) score have been used in the past to stratify patient risk, neither tool is directly applicable to stratifying same-day arthroplasty candidates [36]. Recently, a surgical risk evaluation tool was developed specifically for outpatient total joint arthroplasty, the Outpatient Arthroplasty Risk Assessment (OARA) [37]. This tool is based on nine comorbidity areas and generates a score to indicate whether a patient is generally acceptable or unacceptable to undergo outpatient joint arthroplasty. The details of the scoring algorithm have been commercialized and are not publicly available [38]. A series of 1012 patients undergoing hip and knee arthroplasty at a different institution were also analyzed to create a risk assessment tool for patients undergoing short-stay and outpatient hip and knee arthroplasty [39]. They found that an easy-to-use 6-point scoring scale was useful for identifying patients who had a 3.1% risk of complication, lower than the 6.9% complication rate of the cohort as a whole.

Certain patients and comorbidities may be amenable to medical optimization prior to total hip arthroplasty. An analysis of available literature on optimization prior to total joint arthroplasty found that special attention should be paid to ensuring patients' BMI is less than 40 kg/m^2, hemoglobin (Hb) greater than 12 g/dL, HbA1c less than 7.0%, no tobacco use for 30 days before surgery, methicillin-resistant *Staphylococcus aureus* colonization diagnosed and treated, and albumin greater than 3.5 g/dL [40]. In addition to medical optimization, psychologic optimization is an equally important aspect of preparing a patient for surgery. Successful outpatient surgery relies not only on medical optimization but also on optimization of anxiety about postoperative pain, caring for themselves at home, social support, and rehabilitation [8]. In one study, patients indicated for total hip arthroplasty treated with psychological counseling had a lower incidence of postoperative depression and anxiety and reached their physical therapy milestones 1.2 days sooner than those without professional counseling [41].

Perhaps the most important and powerful optimization tool in the preoperative period is patient education, which is used to set expectations and eliminate apprehensions [7, 10, 42]. At the authors' institution, all patients undergo a mandatory joint education class led by a mid-level provider a few weeks prior to their scheduled surgery. This session is typically done on a group or individual basis based on patient preference or held on a secure video platform. The entire episode of care is reviewed in a chronological order including a basic overview of hip replacement surgery, a preoperative exercise regime including practice with assistive aids, a detailed overview of the perioperative pain protocol, and setting expectations regarding return to various activities. Special attention is paid to reviewing the requirements for discharge home, preparing the home environment for recovery, and reviewing normal and abnormal signs and symptoms after joint replacement surgery. By the end of the session, each patient has individualized goals and expectations and an individual plan for starting and stopping home medications. For patients traveling from out of town for surgery, a dedicated patient liaison to coordinate patient travel, transportation, and accommodations can be helpful, as well as a dedicated discharge planner to arrange in-home physical therapy and nursing visits for the first 2 weeks postoperatively. At 2 weeks, patients are encouraged to attend outpatient physical therapy at a convenient location and are given a prescription for that service preoperatively and expected to set that up on their own before surgery. The shift from inpatient to outpatient surgery has made it, so the majority of the education and planning – tasks that are used to be accomplished during a prolonged inpatient stay – must now be frontloaded and accomplished preoperatively. A well-trained and highly organized team dedicated to the preoperative preparation of patients is essential, especially while preparing for outpatient surgery [33].

Day of Surgery

The day of surgery is a highly anticipated event in a patient's life that puts the preoperative planning of many parties to the test. As part of the preoperative teaching class at our institution, patients will have received detailed instructions regarding the location, parking options, and arrival time for their planned surgery. Patients receive a call from staff at their operative site the day before surgery as a final confirmation of location and arrival time. Arrival time for outpatients at an ASC is 2 hours prior to scheduled surgery and 2.5 hours for patients undergoing same-day surgery at our large academic hospital.

A pivotal part of a successful same-day surgery program is working with anesthesia colleagues to develop a comprehensive anesthesia protocol. In outpatient surgery, anesthesia must prevent postoperative nausea and vomiting (PONV), minimize pain, and avoid prolonged motor blockade to allow for rapid mobilization [43]. Anesthesia for outpatient total hip arthroplasty focuses on multimodal oral and intravenous (IV) medication, local infiltrative analgesics intraoperatively, and a choice of general or neuraxial anesthesia intraoperatively. A number of peripheral nerve blocks have been suggested for THA, including infiltration of the lumbar plexus, fascia iliaca, and sometimes the sciatic nerve [44]. A 2018 survey of the American Association of Hip and Knee Surgeons (AAHKS) membership noted that 10.6% of respondents routinely use a peripheral nerve block for primary THA cases, of which approximately 70% utilize a fascia iliaca block, 20% use a lumbar plexus block, and 10% use a femoral nerve block. Peripheral nerve blocks for THA are not routinely employed at the author's institution, but instead rely on neuraxial, multimodal, and infiltrative analgesia as described below [45].

Both neuraxial and general anesthesia have been used successfully for outpatient THA [46]. Neuraxial anesthesia benefits from a dense neuromuscular blockage while minimizing intravenous (IV) and inhaled general anesthetics that increase the risk of postoperative drowsiness and hypotension [47]. General anesthetics have the advantage of being fast-onset and short-acting, avoiding the additional time for preoperative neuraxial anesthesia, variable metabolism of neuraxial agents, and postoperative nausea and vomiting often associated with intrathecal opioid analgesics. The author's preference is a single-shot 2% lidocaine spinal for ASC cases and a combined spinal and epidural (CSE) for outpatient hospital cases with intraoperative conscious sedation with propofol. The rapid and predictable operating room turnover of an ASC allows the regular use of a single-shot spinal, while the hospital setting is less predictable and requires the use of an epidural that can be re-dosed as needed for any unexpected delays. While there are a number of options available, we prefer the fast-onset, extremely dense neuromuscular blockade and quick reversal that allows for rapid rehabilitation. The use of a lidocaine spinal requires that total operative time is routinely less than 1 hour, as the duration of the blockade is variable and was as short as 1.6 hours from spinal to motor twitch recovery in one study [48]. The use of lidocaine for spinal anesthesia has historically been associated with a risk of transient neurologic symptoms (TNS). This complication is believed to be related to using hyperbaric preparations of 5% lidocaine, and this complication has not been routinely reported with the use of isotonic 2% lidocaine [48]. Given the short duration of neural blockade and avoidance of intrathecal opioids, the risk of urinary retention with this protocol is minimized, and a Foley catheter is not routinely used. For other surgeons at our institution who prefer or necessitate a longer duration of action, mepivacaine or ropivacaine is used in place of lidocaine.

A vital component of modern pain management in THA is the synergistic multimodal medications administered by mouth, IV, and periarticular injection (PAI). In the current protocol, patients receive the following medications in the preoperative holding area: 10 mg oxycodone extended-release tablet, transdermal scopolamine patch (1 mg over 3 days, excluding men over 75 years old or with a history of urinary problems), celecoxib 400 mg tablet (200 mg tablet for patients 75 years and older, excluding in patients older than 70 with serum creatinine greater than 1.5 mg/dL, sulfa allergic, or history of coronary artery disease), and pregabalin 50 mg tablet. Intraoperatively, the second group of medications is administered immediately prior to skin incision by the anesthetist, including 1000 mg IV acetaminophen, 1000 mg IV tranexamic acid, 15 mg IV ketorolac, and 8 mg IV dexamethasone. Intraoperatively, patients are positioned in the lateral decubitus position and receive propofol conscious sedation. An ABMS approach is utilized, as detailed elsewhere in this text (Video 6.1). At the conclusion of the procedure and immediately prior to closure, the deep and superficial tissues are infiltrated with 100 mL of our institutional PAI, administered in two pre-mixed 50 mL syringes, each containing 123 mg of ropivacaine, 0.25 mg of epinephrine, 40 mcg clonidine, and 15 mg ketorolac.

Postoperatively, patients are transferred to the postoperative unit and receive a final multimodal combination designed to prevent and treat postoperative nausea and vomiting including 4 mg IV ondansetron, 8 mg IV decadron (held in diabetic patients with blood glucose >250 mg/dL the morning of surgery), 10 mg IV metoclopramide, and 12.5 g human albumin in 250 mL saline for additional intravascular volume support. While in the recovery room, the patients are monitored as spinal anesthesia wears off and begin gait training with a therapist as soon as their sensory and neuromuscular function has fully returned. A full evaluation and session with physical therapy is completed. A patient is deemed independent for discharge when they are able to accomplish certain tasks independently. Shown in Table 6.1 is a sample physical therapy checklist for clearance home immediately following total hip replacement. The general criteria for independence of function to enable discharge home are the same as goals that must be met after an inpatient stay:

Table 6.1 Postoperative therapy checklist

Rolling
Supine to sit
Sit to lying
Sit to stand
Bed-to-chair transfer
Walk 10 feet
Walk 50 feet
Walk 150 feet
Walk 10 feet on uneven surface
Picking up object
Stair climb – curb
Stair climb 4 steps
Stair climb 12 steps

physical therapy clearance, stable vital signs, adequate pain control, voiding freely, and tolerating food and liquids.

Post-Discharge

Once patients have met all appropriate criteria and are safely discharged from the hospital, interdisciplinary post-discharge care protocols are imperative to maintain patient safety and to optimize the long-term outcome of the procedure. In the immediate post-discharge period, these protocols ensure proper pain control, identify and address possible complications, and establish open communication with the patient to answer questions and avoid hospital emergency department visits and readmissions. In the longer term, they help guide rehabilitation, facilitate return to activity, and optimize patient satisfaction.

Discharge Medications

Essential components of a post-discharge medication regimen include venous thromboembolism prophylaxis, multimodal pain control, a bowel regimen, and anti-emetics. Table 6.2 outlines a sample post-discharge medication regimen for outpatient THA preferred by the senior author. Instituting an anticoagulation regimen has become the standard of care after THA and has been shown to be effective in preventing these complications [49]. While recent studies have shown no difference in postoperative deep vein thrombosis/pulmonary embolism (DVT/PE) between same-day discharge and inpatient [50] cohorts, an anticoagulation regimen must be well-chosen particularly in the outpatient setting to balance the reduction in blood clots with the risk of postoperative hematoma, bleeding, and infection [51–53]. Recent studies have demonstrated the efficacy of aspirin after THA [54–56], with reductions in DVT, PE, and fatal embolism with lower rates of postoperative anemia, showing that it is a viable alternative to other agents such as warfarin and heparin [57]. Duration of postoperative aspirin DVT prophylaxis varies from 3 to 6 weeks between providers at the authors' institution, with the 3-week option still longer than the 14-day prophylaxis recommendation from the American College of Chest Physicians clinical practice guideline [58]. Thromboembolism-deterrent (TED) hose and other means of mechanical compression are useful adjuncts to pharmacologic prophylaxis.

Table 6.2 Multimodal medication protocol

Preoperative	**Intraoperative**
Oxycodone 10 mg extended-release PO Transdermal scopolamine patch 1 mg/3 days* Celecoxib 400 mg* PO Pregabalin 50 mg PO	Acetaminophen 1000 mg IV Tranexamic acid 1000 mg IV Ketorolac 15 mg IV Dexamethasone 8 mg IV Periarticular injection: 2 × 50 mL syringes, each containing ropivacaine 123 mg, epinephrine 0.25 mg, clonidine 40 mcg, ketorolac 15 mg
Immediate post-procedure	**Home medications**
Ondansetron 4 mg IV Decadron 10 mg IV Metoclopramide 10 mg IV Human albumin 12.5 g in 250 mL normal saline IV	Oxycodone immediate-release 10 mg, 1–2 tabs PO Q6H-Q8H PRN Acetaminophen 1 g, TID for 2 weeks Aspirin 325 mg BID for 21 days Tranexamic acid 1950 mg PO, once on postoperative day #1 Standardized senna concentrate and docusate sodium tablet 50 mg/8.6 mg, 2 tablets BID Ondansetron 4 mg oral dissolving tablets, Q8H PRN Scopolamine patch 1.5 mg over 3 days Pregabalin 50 mg PO BID for 2 weeks Diclofenac 75 mg PO BID with meals for 3 months Pantoprazole 40 mg PO QD

*200 mg tablet for patients 75 years and older, excluding in patients older than 70 with serum creatinine greater than 1.5 mg/dL, sulfa allergic, or history of coronary artery disease

Ensuring adequate pain control for patients at baseline and during early therapy and mobilization prevents unnecessary hospital and clinic visits in the short term and poor functional outcomes in the long term [59]. Multiple studies have shown the benefits of multimodal analgesia in allowing faster rehabilitation, decreasing side effects, reducing reliance on opioids, and reducing postoperative complications [11, 57, 59]. A multicenter, randomized study of outpatient versus inpatient THA showed that postoperative pain was not an issue in preventing discharge in either group due to the multimodal analgesia protocols used [11]. However, the authors did note a higher VAS pain score the day after surgery in patients discharged the same day, the clinical significance of which is questionable. Self-administration of a multimodal protocol at home relies on successful preoperative counseling and clear documentation of medication dosages and timing. Prescriptions should be given to patients as early as possible preoperatively so medications are available immediately upon arriving home, avoiding potential pharmacy delays and early readmissions for pain control. Pain medication may also be supplemented with adjuncts like mechanical compression stockings and an ice machine unit to reduce early pain and swelling. While there is a theoretical risk of postoperative non-steroidal anti-inflammatory drug (NSAID) use prohibiting bony ingrowth into implants, this phenomenon has not been subjectively observed. Conversely, there has been subjectively far less cases of heterotopic ossification following THA with administration of postoperative ASA and NSAIDs, which is an observation supported by recent literature [60, 61].

Measures to reduce postoperative blood loss should also extend to the post-discharge setting. Multiple doses of oral TXA have been shown to bring about maximum efficacy in reducing blood loss and mitigating the inflammatory response after THA [62]. In a randomized controlled trial, Wang et al. showed that one preoperative dose prior to incision and three postoperative doses of TXA produced a maximum effective reduction in blood loss after THA, with no difference in thromboembolic complications and transfusions compared to other regimens [63]. As part of the senior authors' protocol, all patients get TXA regardless of medical history, which is increasingly supported in the literature [64].

Rehabilitation

Patient mobilization in the immediate postoperative period is imperative to facilitating same-day discharge. Though there is variability in post-discharge physical therapy protocols in the literature, the common goal is independent ambulation with or without assistive devices. Achieving this goal is crucial to ensure that patients remain safe and independent in the home environment. Protocols regarding formal in-home or on-site physical therapy are variable and are an active area of investigation [65].

Previous work by the author's institution outlines a successful rapid rehabilitation protocol after minimally invasive THA [66, 67]. In a case series of 100 patients undergoing THA with a two-incision technique and same-day discharge, Berger et al. showed that outpatient therapy was initiated in 9% of patients immediately, 62% of patients by 1 week, and 100% patients by 2 weeks postoperatively. Patients were able to discontinue the use of any assistive device by 9 days postoperatively and resume all activities of daily living by 10 days. Home physical therapy was used until the patient was able to drive (average 6 days postoperatively), after which time outpatient physical therapy was begun, indicating that rapid rehabilitation pathways enable patients to meet functional goals faster and without increasing complications [66].

In-home therapy is often set up multiple times a week for up to 2 weeks postoperatively. The transition to outpatient physical therapy is generally begun when the patient has met one of the following criteria: the patient has met their goals and is discharged from home physical therapy, the patient is no longer home-hound and/or has returned to work, the patient is no longer taking narcotics and is able to drive, or the patient has transportation to the outpatient therapy site. The therapist and patient are encouraged to advance as quickly as possible with the primary goal of avoiding gait deviations. The goals for the first 2 weeks are typically to ambulate two blocks without an assistive device and to be independent with activities of daily living. Patients and therapists should be educated and cautioned regarding the risk of excessive activity in causing regression of progress. Patients are typically weight bearing as tolerated through the operative extremity immediately after surgery. For the first 3 weeks postoperatively, it is prudent to limit cross-body hip adduction past the midline, twisting/rotating at the hip, and bending at the waist past 90 degrees. Active abduction of the operative leg may be permitted immediately after surgery, but straight-leg raise should be prohibited for the duration of physical therapy. Aquatic-based therapy can begin once the incision is fully healed.

Follow-Up

In-person follow-up protocols are variable and provider dependent but should be used to assess wound healing, radiographs, range of motion, and functional progress. In the current protocol, all patients are called the day following surgery to answer any questions and check in their early progress. Patients are called again to check in 1 week postoperatively, and the wound is examined using telemedicine. Patients are seen in the office at 3 weeks for a clinical and radiographic follow-up and then on an individualized and as-needed basis until 1 year postoperatively, when all patients return for evaluation. After the 1-year follow-up, patients are seen back at regular annual intervals.

Patient Communication

A key to the success of same-day discharge pathways after total joint arthroplasty is establishing a close relationship and open channel of communication between the patient and the surgeon's office. Strong patient support, frequent contact, and eliminating barriers to communication are cornerstones of avoiding immediate postoperative complications, hospital visits, and readmissions [65]. Post-discharge patient support protocols vary widely in the literature, from the ability to contact the physician's office or clinic with issues to remote home monitoring systems that transmit vital signs and patient information in real time [68–70]. Having a member of the clinical team dedicated to post-discharge care can be helpful to provide patients a single point of contact to answer questions and address concerns. It is crucial to avoid an "out of sight, out of mind" mentality when taking care of patients discharged the same day. These patients experience the same risks and complications as those staying overnight in the hospital but are often geographically isolated from the treating provider. Extra effort is required on the part of the surgical team to create a safety net that ensures patient well-being and minimizes complications and readmissions [17]. The nature of outpatient total joint arthroplasty involves less frequent "touches" by healthcare providers in the immediate-postoperative period compared to those who are inpatients. Staff accessibility must be enhanced compared to inpatient protocols to fill this gap, which shifts the burden of care from the hospital to the surgeon [17, 71]. This increased workload can be mitigated by hiring additional staff, pre-emptive phone calls to patients, extending clinic hours, or employing various technologies to remotely monitor patients [72].

Patient education materials and multimedia resources can be useful adjuncts to support the patient during their time at home. For example, it can be helpful to provide all patients with a comprehensive booklet outlining what to expect after surgery, what constitutes normal pain and swelling, goals for each day and week after surgery, answers to frequently asked questions, and a phone number for questions available 24 hours a day. The goal should be for all patient questions to come to the operating surgeon's office rather than the patient presenting to an emergency department or outside the provider for a non-emergent need.

Results

At Rush University Medical Center, outpatient total hip arthroplasty was first performed by the senior author in 2001 and has continued to grow a practice that is approximately 70–80% outpatient cases year to year. In March 2021, the senior author completed their 12,000th outpatient total joint surgery [73, 74]. Over the last 5 years between 2016 and 2020, the senior author performed 195, 217, 212, 246, and 270 outpatient total hip arthroplasties, respectively. To assess short-term results, the most recent 100 outpatient THA cases with 90-day follow-up were reviewed using an institutional surgical database.

This patient cohort consisted of 100 patients undergoing outpatient THA between October 2020 and February 2021. There were 51 females and 49 males with an average age of 57 years (standard deviation 8 years). Patients were generally healthy with 55 patients without significant medical history, 27 patients having 1 comorbidity, 15 patients having 2 comorbidities, and 3 patients with 3 comorbidities. In the first 2 weeks following surgery, no patients were readmitted. In the first 90 days after surgery, two patients were readmitted: one for a revision of a femoral stem for periprosthetic fracture after a fall and one for an irrigation and debridement with head and liner exchange for acute periprosthetic infection. Other complications noted in the first 90 days after surgery included two patients with persistent wound drainage that resolved with outpatient oral antibiotic therapy and one emergency department visit for a nosebleed that resulted in cessation of aspirin DVT prophylaxis 15 days postoperatively. In this small sample, there were no short-term complications or readmissions that would have likely been prevented with inpatient admission following surgery.

Conclusion

Outpatient THA using the ABMS approach is safe and successful and can provide substantial benefit for the appropriate patient. Outpatient THA is a team-based endeavor that relies on adherence to standardized interdisciplinary protocols to ensure patient safety. The cornerstones to a successful protocol are proper patient selection, preoperative patient education, and close patient follow-up and staff availability.

Nevertheless, care must be employed when creating, altering, or transitioning protocols from inpatient to outpatient surgery. The most commonly cited barriers to initiating an outpatient total joint arthroplasty pathway include patient unfamiliarity with outpatient TJA, concern for adverse events and readmissions, and difficulty establishing standardized clinical pathways with sufficient preoperative planning and postoperative support [42]. Any new protocol should be piloted at a center with inpatient capabilities in case admission is necessary [65]. Outpatient THA as part of a carefully planned and executed clinical pathway can offer an improved patient experience with cost savings without an increased risk of complications in the appropriately selected patient population.

References

1. Dorr LD, Thomas DJ, Zhu J, Dastane M, Chao L, Long WT. Outpatient total hip arthroplasty. J Arthroplast. 2010;25:501–6.
2. Hospitalization for total hip replacement among inpatients aged 45 and over: United States, 2000–2010. 2019. https://www.cdc.gov/nchs/products/databriefs/db186.htm#changed_since_2000. Accessed 29 Mar 21.
3. Epstein AM, Read JL, Hoefer M. The relation of body weight to length of stay and charges for hospital services for patients undergoing elective surgery: a study of two procedures. Am J Public Health. 1987;77:993–7.
4. Molloy IB, Martin BI, Moschetti WE, Jevsevar DS. Effects of the length of stay on the cost of total knee and total hip arthroplasty from 2002 to 2013. J Bone Joint Surg Am. 99(2017):402–7.
5. Berger RA. Total hip arthroplasty using the minimally invasive two-incision approach. Clin Orthop Relat Res. 2003;417:232–41.
6. Hoffmann JD, Kusnezov NA, Dunn JC, Zarkadis NJ, Goodman GP, Berger RA. The shift to same-day outpatient joint arthroplasty: a systematic review. J Arthroplast. 2018;33:1265–74.
7. Berger RA. A comprehensive approach to outpatient total hip arthroplasty. Am J Orthop. 2007;36:4–5.
8. Bert JM, Hooper J, Moen S. Outpatient total joint arthroplasty. Curr Rev Musculoskelet Med. 2017;10:567–74.
9. Varady NH, Amen TB, Chopra A, Freccero DM, Chen AF, Smith EL. Out-of-network facility charges for patients undergoing outpatient total joint arthroplasty. J Arthroplast. 2021;36:S128–33. https://doi.org/10.1016/j.arth.2021.03.001.
10. Kelly MP, Calkins TE, Culvern C, Kogan M, Della Valle CJ. Inpatient versus outpatient hip and knee arthroplasty: which has higher patient satisfaction? J Arthroplast. 2018;33:3402–6.
11. Goyal N, Chen AF, Padgett SE, Tan TL, Kheir MM, Hopper RH Jr, Hamilton WG, Hozack WJ. Otto Aufranc Award: a multicenter, randomized study of

outpatient versus inpatient total hip arthroplasty. Clin Orthop Relat Res. 2017;475:364–72.
12. Arshi A, Leong NL, Wang C, Buser Z, Wang JC, SooHoo NF. Outpatient total hip arthroplasty in the United States: a population-based comparative analysis of complication rates. J Am Acad Orthop Surg. 2019;27:61–7.
13. Weiser MC, Kim KY, Anoushiravani AA, Iorio R, Davidovitch RI. Outpatient total hip arthroplasty has minimal short-term complications with the use of institutional protocols. J Arthroplast. 2018;33:3502–7.
14. Toy PC, Fournier MN, Throckmorton TW, Mihalko WM. Low rates of adverse events following ambulatory outpatient total hip arthroplasty at a free-standing surgery center. J Arthroplast. 2018;33:46–50.
15. Sershon RA, McDonald JF 3rd, Ho H, Goyal N, Hamilton WG. Outpatient total hip arthroplasty performed at an ambulatory surgery center vs hospital outpatient setting: complications, revisions, and readmissions. J Arthroplast. 2019;34:2861–5.
16. Carey K, Morgan JR, Lin M-Y, Kain MS, Creevy WR. Patient outcomes following total joint replacement surgery: a comparison of hospitals and ambulatory surgery centers. J Arthroplast. 2020;35:7–11.
17. Shah RP, Karas V, Berger RA. Rapid discharge and outpatient total joint arthroplasty introduce a burden of care to the surgeon. J Arthroplast. 2019;34:1307–11.
18. Bertin KC. Minimally invasive outpatient total hip arthroplasty: a financial analysis. Clin Orthop Relat Res. 2005;435:154–63.
19. Aynardi M, Post Z, Ong A, Orozco F, Sukin DC. Outpatient surgery as a means of cost reduction in total hip arthroplasty: a case-control study. HSS J. 2014;10:252–5.
20. Theosmy E, Yayac M, Krueger CA, Courtney PM. Is the new outpatient prospective payment system classification for outpatient total knee arthroplasty appropriate? J Arthroplast. 2021;36:42–6.
21. CY 2021 Medicare hospital outpatient prospective payment system and ambulatory surgical center payment system final rule (CMS-1736-FC). n.d. https://www.cms.gov/newsroom/fact-sheets/cy-2021-medicare-hospital-outpatient-prospective-payment-system-and-ambulatory-surgical-center-0. Accessed 29 Mar 2021.
22. Wilson JM, Schwartz AM, Farley KX, Roberson JR, Bradbury TL, Guild GN 3rd. Quantifying the backlog of total hip and knee arthroplasty cases: predicting the impact of COVID-19. HSS J. 2020:1–7.
23. Berger RA, Ambulatory TKA. 2011. https://www.vumedi.com/video/ambulatory-tka/. Accessed 1 Apr 2021.
24. Murphy S. Superior hip approach technique for THA: does it increase component placement accuracy and decrease the complication rate? 2020. https://www.vumedi.com/video/superior-hip-approach-for-tha-results-of-3500-patients-with-up-to-17-yrs-follow-up/. Accessed 1 Apr 2021.
25. Deirmengian CA, Berger RA. A technique for the minimally invasive, Watson–Jones approach to total hip arthroplasty. Oper Tech Orthop. 2006;16:126–34.
26. Bertin KC, Röttinger H. Anterolateral mini-incision hip replacement surgery: a modified Watson-Jones approach. Clin Orthop Relat Res. 2004;429:248–55.
27. Hansen BJ, Hallows RK, Kelley SS. The Röttinger approach for total hip arthroplasty: technique and review of the literature. Curr Rev Musculoskelet Med. 2011;4:132–8.
28. Pfeil J. The anterolateral approach with the patient in supine position. In: Pfeil J, Siebert WE, editors. Minimally invasive surgery in total hip arthroplasty. Berlin, Heidelberg: Springer Berlin Heidelberg; 2010. p. 63–77.
29. Graf R, Mohajer MA. The Stolzalpe technique: a modified Watson-Jones approach. Int Orthop. 2007;31(Suppl 1):S21–4.
30. Henky P. The anterolateral Watson Jones approach in total hip replacement in the supine position. Interact Surg. 2007;2:138–43.
31. Kagan RP, Greber EM, Richards SM, Erickson JA, Anderson MB, Peters CL. Advantages of an anterior-based muscle-sparing approach in transitioning from a posterior approach for total hip arthroplasty: minimizing the learning curve. J Arthroplast. 2019;34:2962–7.
32. Berger RA, Sanders S, Gerlinger T, Della Valle C, Jacobs JJ, Rosenberg AG. Outpatient total knee arthroplasty with a minimally invasive technique. J Arthroplast. 2005;20:33–8.
33. Halawi MJ, Vovos TJ, Green CL, Wellman SS, Attarian DE, Bolognesi MP. Patient expectation is the most important predictor of discharge destination after primary total joint arthroplasty. J Arthroplast. 2015;30:539–42.
34. Berger RA, Kusuma SK, Sanders SA, Thill ES, Sporer SM. The feasibility and perioperative complications of outpatient knee arthroplasty. Clin Orthop Relat Res. 2009;467:1443–9.
35. Lovald S, Ong K, Lau E, Joshi G, Kurtz S, Malkani A. Patient selection in outpatient and short-stay total knee arthroplasty. J Surg Orthop Adv. 2014;23:2–8.
36. Saklad M. Grading of patients for surgical procedures. J Am Soc Anesthesiol. The American Society of Anesthesiologists. 1941;2:281–4.
37. Meneghini RM, Ziemba-Davis M, Ishmael MK, Kuzma AL, Caccavallo P. Safe selection of outpatient joint arthroplasty patients with medical risk stratification: the “outpatient arthroplasty risk assessment score”. J Arthroplast. 2017;32:2325–31.
38. OaraScore®. n.d. https://www.djoglobal.com/our-brands/djo-surgical/oara-score. Accessed 5 Apr 2021.
39. Courtney PM, Rozell JC, Melnic CM, Lee G-C. Who should not undergo short stay hip and knee arthroplasty? Risk factors associated with major medical complications following primary total joint arthroplasty. J Arthroplast. 2015;30:1–4.
40. Johns WL, Layon D, Golladay GJ, Kates SL, Scott M, Patel NK. Preoperative risk factor screening pro-

tocols in total joint arthroplasty: a systematic review. J Arthroplast. 2020;35:3353–63.
41. Tristaino V, Lantieri F, Tornago S, Gramazio M, Carriere E, Camera A. Effectiveness of psychological support in patients undergoing primary total hip or knee arthroplasty: a controlled cohort study. J Orthop Traumatol. 2016;17:137–47.
42. Li J, Rubin LE, Mariano ER. Essential elements of an outpatient total joint replacement programme. Curr Opin Anaesthesiol. 2019;32:643–8.
43. Højer Karlsen AP, Geisler A, Petersen PL, Mathiesen O, Dahl JB. Postoperative pain treatment after total hip arthroplasty: a systematic review. Pain. 2015;156:8–30.
44. Grant CRK, Checketts MR. Analgesia for primary hip and knee arthroplasty: the role of regional anaesthesia. Contin Educ Anaesth Crit Care Pain. 2008;8:56–61.
45. Hannon CP, Keating T, Lange JK, Ricciardi BF, Waddell BS, Della Valle CJ. Anesthesia and analgesia practices in total joint arthroplasty: a survey of the AAHKS membership. J Arthroplast. 2019;34:2872–7. https://doi.org/10.1016/j.arth.2019.06.055.
46. Amundson AW, Panchamia JK, Jacob AK. Anesthesia for same-day total joint replacement. Anesthesiol Clin. 2019;37:251–64.
47. Sayeed Z, Abaab L, El-Othmani M, Pallekonda V, Mihalko W, Saleh KJ. Total hip arthroplasty in the outpatient setting: what you need to know (part 2). Orthop Clin North Am. 2018;49:27–33.
48. Frisch NB, Darrith B, Hansen DC, Wells A, Sanders S, Berger RA. Single-dose lidocaine spinal anesthesia in hip and knee arthroplasty. Arthroplast Today. 2018;4:236–9.
49. Bayley E, Brown S, Bhamber NS, Howard PW. Fatal pulmonary embolism following elective total hip arthroplasty: a 12-year study. Bone Joint J. 2016;98-B:585–8.
50. Mundi R, Axelrod DE, Najafabadi BT, Chamas B, Chaudhry H, Bhandari M. Early discharge after total hip and knee arthroplasty-an observational cohort study evaluating safety in 330,000 patients. J Arthroplast. 2020;35:3482–3487.e3.
51. McDougall CJ, Gray HS, Simpson PM, Whitehouse SL, Crawford RW, Donnelly WJ. Complications related to therapeutic anticoagulation in total hip arthroplasty. J Arthroplast. 2013;28:187–92.
52. Parvizi J, Ghanem E, Joshi A, Sharkey PF, Hozack WJ, Rothman RH. Does "excessive" anticoagulation predispose to periprosthetic infection? J Arthroplast. 2007;22:24–8.
53. Bawa H, Weick JW, Dirschl DR, Luu HH. Trends in deep vein thrombosis prophylaxis and deep vein thrombosis rates after total hip and knee arthroplasty. J Am Acad Orthop Surg. 2018;26:698–705.
54. Kim D, Shim CY, Hong G-R, Kim M-H, Seo J, Cho IJ, Kim YD, Chang H-J, Ha J-W, Heo JH, Chung N. Clinical implications and determinants of left atrial mechanical dysfunction in patients with stroke. Stroke. 2016;47:1444–51.
55. Wilson DGG, Poole WEC, Chauhan SK, Rogers BA. Systematic review of aspirin for thromboprophylaxis in modern elective total hip and knee arthroplasty. Bone Joint J. 2016;98-B:1056–61.
56. Prevention of pulmonary embolism and deep vein thrombosis with low dose aspirin: pulmonary embolism prevention (PEP) trial. Lancet. 2000;355:1295–302.
57. Bala A, Murasko MJ, Burk DR, Huddleston JI 3rd, Goodman SB, Maloney WJ, Amanatullah DF. Venous thromboprophylaxis after total hip arthroplasty: aspirin, warfarin, enoxaparin, or factor Xa inhibitors? Hip Int. 2020;30:564–71.
58. Falck-Ytter Y, Francis CW, Johanson NA, Curley C, Dahl OE, Schulman S, Ortel TL, Pauker SG, Colwell CW Jr. Prevention of VTE in orthopedic surgery patients: antithrombotic therapy and prevention of thrombosis: American College of Chest Physicians evidence-based clinical practice guidelines. Chest. 2012;141:e278S–325S.
59. Parvizi J, Miller AG, Gandhi K. Multimodal pain management after total joint arthroplasty. J Bone Joint Surg Am. 2011;93:1075–84.
60. Van Nest DS, Clarkson S, Chisari E, Sherman MB, Parvizi J. Low-dose aspirin administered for venous thromboembolism prophylaxis reduces the incidence of heterotopic ossification in total joint arthroplasty. J Arthroplast. 2021;36:1543–7.
61. Migliorini F, Trivellas A, Eschweiler J, Driessen A, Tingart M, Maffulli N. NSAIDs for prophylaxis for heterotopic ossification after total hip arthroplasty: a Bayesian network meta-analysis. Calcif Tissue Int. 2021;108:196–206.
62. Wang D, Yang Y, He C, Luo Z-Y, Pei F-X, Li Q, Zhou Z-K, Zeng W-N. Effect of multiple doses of oral tranexamic acid on haemostasis and inflammatory reaction in total hip arthroplasty: a randomized controlled trial. Thromb Haemost. 2019;119:92–103.
63. Wang D, Wang H-Y, Luo Z-Y, Pei F-X, Zhou Z-K, Zeng W-N. Finding the optimal regimen for oral tranexamic acid administration in primary total hip Arthroplasty: a randomized controlled trial. J Bone Joint Surg Am. 2019;101:438–45.
64. Franchini M, Mengoli C, Marietta M, Marano G, Vaglio S, Pupella S, Mannucci PM, Liumbruno GM. Safety of intravenous tranexamic acid in patients undergoing majororthopaedic surgery: a meta-analysis of randomised controlled trials. Blood Transfus. 2018;16:36–43.
65. Scully RD, Kappa JE, Melvin JS. "Outpatient"-same-calendar-day discharge hip and knee arthroplasty. J Am Acad Orthop Surg. 2020;28:e900–9.
66. Berger RA, Jacobs JJ, Meneghini RM, Della Valle C, Paprosky W, Rosenberg AG. Rapid rehabilitation and recovery with minimally invasive total hip arthroplasty. Clin Orthop Relat Res. 2004;429:239–47.
67. Berger RA, Sanders SA, Thill ES, Sporer SM, Della Valle C. Newer anesthesia and rehabilitation protocols enable outpatient hip replacement in selected patients. Clin Orthop Relat Res. 2009;467:1424–30.

68. Bodrogi A, Dervin GF, Beaulé PE. Management of patients undergoing same-day discharge primary total hip and knee arthroplasty. CMAJ. 2020;192:E34–9.
69. Yang H, Dervin G, Madden S, Beaulé PE, Gagné S, Crossan ML, Fayad A, Wheeler K, Afagh M, Zhang T, Taljaard M. Postoperative home monitoring after joint replacement: feasibility study. JMIR Perioper Med. 2018;1:e10168.
70. Yang H, Dervin G, Madden S, Fayad A, Beaulé P, Gagné S, Crossan ML, Wheeler K, Afagh M, Zhang T, Taljaard M. Postoperative home monitoring after joint replacement: retrospective outcome study comparing cases with matched historical controls. JMIR Perioper Med. 2018;1:e10169.
71. Sah A. Considerations for office and staff protocols for outpatient joint replacement. J Arthroplast. 2019;34:S44–5.
72. Hällfors E, Saku SA, Mäkinen TJ, Madanat R. A consultation phone service for patients with total joint arthroplasty may reduce unnecessary emergency department visits. J Arthroplast. 2018;33:650–4.
73. Condon A. Dr. Richard Berger becomes 1st US physician to perform 10,000 outpatient joint replacements. n.d. https://www.beckersspine.com/orthopedic/item/45593-dr-richard-berger-becomes-1st-us-physician-to-perform-10-000-outpatient-joint-replacements.html. Accessed 11 May 2021.
74. Behm C. Dr. Richard Berger marks his 12,000th outpatient joint replacement. n.d. https://www.beckersspine.com/orthopedic/item/51448-dr-richard-berger-marks-his-12-000th-outpatient-joint-replacement.html. Accessed 11 May 2021.
75. Anterior Based Muscle Sparing (ABMS) approach for total hip arthroplasty. Rush University Medical Center, United States. 2021.

7

ABMS Approach for Cementless Total Hip Replacement

Ian Duensing, Max Greenky, and Rhett Hallows

Learning Points

- The anterior-based muscle-sparing (ABMS) cementless total hip arthroplasty follows many of the same workup and principles and relies on the same biologic process for fixation as other approaches to the hip.
- Subtle exposure alterations, fascial incision, and incision position can aid placement of specific implants.
- Heavy reliance on the acetabular teardrop during cup placement allows for reproducible positioning based on individual patient anatomy.
- While no clear contraindications to cementless fixation exist, Dorr C bone can pose unique challenges, and periprosthetic fractures may occur more frequently in this setting.
- In the setting of a periprosthetic fracture during implantation, prophylactic cerclage cabling or cabling for treatment can be performed using standard techniques.

Introduction

Cementless total hip arthroplasty is associated with excellent medium- and long-term clinical results in the literature boasting greater than 90% survivorship at 15–20 years [1–10]. The indications for cementless total hip arthroplasty through the anterior-based muscle-sparing (ABMS) approach are analogous to those for cementless fixation through any approach and should be thought about similarly. The decision to proceed with cementless fixation in total hip arthroplasty, like many procedural decisions, begins with careful evaluation of individual patient factors. Patients undergoing total hip arthroplasty are a diverse group with varying age, gender, preoperative functional status, postoperative functional goals, and expectations. As such, thorough evaluation of preoperative radiographs, assessment of patient function, history, underlying comorbid conditions, and surgical history is important to appropriately stratify and select those who would benefit from cementless fixation. Patient selection is paramount because biologic fixation, either ingrowth into the porous microstructure of the implant or ongrowth to the grit blasted micro-divots of the stem [1], relies on adequate bone stock and quality. Patient age is often thought about categorically; however,

I. Duensing
Adult Reconstruction Division, Department of Orthopedics, University of Virginia, Charlottesville, VA, USA
e-mail: nuz2rr@hscmail.mcc.virginia.edu

M. Greenky
Syracuse Orthopedic Specialists, Syracuse, NY, USA
e-mail: max.greenky@sosbones.com

R. Hallows (✉)
North Carolina Orthopedic Clinic, Department of Orthopedic Surgery, Duke University, Durham, NC, USA
e-mail: Rhett.hallows@duke.edu

J. A. Geller, B. J. McGrory (eds.), *The Anterior-Based Muscle-Sparing Approach to Total Hip Arthroplasty*, https://doi.org/10.1007/978-3-031-02059-9_7

for the purposes of discussion regarding total hip arthroplasty, patients are generally stratified as elderly (those greater than 65 years of age) and younger (less than the age 65). However, with an aging, active population, these age categories should not, by themselves, be the main criteria by which to opt for cementless fixation. Careful scrutiny of preop radiographs during the templating process, as well as intra-op assessment should still be the main factor to decide upon stem fixation.

Indications and Considerations for Cementless Implants

Well-accepted indications for cementless femoral stems include younger and more active patients. Biologic fixation is argued to be superior for this demographic to mitigate chances of stem and cup micro-motion, settling, and ultimately loosening during higher levels of activity as well as bone preservation in the likelihood of requiring revision procedures [2–4]. Patients of more advanced age with adequate femoral and pelvic bone quality may also be considered. Radiographic appearance of bone quality is assessed reliably as described by Dorr et al. in 1993 [5] by a ratio of inner canal diameter at the diaphysis and the metaphysis. Dorr A and B femurs, defined as an inner canal ratio of 0.5 and 0.5–0.75, respectively, and minimal thinning on radiographs are appropriate candidates for cementless stems regardless of age (Fig. 7.1). Recent enthusiasm for cementless stems, however, has broadened the indications; there is encouraging evidence for the use of these devices in elderly patients [6] including those with osteopenic or osteoporotic bone including Dorr C femurs or those with a

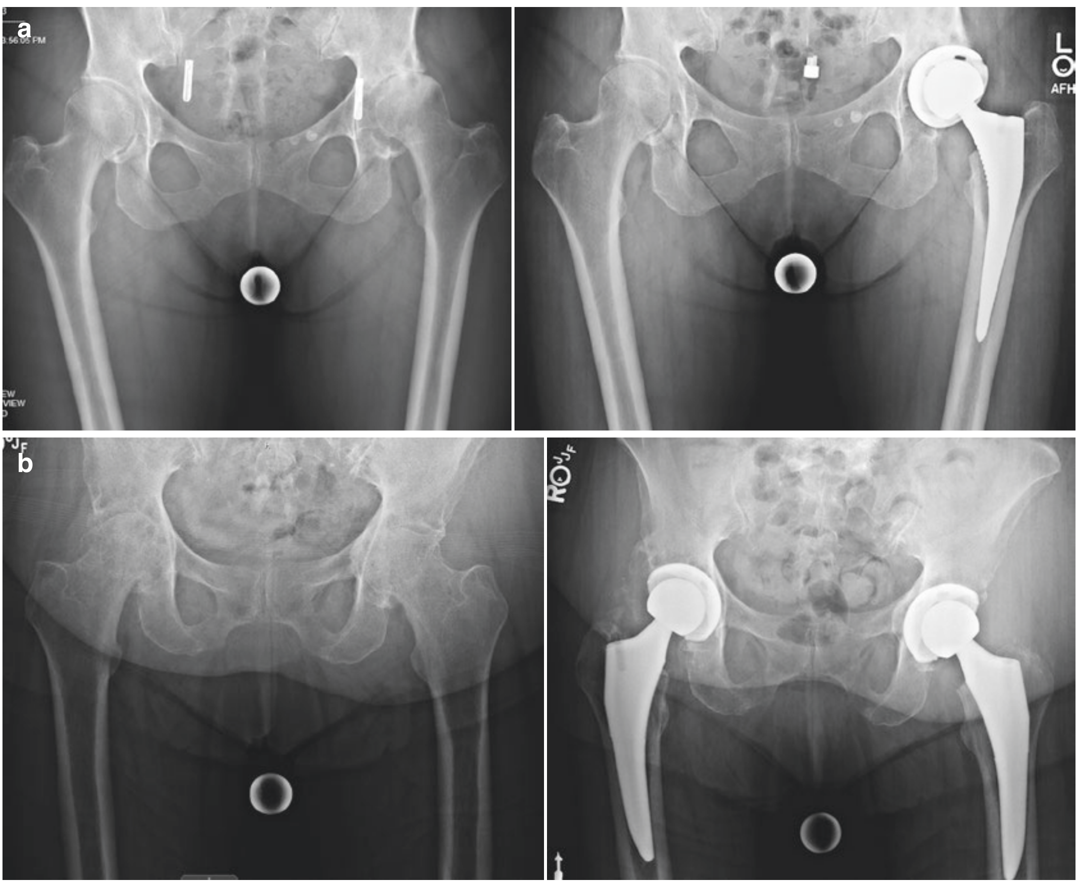


Fig. 7.1 Pre-operative and post-operative films of patients with different bone morphology. (**a**) Pre-operative and post-operative radiographs of a left THR in Dorr A-type femur (**b**) Pre-operative and post-operative radiographs of bilateral THRs in Dorr B-type femur

diaphysis to metaphysis inner canal ratio of greater than 0.75 and thinning of cortices on multiple orthogonal views [7–10]. While exposure is usually excellent, particular care should be exhibited in patients with a history of osteopenia or osteoporosis, certain medical or endocrine conditions that may weaken the bone, or medications that may alter osseous integrity. Manipulation of the limb during anterior approaches, including the ABMS approach, may require marginally greater force or more skilled manipulation to bring the limb into position for component placement than traditional posterior or direct lateral approaches. Such manipulation creates higher levels of torsional force which increase the force experienced by the femoral shaft which acts as a thick-walled cylinder [11–13] which, in theory, increases hoop stresses during femoral component insertion. This force is directly related to the thickness of the cylinder walls, i.e., cortical thickness, which may predispose patients with poorer bone quality to periprosthetic fracture. Increased awareness and caution should be exercised during the final broaching and stem placement to avoid intra-operative fracture.

While cemented stems have been the accepted technique for treating displaced femoral neck fractures in the elderly due to the low rates of intra-operative fracture and immediate stability enabling immediate postoperative mobilization, canal pressurization leading to cardiopulmonary compromise is a known risk [1, 14, 15]. These risks may be diminished by cementless fixation [16, 17]; however, recent studies suggest superiority of cemented stems with lower complication rates and rates of reoperation [18, 19]. Despite this, as of 2017, up to 60% surgeons prefer to address femoral neck fractures with cementless fixation [20] (Fig. 7.2). The ABMS approach enables surgeons to use the best clinical judgment for fixation method when treating displaced femoral neck fractures. A necessity of any approach when managing femoral neck fractures is the capacity to extend the approach and address intra-operative complications such as calcar fracture or propagation of existing calcar compromise. Addressing these concerns through this approach is easily managed including cabling the proximal femur or, if necessary, accessing the entire femur. The calcar and entire proximal femur are easily visualized and readily accessible, as is the lesser trochanter which can be helpful for some surgeons to gauge stem height and position. The tip of the greater trochanter can also be directly visualized and easily palpated which allows for another excellent reference point for the shoulder of the implant to confirm implant depth based on preoperative templating.

On the acetabular side, cementless fixation has been the preferred technique for fixation for many decades. Results are excellent with very few failures and survivorship of 94.7–100% at 1- to 15-year follow-up [21–28]. The same success can be expected when implanting acetabular

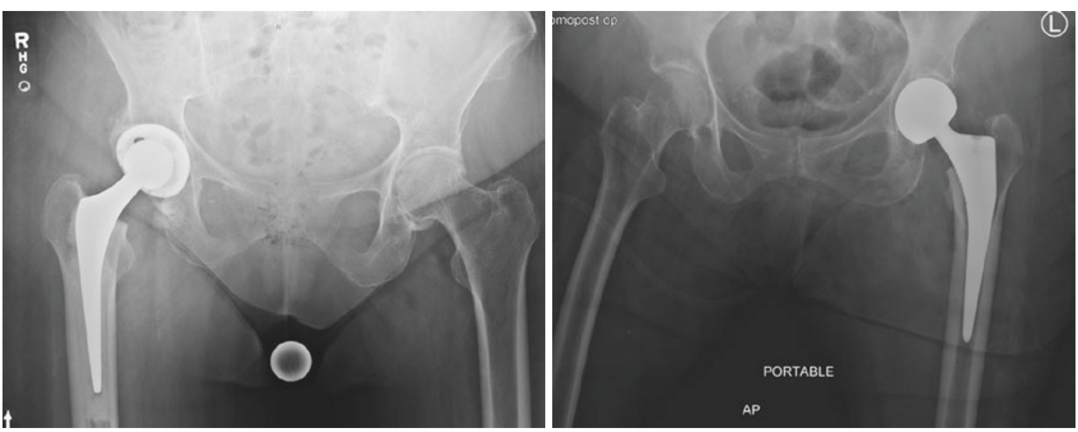


Fig. 7.2 Examples of cemented total hip and press-fit hemiarthroplasty for femoral neck fractures. The example on the right is a left hemiarthroplasty in a 90-year-old female patient who used a walker at home and who had preserved femoral bone stock

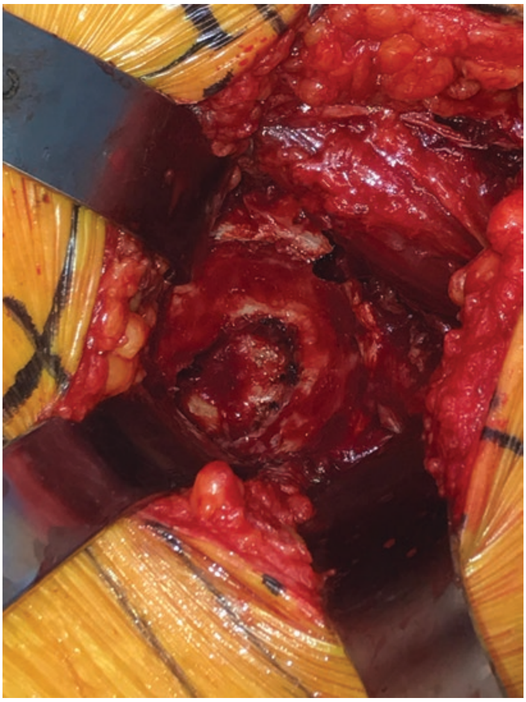


Fig. 7.3 Retractors over the anterior and posterior wall of the acetabulum as well as in the cotyloid fossa

devices through an ABMS approach. The use of anterior and posterior retractors as well as a Steinman pin or Schanz pin placed in the supra-acetabular bone gives a 360° view of the acetabulum (Fig. 7.3). Under-reaming or line-to-line reaming is performed according to the preferred implant technique. Screw placement is easily performed through this approach to augment fixation of the cup as needed using standard flexible drill and articulating driver for screw insertion. Visualization through reproducible exposure of the native acetabulum allows for the accurate and consistent placement of cementless cups using bony landmarks, external implant-specific version guides, or imaging guidance. Specifically, fluoroscopy can be used when the patient is positioned supine or cross-table lateral if in the lateral decubitus position. Cup position is based heavily on the dense bony ridge running along the interior edge of the cotyloid fossa, also referred to as the acetabular teardrop. Visualization of this landmark is of the utmost importance; therefore, extra efforts should be made to visualize this in its entirety often requiring removal of large intraarticular osteophytes to do so. Sequential reaming and impaction of press-fit cups are carried out such that the inferior edge of the implant will rest at the level of the teardrop. This provides a reliable and anatomic intra-operative check for appropriate cup inclination. Anteverting the cup 10° to the native angle of the teardrop and slightly recessed below the anterior wall of the native acetabulum after removal of osteophytes also provides a reliable guide for cup anteversion. Placement of the final implants can be done with a straight or offset cup impactor.

Goals/Strategies of Different Types of Cementless Stems

Implant selection is an extremely important part of a successful surgery and ultimately clinical success and patient satisfaction. A limitation of the direct anterior approach is femoral exposure and lack of extensibility which makes it difficult to utilize longer, straight, ream-and-broach style implants. Exposure confines can limit access to the femoral canal which, many times, leads to undersized or malaligned (Fig. 7.4) components increasing the risk for subsidence, loosening, and fracture, with rates reported between 1.2% and 5.3% [29–33]. To help aid with some of these problems, implant companies began to develop more collared stems to offset some of these issues. There is biomechanical data that shows increased implant stability [42], increased load to fracture [43], lower risk of subsidence [44], as well as registry data of one implant design with 30-year follow-up which shows better survivorship with a collared vs collarless implant.

Additionally, adequate exposure to improve access sometimes involves releasing the attachment of most of the short external rotators and some posterior capsule which has the potential to effectively eliminate the stability advantages of the anterior approach. Exposure and accessibility of the hip through the ABMS approach as well as maintenance of the posterior stabilizing structures allow for unrestricted implant selection.

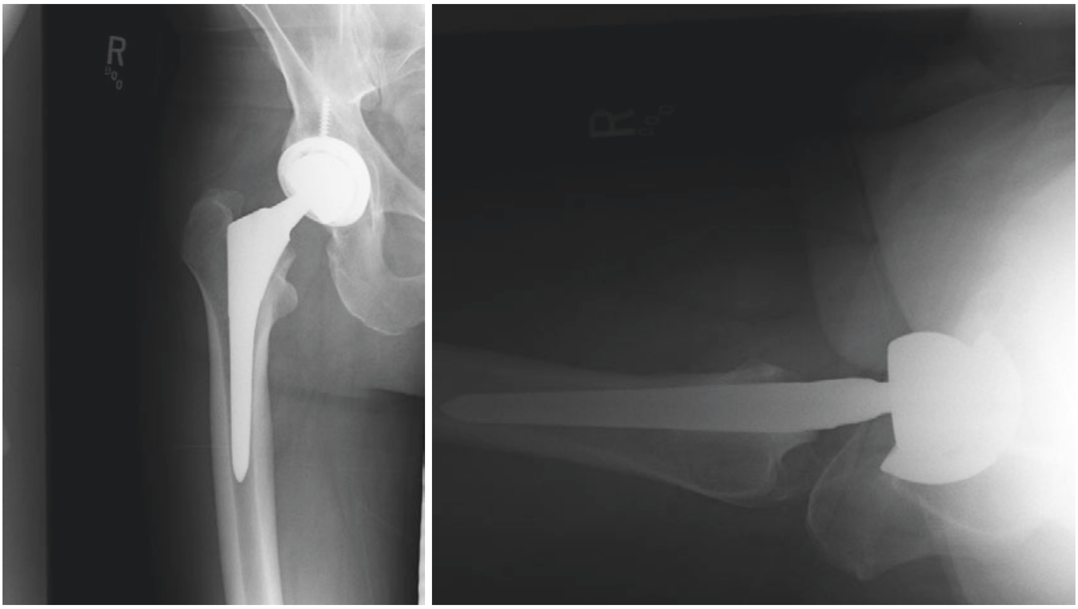


Fig. 7.4 AP (anteroposterior) and cross-table lateral radiographs showing undersized stem in varus and flexion

Broach-Only Systems

Broach-only systems (or single-wedge prosthesis) are designed to gain fixation in the medial to lateral cortices of the proximal femoral metaphysis [34] (Fig. 7.5). They are flat and broad in the AP dimension to provide rotational stability. Broach-only systems require unrestricted access to the cut surface of the femoral neck to appropriately size the metaphysis and achieve appropriate version (Fig. 7.6). Khanuja et al. described a detailed summary of stem classification, and although not all stems necessarily fit into these categories, it provides a starting point for referencing stems and how they might fit together as well as how they obtain their fixation. Many broach-only blade stem systems attempt to gain fixation through medial-lateral press fit and traditionally are thinner in the anterior posterior dimensions (Fig. 7.7). Newer stem variations attempt to maximize metaphyseal engagement with proximal geometries approaching similarity to a fit-and-fill model. These stems are widely used and can be used for most bone types. Some surgeons advocate, once again, that Dorr C femurs are a relative contraindication for these stems as is significant proximal femoral deformity.

Fig. 7.5 One-year postop film broach-only single-wedge taper stem placed in ABMS approach

The superficial and fascial incisions can be modified to aid in exposure and insertion of the curved, blade-type, femoral components. This is accomplished by curving the proximal third of the incision anteriorly aimed towards the anterior superior iliac spine and, similarly, curving the

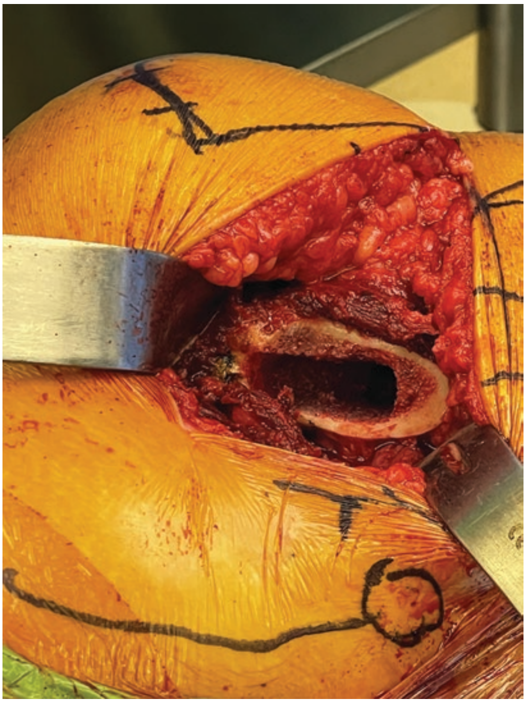


Fig. 7.6 Adequate exposure to proximal femur and femoral neck allows for appropriate proximal femoral preparation

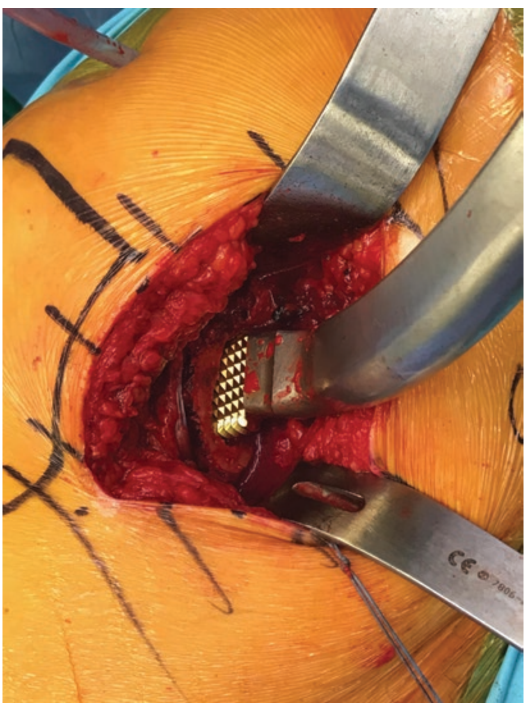


Fig. 7.7 Femoral preparation with broach-only blade-type stem showing medial/lateral fill

fascial incision to run along the anterior border of the abductor musculature. Increasing anterior access by altering incision direction facilitates the use of curved implants while minimizing trauma to the skin and deeper soft tissue. Appropriate implant size depends heavily on exposure of the lateral metaphyseal bone adjacent to the piriformis fossa as it flares to become the medial wall of the trochanter. Accessing this sclerotic, dense bone and removing it or lessening the thickness with lateralizing reamers or rasps is a key step and one that is easily accomplished through the ABMS approach with no minimal threat of damage to the skin or deeper musculature.

Ream and Broach Systems

One of the greatest benefits of the ABMS approach is the ease of the use of longer, straighter stems prepared with a ream and broach method while still being able to preserve posterior stabilizing attachments (Fig. 7.8). Ream-only and ream and broach implants have historically been difficult to place through the direct anterior approach which may limit their use and ultimately may require surgeons to either alter their surgical plan, implant choice, or utilize a more extensile alternative approach. By making a few small adjustments to direction and location of the incision, ream and broach preparation and stem insertion through the ABMS approach becomes straightforward. The superior portion of the skin and fascial incision remains straight and in line with the distal portion of the incision to prevent damage to the skin and deeper structures during broach insertion and removal. The femoral release can be titrated to rotate the femur in order to allow straight, unobstructed access to the femoral canal. Body habitus may dictate the amount of release needed as larger patients and those with more muscle or adipose may require greater femoral mobilization for in-line access to the canal. After a preliminary release is performed, the posterior aspect of the cut edge of the femoral neck can be beveled to improve access for further release, including obturator externus, if necessary. A flat, flexible

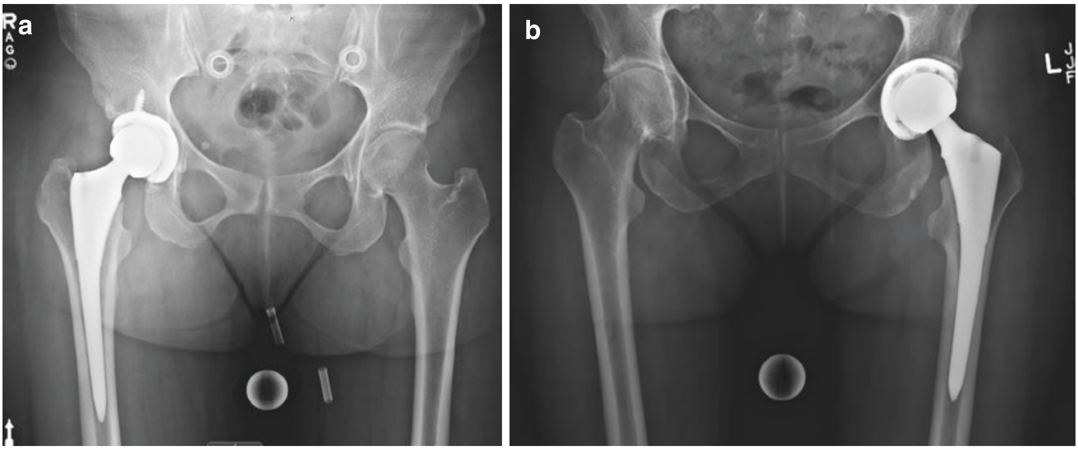


Fig. 7.8 (**a**) Six-week post-operative film showing ream and broach stem placed with ABMS approach. (**b**) One-year post-operative ream and broach stem through ABMS approach

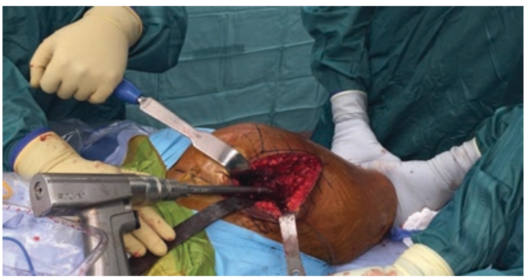


Fig. 7.9 A reamer in place with a malleable placed behind the posterior cortex of the femur and extending superiorly from the wound to protect gluteus musculature while reaming and broaching

retractor, such as a malleable or ribbon retractor, can be placed along the posterior cut surface of the proximal femur to further protect the abductor musculature (Fig. 7.9).

Contraindications

While no absolute contraindications exist for cementless total hip arthroplasty, surgeons must take into account predicted longevity, expected benefits, and risk profiles for the implants and patient alike. For the ABMS approach, these relative contraindications are not considerably different from other approaches but should be recognized and regarded.

Short stems, with the intention of bone preservation, should be avoided in the elderly patient with poor bone quality and integrity. While theoretically easier to implant secondary to the reduced bulk and bowed geometry of these implants, the compact length lacks the capacity to self-center [35]. As such, this predisposes the implant to varus and valgus malpositioning as well as undersizing which may affect implant longevity and survivorship as well as stability and resistance to subsidence. In general, as discussed previously, marked osteoporosis, or radiographically diagnosed Dorr C bone or "stovepipe" femurs, should be treated with extreme caution, and cemented fixation of the femoral stem should be considered. Additionally, many medical device companies maintain that certain cementless implants, including both cutting and compaction broach systems should be "used with caution" or frankly contraindicated in overweight and obese patients [36]. This should be taken case by case and, ultimately, left to the discretion of the surgeon as many of these implants have had tremendous success in overweight and obese patients. These warnings, however, should be heeded, and appropriate patient education and counseling should be provided. Lastly, anatomic variation between patients may affect the success of hip arthroplasty. Patient-specific outliers of neck-shaft angles, anteversion abnormalities, and small canal diameters may make many contemporary implants difficult or impossible to use successfully which may necessitate the use of alternative/secondary implant choices including Wagner-style stems or in some cases cemented fixation to allow more freedom for adjusting stem position.

Cerclage Cabling

Initial stability of total hip arthroplasty components is crucial for implant success and survival [37]. Intra-operative calcar fracture is a rare but known complication of cemented and cementless implants with a reported rate of nearly 5% for press-fit stems [38], while other studies report rates ranging from 1.5% to as high as 27.8% [39]. Immediate recognition and appropriate treatment of these complications is critical to achieve appropriate implant stability. Fractures may occur during broaching or final stem insertion [33]. Broaching-related fractures may be influenced by broach geometry, tooth design (i.e., cutting vs compaction broach), surgical technique, and exposure [40]. The mainstay of treatment of the majority of these fractures is cerclage fixation using metallic or polymer cables for fracture reduction and compression [40, 41] (Fig. 7.10).

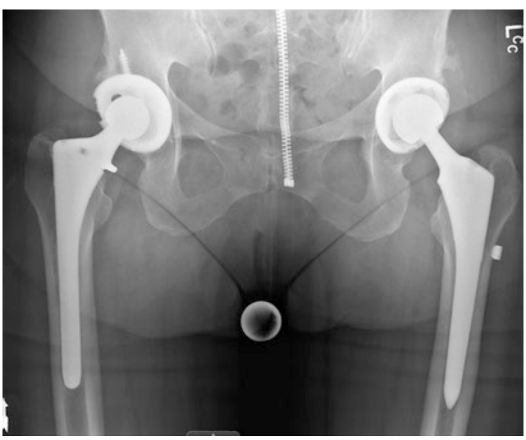


Fig. 7.10 Postop radiograph showing the placement of radiolucent plastic cerclage cable on the left femur (right side of image) just below the lesser trochanter for fixation of intra-operative calcar fracture. The cable locking clamp can be visualized below the lesser trochanter, on the lateral cortex

These are placed at the level of the fracture site and, occasionally if needed, distal to the extent of the fracture to prevent crack propagation and ensure implant stability. Although rare, there are certain circumstances in which cementless stems may lead to more extensive fractures leading to unstable implants, fractures distal to the tip of the implant, or fracture fragment comminution. These scenarios, and others like them, require wider and complete visualization, with open reduction of the fractured fragments, cerclage cabling, possibly with the addition of cortical strut grafting, or internal fixation of the fractured segment with a plate in addition to converting the stem choice to a longer diaphyseal engaging component. The full extent of the fracture must first be determined by implant removal followed by full and thorough evaluation of the metaphysis and diaphysis. Intra-operative radiographs may be very helpful. To accomplish these goals, the hip approach must be extensile, and the ABMS approach allows full, uncompromised approach to the hip and femur. For cabling of the proximal femur, return the leg back to resting position on the bed with bump between legs. In this position, the surgeon is looking directly at anterior border of the vastus lateralis and the vastus insertion on the lateral surface of the greater trochanter. A cable passer can be passed circumferentially around the proximal femur beneath vastus musculature. External rotation or, if needed, bringing the leg to a full "Fig. 7.4" position can aid with medial exposure and access along the calcar to see and pass the wire or cable. Greater external rotation is needed often in larger, muscular patients or those with more adipose tissue. To address fractures that extend distally beyond what can be accessed from the standard approach, the entire surface of the lateral femur may be accessed by extending the incision in line with the anterolateral border of the femur toward the lateral epicondyle of the knee to expose as much, or as little, of the femur as needed. From here, a standard subvastus approach can be performed including an "L"-shaped takedown of the vastus origin from its insertion at the intertrochanteric ridge. The extensibility of the ABMS approach is a major advantage over the direct anterior approach.

Conclusion

Cementless total hip arthroplasty is a tremendously successful surgical intervention with a proven track record for most patients. Barring certain relative contraindications that hold true with all approaches to the hip, the ABMS approach allows for complete, unhindered access to both acetabulum and femur with multiple anatomic checks for component positioning during the final seating of press-fit cups and stems. It enables the surgeon to use any implant style without having to make concessions on choice of prosthesis because of the approach. Lastly it is extensile and allows surgeons to fully care for any and all intra-operative complications that should arise with the use of cementless implants.

References

1. Chen KK, et al. Cemented compared with uncemented femoral fixation in the arthroplasty treatment of displaced femoral neck fractures: a critical analysis review. JBJS Rev. 2018;6(4):e6.
2. Zhang CHYCZ. Wenming, cemented or cementless fixation for primary hip arthroplasty—evidence from the international joint replacement registries. Ann Joint. 2017;2:57.
3. Takenaga RK, et al. Cementless total hip arthroplasty in patients fifty years of age or younger: a minimum ten-year follow-up. J Bone Joint Surg Am. 2012;94(23):2153–9.
4. Lenze F, et al. A 30-year single-center experience of cementless total hip arthroplasty with spongy metal structured implants: a follow-up of a previous report. In Vivo. 2019;33(3):833–8.
5. Dorr LD, et al. Structural and cellular assessment of bone quality of proximal femur. Bone. 1993;14(3):231–42.
6. Kheir MM, Drayer NJ, Chen AF. An update on cementless femoral fixation in Total hip arthroplasty. J Bone Joint Surg Am. 2020;102(18):1646–61.
7. Dalury DF, Kelley TC, Adams MJ. Modern proximally tapered uncemented stems can be safely used in Dorr type C femoral bone. J Arthroplast. 2012;27(6):1014–8.
8. Rhyu KH, et al. Does osteoporosis increase early subsidence of cementless double-tapered femoral stem in hip arthroplasty? J Arthroplast. 2012;27(7):1305–9.
9. Polat A, et al. Cementless rectangular stems yield satisfactory results in osteoporotic bones. Ulus Travma Acil Cerrahi Derg. 2021;27(2):243–8.
10. Zhen P, et al. Primary total hip arthroplasty using a short bone-conserving stem in young adult osteoporotic patients with Dorr type C femoral bone. J Orthop Surg Res. 2021;16(1):17.
11. Les Skinner P. Snubbing theory and calculations. In: Hydraulic rig technology and operations. Amsterdam: Gulf Professional Publishing; 2019.
12. McKee LW. Introduction to fatigue of plastics and elastomer. In: Fatigue and tribological properties of plastics and elastomers. Amsterdam: William Andrew; 2016.
13. Bai QB. Yong, pipeline stress checks. In: Subsea pipeline design, analysis, and installation. Amsterdam/Boston: Elsevier; 2014.
14. Christie J, et al. Echocardiography of transatrial embolism during cemented and uncemented hemiarthroplasty of the hip. J Bone Joint Surg Br. 1994;76(3):409–12.
15. Clark DI, et al. Cardiac output during hemiarthroplasty of the hip. A prospective, controlled trial of cemented and uncemented prostheses. J Bone Joint Surg Br. 2001;83(3):414–8.
16. Holt EM, et al. 1000 femoral neck fractures: the effect of pre-injury mobility and surgical experience on outcome. Injury. 1994;25(2):91–5.
17. Ozturkmen Y, et al. Cementless hemiarthroplasty for femoral neck fractures in elderly patients. Indian J Orthop. 2008;42(1):56–60.
18. Mao S, et al. Cemented versus uncemented total hip replacement for femoral neck fractures in elderly patients: a retrospective, multicentre study with a mean 5-year follow-up. J Orthop Surg Res. 2020;15(1):447.
19. Kristensen TB, et al. Cemented or uncemented hemiarthroplasty for femoral neck fracture? Data from the Norwegian Hip Fracture Register. Clin Orthop Relat Res. 2020;478(1):90–100.
20. Okike K, et al. Association between uncemented vs cemented hemiarthroplasty and revision surgery among patients with hip fracture. JAMA. 2020;323(11):1077–84.
21. Lass R, et al. A cementless hip system with a new surface for osseous integration. Int Orthop. 2014;38(4):703–9.
22. Epinette JA. Clinical outcomes, survivorship and adverse events with mobile-bearings versus fixed-bearings in hip arthroplasty-a prospective comparative cohort study of 143 ADM versus 130 trident cups at 2 to 6-year follow-up. J Arthroplast. 2015;30(2):241–8.
23. Carli AV, et al. Short to midterm follow-up of the tritanium primary acetabular component: a cause for concern. J Arthroplast. 2017;32(2):463–9.
24. Yoshioka S, et al. Comparison of a highly porous titanium cup (Tritanium) and a conventional hydroxyapatite-coated porous titanium cup: a retrospective analysis of clinical and radiological outcomes in hip arthroplasty among Japanese patients. J Orthop Sci. 2018;23(6):967–72.

25. Teoh KH, Lee PY, Woodnutt DJ. Our early experience of the Corin Minihip prosthesis. Hip Int. 2016;26(3):265–9.
26. Dettmer M, Pourmoghaddam A, Kreuzer SW. Comparison of patient-reported outcome from neck-preserving, short-stem arthroplasty and resurfacing arthroplasty in younger osteoarthritis patients. Adv Orthop. 2015;2015:817689.
27. Van Den Eeden YN, De Turck BJ, Van Den Eeden FM. 24 hours stay after hip replacement. Acta Orthop. 2017;88(1):24–8.
28. Sodhi N, et al. Survivorship and radiographic analysis of highly porous acetabular cups designed for improved osseointegration potential. Surg Technol Int. 2019;34:425–9.
29. Barnett SL, et al. Is the anterior approach safe? Early complication rate associated with 5090 consecutive primary Total hip arthroplasty procedures performed using the anterior approach. J Arthroplast. 2016;31(10):2291–4.
30. Dietrich M, et al. Perioperative fractures in cementless total hip arthroplasty using the direct anterior minimally invasive approach: reduced risk with short stems. J Arthroplast. 2018;33(2):548–54.
31. Hartford JM, Knowles SB. Risk factors for perioperative femoral fractures: cementless femoral implants and the direct anterior approach using a fracture table. J Arthroplast. 2016;31(9):2013–8.
32. Lee GC, Marconi D. Complications following direct anterior hip procedures: costs to both patients and surgeons. J Arthroplast. 2015;30(9 Suppl):98–101.
33. Tamaki T, et al. Cementless tapered-wedge stem length affects the risk of periprosthetic femoral fractures in direct anterior total hip arthroplasty. J Arthroplast. 2018;33(3):805–9.
34. Khanuja HS, et al. Cementless femoral fixation in total hip arthroplasty. J Bone Joint Surg Am. 2011;93(5):500–9.
35. Gkagkalis G, et al. Cementless short-stem total hip arthroplasty in the elderly patient - is it a safe option?: a prospective multicentre observational study. BMC Geriatr. 2019;19(1):112.
36. Craik JD, Bircher MD, Rickman M. Hip and knee arthroplasty implants contraindicated in obesity. Ann R Coll Surg Engl. 2016;98(5):295–9.
37. Mallory TH, et al. Why a taper? J Bone Joint Surg Am. 2002;84-A(Suppl 2):81–9.
38. Dammerer D, et al. Occult intra-operative periprosthetic fractures of the acetabulum may affect implant survival. Int Orthop. 2019;43(7):1583–90.
39. Berend KR, Lombardi AV Jr. Intraoperative femur fracture is associated with stem and instrument design in primary total hip arthroplasty. Clin Orthop Relat Res. 2010;468(9):2377–81.
40. Siddiqi A, et al. Diagnosis and management of intraoperative fractures in primary total hip arthroplasty. J Am Acad Orthop Surg. 2021;29:e497–512.
41. Young PS, Patil S, Meek RMD. Intraoperative femoral fractures: prevention is better than cure. Bone Joint Res. 2018;7(1):103–4.
42. Lamb JN, Baetz J, Messer-Hannemann P, Adekanmbi I, van Duren BH, Redmond A, West RM, Morlock MM, Pandit HG. A calcar collar is protective against early periprosthetic femoral fracture around cementless femoral components in primary total hip arthroplasty: a registry study with biomechanical validation. Bone Joint J. 2019;101-B(7):779–86.
43. Demey G, Fary C, Lustig S, Neyret P, si Selmi T. Does a collar improve the immediate stability of uncemented femoral hip stems in total hip arthroplasty? A bilateral comparative cadaver study. J Arthroplast. 2011 Dec;26(8):1549–55.
44. Perelgut ME, Polus JS, Lanting BA, Teeter MG. The effect of femoral stem collar on implant migration and clinical outcomes following direct anterior approach total hip arthroplasty. Bone Joint J. 2020;102-B(12):1654–61.

Cemented Total Hip Replacement through the ABMS Approach

8

Michael B. Held, Alirio J. deMeireles, Sohil S. Desai, and Roshan P. Shah

Learning Points

- Cemented hybrid hip replacement is feasible and safe via the ABMS approach.
- Though less popular in the United States, cemented femoral stems should be considered for some patients.
- Modern results with cemented femoral stems are favorable especially to minimize acute periprosthetic fracture risk.
- ABMS allows for straight access to the femur, to prevent malpositioning of the stem into the varus or extension.

Introduction

Total hip replacement is commonly accepted as the most effective surgical treatment of end-stage hip arthritis. In fact, in 2007, Learmonth et al. recognized THR as the "operation of the century" [1]. While the merits of the overall procedure are clear, the most effective means of component fixation has been the subject of vigorous debate. In 1891 Glück first described the use of methacrylate bone cement to augment THR component fixation [2]. This was later popularized by Charnley in the 1950s who, in his seminal paper, described his technique of component fixation using cement adapted from dental implants [2].

While original Charnley cemented stems performed exceptionally well, other cemented stems such as the Müller-type stem were associated with significantly poorer outcomes and unacceptably high failure rates [3]. This erroneously led to cement itself being labeled as the cause of failure, and the associated aseptic loosening was termed "cement disease" [4]. This incorrect identification of cement as the cause of failure naturally led to the development of cementless components. The early cemented stems which demonstrated poor outcomes were largely utilized in the United States, which in turn lead to rapid abandonment by North American surgeons and the rise of cementless components [4]. This early adoption of cementless components by North American surgeons has contributed to what is referred to today as the "North Atlantic divide" among arthroplasty surgeons. That is, cemented components are particularly popular in Scandinavian countries and across the United Kingdom, while cementless components are most common in North America [5].

Despite these differences in geographic popularity, given there are merits and drawbacks of each modality, it is important for surgeons to be

M. B. Held (✉)
New York Presbyterian- Columbia University Irving Medical Center, New York, NY, USA
e-mail: mh3821@cumc.columbia.edu

A. J. deMeireles · S. S. Desai R. P. Shah
Columbia University Medical Center, Department of Orthopaedic Surgery, New York, NY, USA
e-mail: ajd2226@cumc.columbia.edu; sd3515@cumc.columbia.edu; rs3464@cumc.columbia.edu

J. A. Geller, B. J. McGrory (eds.), *The Anterior-Based Muscle-Sparing Approach to Total Hip Arthroplasty*, https://doi.org/10.1007/978-3-031-02059-9_8

facile with both cemented and cementless techniques. Therefore, the purpose of this chapter is to discuss the common indications for cemented components, summarize the important biomechanical properties of various cement options, describe the authors' preferred cementation technique, and lastly provide important considerations when using cemented fixation through the anterior-based muscle-sparing (ABMS) approach to the hip.

Indications for Cementation

Acetabular Component

Indications for cementation are the subject of vigorous debate and vary based on geographic location and surgeon training and preference. While there are few who argue that all components should be cemented, most surgeons recognize there is a role for each method of fixation. Modern surgeons commonly use a combination of factors to determine means of fixation. These include patient-specific factors such as age, gender, and activity level, as well as the specific indication for surgery (e.g., fracture vs primary osteoarthritis vs metastatic disease), bone quality, and morphology of the acetabulum and proximal femur. Additionally, given the increased emphasis on value-based care, cost has become a factor in implant selection.

In the United States, cementless acetabular fixation is commonly accepted as the preferred approach for the majority of THRs. In 2012 Clement and colleagues published a critical review of the literature describing the use of cement in acetabular fixation. They demonstrated that there was limited evidence to support the near-complete adoption of cementless cups when looking at the overall risk of revision [6]. However, a more recent study in 2020 suggested that cementless acetabular components have a decreased long-term risk of loosening and improved survivorship compared to cemented acetabular components [7]. Given the concern of long-term cement-bone interface loosening and failure leading to revision, cementless acetabular components are most commonly used in the routine primary THR, even in the setting of intracapsular proximal femur fracture. A 2020 review of cement in hip arthroplasty describes pathologic bone and large bone defects as relative indications for the use of cemented acetabular components (Table 8.1).

Table 8.1 Relative indications for cemented femoral and acetabular components

Relative indications for cemented femoral components
Femoral neck fracture
Dorr type C femur
Age >75
Conversion arthroplasty
Inflammatory arthritis
Dysmorphic proximal femur
Relative indications for cemented acetabular components
Pathologic bone
Severe bone defects

Femoral Component

Indications for cemented femoral components have continuously evolved. There have been multiple studies demonstrating excellent outcomes with the use of cemented femoral fixation across a wide cross section of patient demographics. Bedard and colleagues conducted a systematic review of cemented femoral components with a minimum of 20-year follow-up. The authors demonstrate that when using polished, cemented femoral stems, excellent long-term fixation was established in patients of all ages [8]. While some authors advocate for the use of cemented components in all patients, Moskal et al. published a systematic review and were unable to demonstrate that exclusive use of one form of femoral fixation is the best option of all patients [9]. Additionally, they showed that the treatment of elderly patients with cementless components results in increased rate of revision; however, younger patients had improved clinical outcomes with cementless fixation [9]. Thus, the authors conclude that there is no "single gold standard" for femoral fixation in hip arthroplasty [9].

Based on current literature, the relative indications for the use of cement for femoral fixation are outlined in Table 8.1. The Dorr classification helps guide surgical decision-making and has been previously described in detail [10]. The Dorr ratio is calculated as the diameter 10 cm distal to the mid-portion of the lesser trochanter divided by the inner canal diameter at the same level. Type A or "champagne flute" proximal femora have a Dorr ratio of <0.5 and typically receive cementless components. Type B proximal femora have a Dorr ratio 0.5–0.75 and typically receive cementless components. Type C or "stove pipe" proximal femora have a Dorr ratio >0.75 and can be indicated for cemented fixation [10].

Components of Bone Cement

Polymethyl methacrylate (PMMA) is the most commonly used bone cement. It is composed of two main components: a liquid methyl methacrylate (MMA) monomer and a powered MMA-styrene copolymer [11]. When these two components are mixed, an exothermic reaction occurs wherein the liquid monomer polymerizes around powered polymer particles, in the process creating hardened PMMA. There are also various additives present in commercially available PMMA. Hydroquinone and N,N-dimethyl para-toluidine are routinely added to the liquid component and function as a stabilizing agent and an accelerator, respectively [11]. Zirconium dioxide (ZrO_2) or barium sulfate ($BaSO_4$) are commonly added to commercially available PMMA and make the cement radiopaque. Additionally, antibiotics may be added to the cement to help prevent periprosthetic joint infection (PJI). While there is limited evidence to suggest this technique can help prevent PJI, it still is not universally practiced [12].

Cementing Technique

Generations of Cementing Technique

Proper cementing technique is crucial to achieving favorable outcomes when using cemented components for hip arthroplasty. Cementation techniques have progressed from "first generation" to the current "fourth generation." The changes largely involve improvements to bone preparation, cement preparation, and application of the cement itself. With first-generation techniques, the cement was mixed by hand in bowls, the cancellous bone was left in situ, and the cement was inserted by hand, with little emphasis on pressurization. Second-generation techniques involved the removal of all loose cancellous bone, the use of a distal cement restrictor, and femoral canal preparation by packing and drying. Cement was introduced with a cement gun, and the prosthesis was positioned by hand.

Third-generation techniques improved on prior practice by using a vacuum or centrifuge to mix cement and decrease porosity. The canal was irrigated with pulse lavage and packed with epinephrine-soaked sponges. The cement was inserted using a cement gun with the ability to pressurize the cement as it delivers it into the canal. Specifically, a rubber seal was placed around the nozzle of the cement gun which effectively secures the proximal aspect of the femoral canal for the next step in the process. This results in increased pressurization within the canal and a higher degree of cement/bone interdigitation. Fourth-generation technique refers to the use of third-generation techniques but with the addition of a distal stem centralizer and proximal rubber seal to ensure an even cement mantle and avoidance of the distal stem tip touching the cortical bone (i.e., a uniform cement column) [11].

Acetabular Cementing Technique

The acetabulum is first reamed down to bleeding subchondral bone without effacing the subchondral bone entirely. Note that if being performed for osteoarthritis, there is likely to be a thick layer of sclerotic bone. However, when the indication for surgery is a femoral neck fracture, the bone is likely to be of poor quality, and care should be taken to not perforate the medial wall. Drill holes are then made circumferentially to allow for cement penetration, and traditionally larger anchorage holes in the ilium, ischium, and pubis are placed to increase torsional resistance at the cement-bone interface. The surface of the acetabulum is then dried. One bag of cement is mixed using a vacuum and allowed to reach ideal viscosity. The cement is then applied to the acetabulum, aiming for a 2- to 3-mm mantle around the component. The cement may be pressurized, with the latex-covered bulb of a bulb syringe, for example. The polyethylene acetabular component is then inserted, taking care to ensure there is no exposure of the component outside the bony acetabulum. Pressure is applied to the component until the cement hardens.

Femoral Cementing Technique

First, the sizes of the centralizers and the cement restrictor are measured. The cement restrictor is then placed, taking care to position it no more than 2 cm distal to where the tip of the stem will be positioned (Fig. 8.1). The femoral canal is then irrigated with pulse lavage, dried, and then packed with epinephrine-soaked swabs (Fig. 8.2). Two bags of cement are mixed using a vacuum set-up and then allowed to reach ideal viscosity

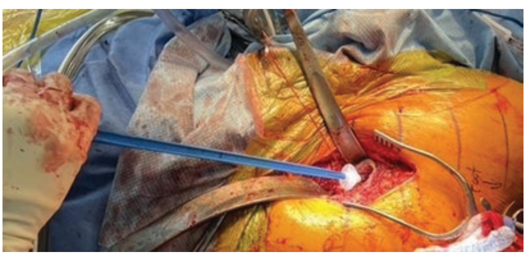


Fig. 8.1 Insertion of cement restrictor

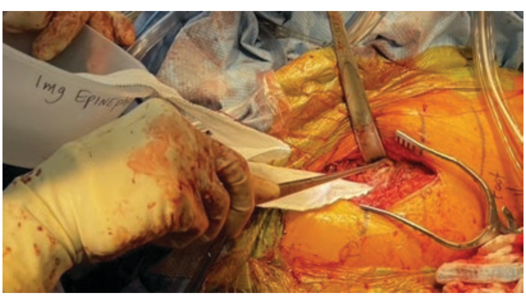


Fig. 8.2 Insertion of epinephrine-soaked gauze

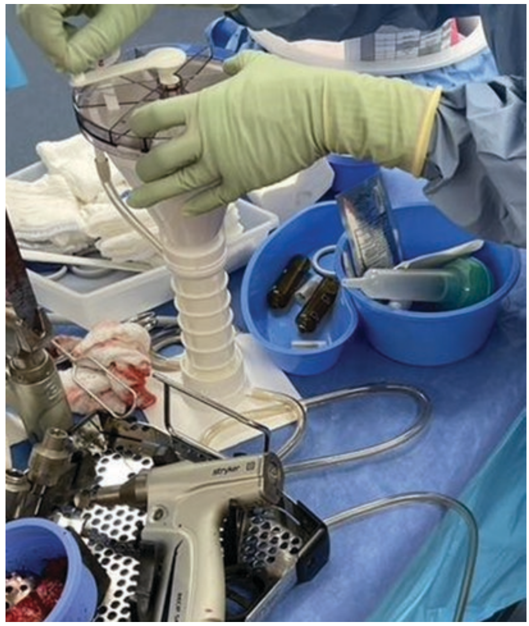


Fig. 8.3 Cement preparation under vacuum seal

(Fig. 8.3). The cement is delivered into the canal in a retrograde fashion using a cement gun. The cement is then pressurized around the calcar by utilizing the rubber nozzle of the cement gun (Fig. 8.4a–c). The stem is then inserted and positioned at the desired anteversion, extension, depth, and alignment, while the cement is allowed to harden completely. It is important to minimize movement of the stem or leg during this step, to ensure a well-formed cement column around the stem (Fig. 8.5).

Benefits of Cementing

There are several advantages associated with cementing components in THR. In accordance with the specific indications for cementing, cemented techniques provide improved outcomes for patients with advanced age and osteoporotic bone by decreasing the risk of complications specifically seen in these patients. The data regarding differences in outcomes between cemented and cementless fixation, however, can be difficult at times to interpret. Across the dozens of studies evaluating these fixation methods, vast differ-

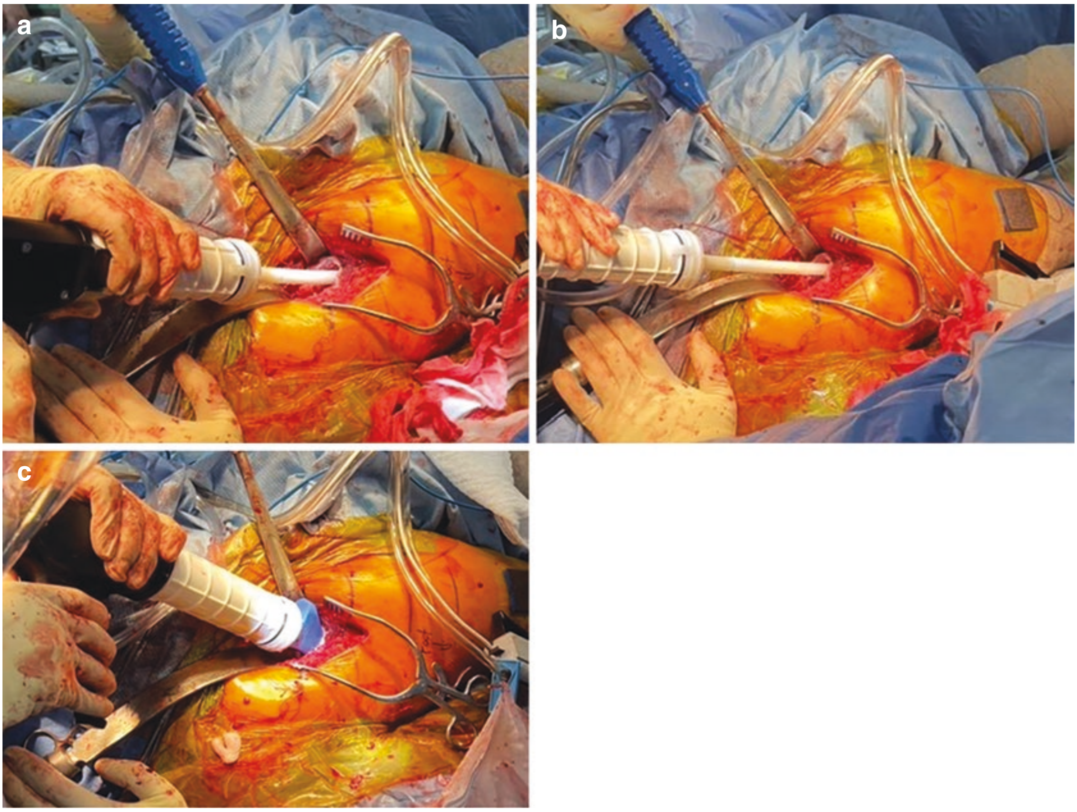


Fig. 8.4 (**a**) Cementing at the distal end, (**b**) with retrograde progression, (**c**) and final pressurization

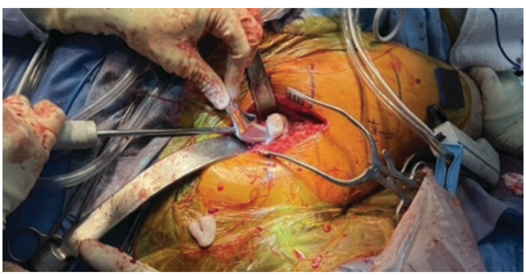


Fig. 8.5 Inserting cemented stem with care to eliminate rotation movement of the stem or leg until fully cured

ences exist regarding the specific prostheses used, operative technique, cementing technique, and specific patient populations undergoing arthroplasty with each fixation method. There are multiple clear benefits related to cementing in hip arthroplasty, but there are also several potential benefits that are still relatively unclear in the literature that may require further research to elucidate.

Additionally, it is important to bear in mind that the benefits and supporting data regarding cementing in total hip arthroplasty are *for the most part* limited to the femoral component. While some of these benefits may also apply to acetabular component cementing (e.g., decreased intraoperative fracture of the acetabulum with cementing), the associated risks have prevented the use of this technique and thus limited the overall data regarding its benefits.

Decreased Risk of Intraoperative and Postoperative Periprosthetic Fracture

Periprosthetic fractures are among the most discussed complications associated with anterior total hip arthroplasty. Roughly 3.5% of primary THRs result in a postoperative PPFx long term, and PPFx are responsible for between 5% and

12% of all revision total hip replacements (rTHR) [13–16]. These fractures are also associated with significant morbidity and mortality, with mortality rates ranging between 13% and 18% in the 1-year period following revision after PPFx [17–19]. These fractures are generally classified as intraoperative, early postoperative (within 5 years of surgery), and late postoperative (greater than 5 years after surgery). The fracture can involve the acetabulum or the femur. Femoral fractures are further classified by the Vancouver system, which is a validated system that correlates well with management indications [20]. In the Vancouver classification of *intraoperative* femoral PPFx, fractures are either type A (proximal metaphyseal), type B (diaphyseal), or type C (distal to the stem), and within each type, the fracture can be grade 1 (cortical perforation), grade 2 (non-displaced crack), and grade 3 (displaced and unstable) [21]. In the Vancouver classification of postoperative femoral PPFx, fractures are type A if they involve the trochanteric region (A_G if involving the greater trochanter, A_L if involving the lesser trochanter), type B if they occur around or just below the stem (B_1 involves a well-fixed stem, B_2 involves a loose stem with good proximal bone stock, B_3 involves a loose stem and ectatic proximal bone stock), and type C if they occur below the stem [20].

Among the many risk factors for intraoperative PPFx, including age greater than 65 and female gender, is the use of cementless prostheses [14]. A study evaluating 32,644 femoral PPFx following THR revealed that there was an overall incidence of intraoperative PPFx of 1.7%, with a 3.0% incidence in the cementless group and 0.2% incidence in the cemented group ($p < .001$) [14]. Interestingly, 3.7% of the patients that sustained intraoperative PPFx in this group sustained a second PPFx during the postoperative follow-up period. Additional studies with smaller cohorts have shown similar results, with intraoperative femoral PPFx rates between 0.1% and 2.5% for cemented THRs and 3.7% and 5.4% for cementless THRs [22, 23]. Press-fit, cementless fixation methods require more force in order to effectively fix the implants, and as a result, the majority of intraoperative PPFx during press-fit fixation occurs during broaching and implant placement [14, 24, 25]. This fixation method also has an inherent increased risk for fracture due to the size mismatch of the femoral stem and broached femoral shaft [26]. While underreaming is the most common reason for intraoperative acetabular fractures, these same technical considerations lead to an increased risk of intraoperative acetabular PPFx as well [27]. Proper exposure and technique is critical to help minimize the risk of PPFx.

It has also been well described that there is a decreased risk of early postoperative femoral PPFx when using cemented stems [14, 25, 28, 29]. The same study analyzing 32,644 PPFx showed a cumulative probability of postoperative PPFx of 0.4% at 1 year, 0.8% at 5 years, and 1.6% at 10 years [14]. The cumulative probabilities at these same time points were 0.2%, 0.4%, and 0.9% in the cemented group and 0.7%, 1.2%, and 2.6% in the cementless group. Specifically, the risk of fracture between year 1 and year 5 was 0.4% in the cemented group and 1.2% in the cementless group. Of note, Vancouver A_G, A_L, B_1, and B_2 occurred at a higher frequency among cemented stems ($p < .001$), while Vancouver B_3 and C, the more unstable patterns, were more common among cementless stems ($p < .001$). The explanation for this finding has not been elucidated. Another study evaluating the occurrence of femoral PPFx within 90 days of THR found an incidence of 0.9% in the cemented group and 2.4% in the cementless group ($p < .001$) [25]. There are multiple explanations for the increased risk of early postoperative PPFx with cementless stems. First, stress risers may be formed at a higher frequency intraoperatively during press-fit fixation due to the force while broaching and implant placement [26, 30]. These stress risers may manifest as postoperative fractures in the early postoperative period. Additionally, press-fit techniques rely on biologic fixation, which may not have yet occurred in the early postoperative period. Thus, low energy-trauma or even out-of-plane forces associated with activities of daily living occurring in these patients may be more likely to result in fracture when compared to a patient with a cemented stem that is already fixed and contributing to load distribution [29, 31]. Finally, it is believed that a large portion of early postoperative PPFx are in actuality unrecognized intraoperative fractures [32]. Thus, the aforementioned mechanisms of increased intraoperative fracture risk using press-fit techniques result in increased rates of documented early postoperative fractures.

The difference in incidence of late postoperative PPFx between cemented and cementless techniques has been controversial in the literature, but emerging evidence shows that cemented fixation is superior in this parameter as well. Late postoperative PPFx are generally associated with loosening and osteolysis, which can result in femoral endosteal defects [26, 33]. It was initially believed that the incidence of osteolysis was higher in cemented fixation methods, and as a result, this technique was determined to have a higher risk of late postoperative PPFx [26, 34]. A recent systematic review of femoral PPFx, however, showed an incidence of late postoperative PPFx of 0.07–3.5% in cemented implants and 0.47–7.1% in cementless implants [29]. The analysis of 32,644 THRs performed by Abdel et al. showed a 3.1% (95% CI 2.6–3.6) cumulative probability between year 5 and year 20 of PPFx in the cemented group, and 12.5% (95% CI 8.4–17.3) in the cementless group during this same time period. The authors posited that the difference may have been due to the increased activity level in the cementless group, which was the younger group overall based on operative indications between the two techniques [14].

Ultimately, surgeons should be aware of this decrease in risk of both intraoperative and postoperative PPFx when using cemented stems through any approach. These considerations may have even greater import with anterior approaches, given the increased challenges with femoral exposure. Operative decision-making remains multifactorial, but the presence of an increased preoperative risk of PPFx represents an additional reason to consider the use of cemented femoral stem fixation (Fig. 8.6).

The ABMS approach can provide excellent visualization of the proximal femur to help mitigate the risk of intraoperative PPFx. Femoral

Fig. 8.6 Positioning for femoral exposure with the contralateral leg raised

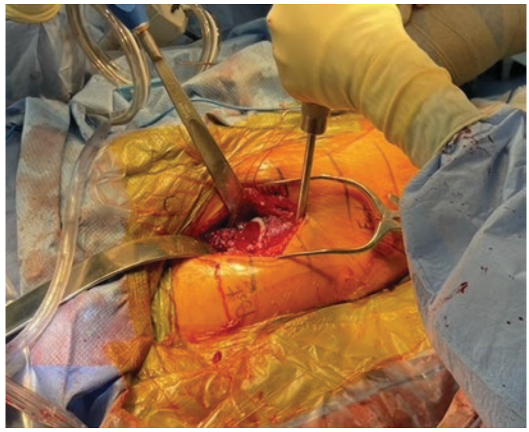


Fig. 8.7 Occasional use of a bone hook can help elevate the femur while performing releases of the capsule and conjoint tendon

elevation is a critical step to prevent this uncommon but worrisome complication. A straight shot down the femoral canal is necessary to prevent off-axis broaching which can put the femur at risk for fracture. It is the senior author's preference to release the obturator internus, piriformis, and obturator externus sequentially as needed to attain this ideal visualization. Obturator internus and piriformis are almost always released, with obturator externus being rarely released. Once the femur is adequately released, it can be elevated using a combination of hip extension, external rotation, and adduction. This is done while pulling anterior with a bone hook, which can carefully be placed from lateral to medial around the proximal femur (Fig. 8.7). When adequately elevated, the femur should almost deliver through the wound. This will allow for easy passage of a canal finder and subsequent broaches to pass easily without resistance (Fig. 8.8). Care

Fig. 8.8 Safely positioning the femur to easily insert a canal finder in the appropriate posterior and lateral location

should be taken in poor bone stock when broaching, as it is important to recognize fractures in the calcar that may warrant cable fixation. Moreover, one may place a prophylactic cable around the calcar to help mitigate the risk of PPFx when bone quality is worrisome.

Intraoperative Advantages of Cementing

In addition to a lower risk of PPFx, there are additional intraoperative benefits to the use of cement. These include an improved control of femoral version, leg length, and neck offset, as well as stronger initial fixation which may ultimately lower the risk of aseptic loosening or component migration in the short term.

One of the difficulties of THR procedures is maintaining control over femoral version, leg length, and neck offset while fixing the stem. Press-fit fixation inherently results in limited maneuverability as the prosthesis becomes firmly seated in the femoral canal. Especially in femurs with wide metaphyseal spaces, it can be difficult to achieve rotational stability with cementless fixation [35]. In cemented femoral stem fixation, after preparing the femoral canal surgeons will introduce cement in a retrograde fashion using a cement gun. With the cement pressurized and the cement mantle prepared, surgeons then insert the stem with careful control of femoral version, leg length, and offset, while the cement increases in viscosity and eventually cures [36]. Any adjustments to the stem orientation or alignment are prohibited after full insertion of the stem due to the risk of compromising the cement mantle and introducing air voids. Thus, these adjustments should be fine-tuned when roughly two thirds of the stem has been introduced into the canal [37].

Additionally, there may be advantages with cemented stem fixation because of immediate and perhaps stronger initial implant fixation. Press-fit techniques rely on biologic fixation, which takes several weeks to reach maximal strength [31]. With press-fit fixation, there are a host of factors that may decrease initial fixation strength, including pore sizes larger than 400 μm or smaller than 50 μm, decreased pore depth, gaps between the bone and prosthesis greater than 50 μm, and micromotion greater than 150 μm. With the advent of modern cementing and pressurization techniques, surgeons are consistently able to achieve immediate and strong fixation of implants, which may ultimately decrease aseptic loosening rates down the road [38]. When utilized effectively, the ABMS approach provides excellent visualization of the proximal femur to allow for successful cementation and mantle creation.

Survivorship

Cementing provides clear improvements in complication rates and survivorship in elderly patients and those with poor bone quality [35]. There are multiple complications historically associated with cemented arthroplasty, however, that have ultimately led to a sharp decline in the use of this technique. Cemented femoral fixation was once the primary operative technique throughout the world, but by 2018 in the United States, 98% of patients younger than 70 years, 94.6% of patients in their 70s, and 84.3% of patients in their 80s receive cementless THRs [35].

In a prospective study, bilateral THRs were compared in 70 patients who underwent cementless stem fixation in one hip and cemented fixation in the other. Initial Harris hip scores (HHS) were slightly higher in the cemented group up to 1 year postoperatively, but the mean HHS scores at the final follow-up examination were similar and excellent in both groups, with 91.5 in the cementless group and 90.8 in the cemented group ($p = .78$) [39]. No patients in this cohort reported thigh pain after 2 years post-procedure; while all 70 patients reported limping before the procedure, only 4 patients still reported limping at the end of the follow-up period, and it was mild in all cases. Similar results were identified in a second, larger analysis with no difference in Harris hip score and UCLA activity score between 492 cemented and 532 cementless total hip arthroplasties [40]. Additionally, a study evaluated the mortality rates between cemented and uncemented stems in patients over the age of 80, with no difference in mortality noted when correcting for Anesthesia Severity Score [35]. Finally, in a systematic review comparing mortality rates between both cemented and uncemented hemiarthroplasties, the investigators found that there was a higher likelihood of death with the use of cemented components within the first 2 days. After 2 days, there was no difference in mortality between groups [41].

Short-term survivorship is comparable if not greater with cemented femoral stem fixation, especially in elderly patients with osteoporotic bone. As discussed, the risk for PPFx is significantly greater in THRs with cementless stems, which decreases short-term survivorship with cementless techniques. A study analyzing 5868 THRs showed 10-year all-cause survival to be greater in the cemented group versus the cementless group. In this study, aseptic loosening rates at 10 years were greater in the cementless group, perhaps as a result of the weaker initial fixation prior to biological on-growth [42].

Long-term survivorship is comparable with cemented stem fixation. A systematic review showed that for patients older than 50 years old, survivorship at 20 years is between 86% and 98% [8]. An analysis of the New Zealand Joint Registry report in 2018 showed 18-year survivorship of 86.1% with cemented stems and 84.5% with cementless stems [35]. In individuals over 75 years old, the revision rate was 0.52 per 100 component-years versus 0.76 per 100 component-years when comparing cemented and cementless stems, respectively. A study by Meding et al. with 1017 THRs showed excellent 20-year survivorship in both the cemented (98.1%) and cementless (99.6%) methods with no statistically significant difference between the two [43]. Results may even be comparable in younger individuals. Kim et al. performed a prospective study performing bilateral THR in individuals younger than 50 years of age, with cemented fixation in one hip and cementless fixation in the other. At the end of the 26.1-year follow-up period, survivorship was similar between the cemented femoral components (96%) and cementless femoral components (95%) [40].

Thus, there is emerging data that cemented stems, especially with modern techniques, are underutilized today when considering survivorship. The evidence is clear that excellent long-term survivorship can be achieved with cementless fixation in younger patients [44, 45]. But the evidence is also clear that cemented femoral fixation shows comparable survivorship, especially in older patients, and arguments can be supported that it should be utilized more frequently in the United States today.

Risks and Disadvantages of Cementing

Increased Operative Time

One of the potential disadvantages of cemented stem fixation is the added time required to properly cement the femoral stem. While surgical assistants can begin the process of cement preparation and mixing, there still is a time delay of at least 7 or 8 minutes required to allow hardening and polymerization of the cement once the stem has been inserted into the cement mantle. A study comparing cemented and cementless fixation methods found that cemented procedures required a mean length of time under anesthesia of 13.3 minutes longer than cementless THRs [46]. This additional time can be mitigated by performing other tasks while the cement hardens, including lavage and wound infiltration [36].

Bone Cement Implantation Syndrome

Bone cement implantation syndrome (BCIS) remains a poorly understood condition. This syndrome was defined by Donaldson et al. as the occurrence of hypoxia, hypotension, and/or unexpected loss of consciousness around the time of cementation, prosthesis insertion, reduction of the joint, or limb tourniquet deflation in patients undergoing joint replacement with cement fixation [47]. Studies using transesophageal echocardiography have shown the passage of fat and marrow emboli during total hip arthroplasty, particularly when intramedullary pressures exceed 200 mmHg during cementation and implant insertion [48, 49].

In a 1999 study of 23 intraoperative deaths in 29,431 patients in the analysis, all deaths occurred in the 16,680-patient cohort that received cemented stems. All deaths were recorded as irreversible cardiorespiratory failure that occurred during the cementing process or during hip relocation. Of the 13 patients for whom autopsy was performed, 11 patients showed bone marrow microemboli in their lungs, and 3 of these had methyl methacrylate particles in their lungs [50]. While embolization of fat and marrow contents can occur with either cemented or cementless implants, studies showed that the increased intramedullary pressures associated with packing cement in the femoral canal led to an increased risk of embolization [51]. The generation of emboli does not show a strong correlation to the extent of hypotension or hypoxemia experienced by these patients, however [52]. BCIS is likely a multifactorial syndrome, explained not only by emboli but also histamine reactions to marrow contents and individual patient risk factors [53]. Notably, the majority of deaths in the aforementioned series of 29,431 patients occurred during THR performed for a fracture diagnosis, and the vast majority of patients exhibited underlying cardiovascular disease [50].

Recent studies have shown there is no significant increase in the rate of BCIS between cemented and cementless stems using modern THR techniques. A review of 9082 cemented stems from a single institution showed only one intraoperative fat embolism mortality related to cementation [54]. Another study, a randomized controlled trial of 100 cemented and 106 cementless stems, showed no difference in the incidence of fat embolism [46]. A retrospective analysis of THR intraoperative mortality over a 28-year period showed a threefold reduction in intraoperative mortality in the final 9 years of the study, further suggesting the reduced risk and incidence of BCIS overall. The primary cause for this reduction is due to the decreased embolization risk associated with the use of pulsatile lavage in all modern techniques [55]. High-volume, high-pressure lavage leads to removal of particular marrow, fat emboli, and tissue thromboplastins from the canal before cementation and directly leads to a reduction of emboli that enter the vasculature [55]. Even with the prioritization of maximal cement pressurization seen in modern techniques in order to attain optimal cement-bone interfaces, the use of pulsatile lavage has still been effective in eliminating the likelihood of marrow content embolization [38, 56]. The use of cement guns to introduce cement into the canal leads to a more even pressure distribution and has also been linked to the decreased risk of BCIS-related mortality [38]. Thus, BCIS represents a dangerous complication that should always be on the radar of surgeons and anesthesiologists during THR, but the incidence has significantly declined with modern operative techniques. Early postoperative mortality following cementation is a real concern, and surgeons should tailor their operative plan based on the physiologic reserve of individual patients [41].

Long-Term Aseptic Loosening Rates May Be Increased When Cementing

Aseptic loosening can occur for three primary reasons: poor initial fixation of prostheses, mechanical loss of fixation over time, and osteolysis. Aseptic loosening should be viewed as separate complications affecting either the acetabular or femoral component. It is widely believed that cementing of the acetabular component leads to increased rates of failure and aseptic loosening, which has essentially led to a near-complete discontinuation of its use in the United States [35, 57]. Based on the orientation of the joint, the femoral component experiences primarily compressive forces which the cement tolerates, while the acetabular component primarily experiences shear forces which are poorly tolerated by cement. Toosi et al. published an article in 2013 arguing that the available evidence may not, in fact, show as great of a difference between outcomes of cemented and cementless acetabular fixation as is currently assumed. Due to the relative lack of data regarding cemented acetabular fixation using modern techniques, however, it is difficult to support the revival of its use at this time [58].

When considering aseptic loosening of the femoral stem, cementing is generally believed to achieve stronger and more consistent initial fixation, as it does not rely on biologic fixation which may fail with poor technique or early micromotion. The data regarding differences in mechanical loss of fixation over time, osteolysis, and the overall risk of aseptic loosening, however, are variable. Some studies have shown equivalent or even decreased rates of aseptic loosening with cemented techniques. Kim et al. performed bilateral THRs in 70 patients with cemented fixation in one hip and cementless fixation in the other. After a mean follow-up of 7.8 years, no stem showed aseptic loosening or subsidence in either group [39]. Another bilateral THR study published in 2019, with 2934 patients receiving cemented stems in one hip and cementless stems in the other, showed increased aseptic loosening rates at 10 years in the cementless group [42].

Other studies, however, have shown increased rates of aseptic loosening in cemented stems. An analysis of the Swedish Hip Arthroplasty Registry from 1992 to 2007 showed an increased risk for revision for any reason (RR = 1.5, 95% CI 1.4–1.6) associated with cementless stems but noted that the risk of aseptic loosening in the femoral stems specifically was lower in the cementless group (RR = 0.4, 95% CI 0.3–0.5). They attributed this increased risk of loosening in the cemented group to the belief that the cemented stems were generally of smaller sizes inserted into narrow femurs which perhaps resulted in thin or absent cement mantles [59]. A randomized controlled trial of 250 patients compared revision rates between cemented and cementless THR. While the overall revision rates did not show a statistically significant difference, there were eight cases of femoral stem aseptic loosening in the cemented group compared to zero cases in the cementless group [60]. This study, which was completed in 2002, used second-generation cementing techniques, and all of the femoral stems were Ti alloy, which have been associated with worse outcomes than Co-Cr alloy stems [61]. The authors were aware of these factors and cited the use of Ti alloy as the primary reason for poor outcomes with cemented fixation in their trial. Wechter et al. found that in their retrospective analysis of 6498 THRs, cemented stems were 3.76 times as likely to be revised for any cause of aseptic loosening [62]. They cited that this difference may have been due to increased wear debris generation in the cemented THRs. However, in a study by Warth et al. in 2014, they found great durability of cemented Charnley implants in young patients with 35 years of follow-up. However, one must critically examine their findings as patient dropout due to death is potential bias that may have influenced their results [63].

Osteolysis is a known cause of aseptic loosening and represents a major cause of revision for all THRs. The overall prevalence of revision secondary to osteolysis, using any fixation approach, is estimated to be 9–20% [64]. Historically, it was believed that a primary cause of failure of total hip arthroplasties was "cement disease." Throughout the 1960s and 1970s, Charnley described multiple cases of "cystic erosion of bone" surrounding THR implants with localized macrophage reaction. He noticed cement particles in the surrounding tissue and posited that the erosion of bone may have been due to a deficiency of the cement mantle [65–67]. Harris et al. described localized bone resorption in the femur after total hip arthroplasty and believed micromotion between cement and bone may have been the primary cause of this resorption [68]. The authors of this study, along with others, performed histologic analyses of the area of lysis surrounding femoral stems and noted macrophages containing cement particles in some cases. Resultantly, the term “cement disease” was popularized [34]. Similar radiographic and pathologic findings in cementless THRs, however, raised discussion of whether or not cement was truly the key player in this resorptive process. These findings were in actuality explained by what we now understand to be osteolysis, which is the response to sub-micron particulate debris from *any* component of the implant [69]. Polyethylene has been found to be the primary culprit of particle formation and is responsible for roughly 90% of the debris formed in THRs [70]. The current literature does not support a difference in rates of osteolysis between cemented and cementless arthroplasties [39, 40, 71–74].

A systematic review found high activity level (UCLA activity score >8 points) to be significantly associated with increased rate of aseptic loosening (OR 4.24, 95% CIT 2.46–7.31). Additional factors including age, bone quality, surgeon-specific indications for cementing, and prosthetic design may also influence the data in several of these studies. The “generation” of cementing, overall cementing technique, design of prosthesis, and prosthetic materials varied widely within each study and between each separate study. In summation, it is likely that strength and consistency of initial fixation are greater with cemented stem fixation. Higher-quality prospective studies are needed, however, to effectively compare the overall rates of mechanical loss of fixation over time, osteolysis, and aseptic loosening.

Revision Difficulties with Cemented Fixation Techniques

All revision THRs, regardless of fixation technique or prosthetic design, are associated with the increased risk of postoperative complications, subsequent revision rates, and overall morbidity [75–77]. Revision of cemented stems poses additional challenges due to the difficulty that comes with removing a well-fixed cement mantle. Traditional revision of a cemented stem THR requires careful and complete removal of the cement using a rasp, burr, or ultrasound [78]. In addition to increased operative times and technical challenges, these revisions are associated with an increased risk of bleeding and postoperative complications [79]. Of note, cemented stems still show a decreased incidence of postoperative PPFx after revision THR, with an incidence ranging between 3.2% and 6.3% in cemented revisions and 17.6–18% in cementless revision THRs [29].

A unique technique, called the “cement-in-cement” revision, however, can mitigate this challenge for patients with polished cemented stems used for the primary arthroplasty. This procedure involves using an existing intact cement mantle, removing the old femoral prosthesis, adding new cement, and inserting a new, thinner, and shorter femoral stem specifically designed for this procedure. The surgeon should carefully ensure that the cement-bone interface is still intact. Loosening of the cement-bone interface distal to the lesser trochanter is a relative contraindication to the cement-in-cement revision technique [36]. It is also critical that the cementing interface is thoroughly cleaned before the new cement layer is introduced. A study performed by Lee showed an 82% decrease in shear strength if the interface was contaminated with blood or fat [80]. Results have been good with this technique, with one study of 136 hips revised using the cement-in-cement technique results in no re-revisions due to aseptic loosening at 8 years [81]. A systematic review evaluating the outcomes of this technique in femoral stems showed a 1.4% failure rate out of 620 cases at 5.4 years [79]. Four studies from this review reported data on preoperative and postoperative HHS scores, showing an improvement in mean scores from 41.1 to 75.9.

The outcomes for revision arthroplasty are universally poorer than the outcomes of primary arthroplasty, and the technical challenge associated with revising cemented primary THRs can worsen these outcomes. While the cement-in-cement technique can help address this problem, the procedure cannot be performed when the cement-bone interface is disrupted, leaving surgeons with limited options in those scenarios. These risks must be a consideration during preoperative planning of THRs, especially in younger patients who are likely to require a revision in the future. Revising cemented stems through the ABMS can be challenging; however, when the femur is properly released and delivered, implant and cement removal can be as easily performed as in a posterior approach. Visualization is paramount in the ABMS, so time and care must be taken to properly elevate the femur to allow easy access down the femoral canal. In the patient supine variation of ABMS, utilizing intraoperative fluoroscopy is simple and can help in the process of removing cement.

Unique Considerations When Cementing Through the ABMS Approach

Popularized in the modern era by Bertin and Röttinger in 2004, the name "anterior-based, muscle-sparing" approach was proposed by Kelley et al. in 2015 so as to not be confused with modified anterolateral approaches that still involved violation of the hip abductors [82, 83]. The proposed benefits of muscle-sparing approaches are decreased soft tissue trauma, reduced perioperative pain, decreased blood loss, faster recovery time, and shorter skin incisions. The key technical points of this approach involve a muscular plane between the tensor fascia latae (TFL) medially and gluteus medius laterally, dissecting down to the anterior capsule without disrupting the hip abductors and adducting, extending, and externally rotating the operative leg for adequate access when preparing the femoral prostheses. The aforementioned benefits of cementing the femoral component in total hip arthroplasty should still be pursued when using the ABMS, but the surgeon should consider additional factors specific to the surgical approach that may influence preoperative decision-making.

The Use of Intraoperative Fluoroscopy

The use of intraoperative fluoroscopy is simpler when a patient is supine in an ABMS approach, as compared to the lateral decubitus position used for the ABMS or posterior approaches to the hip. Intraoperative fluoroscopy allows for real-time feedback to improve the fit of the femoral stem, as well as restoring the proper leg length and offset for each individual patient. Figure 8.9a shows a trial with over-lengthening of the hip. Figure 8.9b shows more equal reconstruction

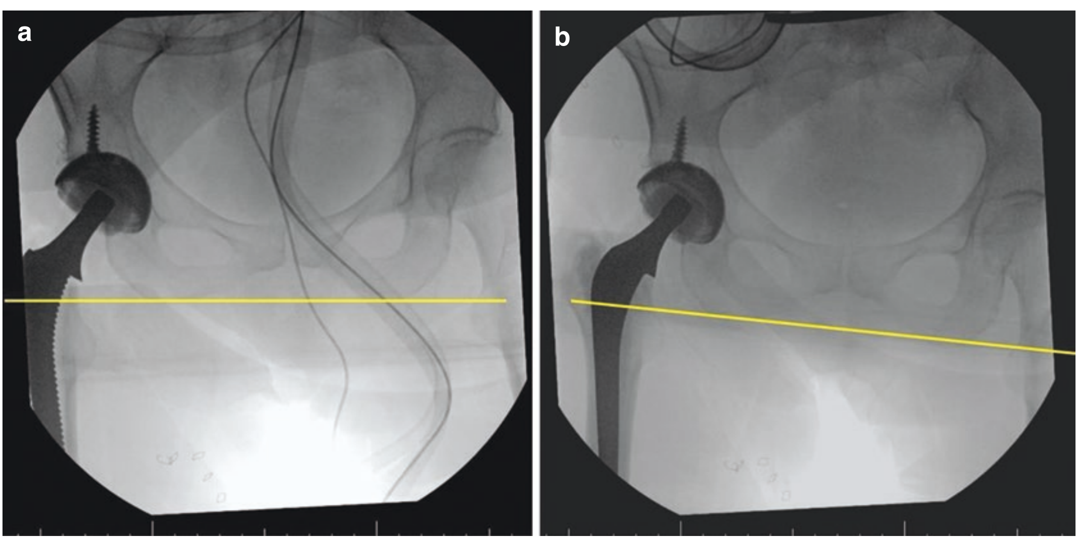


Fig. 8.9 Fluoroscopy reveals (**a**) over-lengthening (**b**) and confirms correct reconstruction

after deeper preparation of the femoral implant. Additionally, intraoperative imaging allows a surgeon to recognize excess cement prior to closure. This can be very useful in conversion cases where there may be prior screw tracks from intramedullary nails and plates.

Cement Mantle Quality

One such consideration is whether an effective cement mantle can be achieved using the ABMS approach. Unequivocally the answer is yes (Fig. 8.10). The thickness and homogeneity of the cement mantle are directly correlated to the onset of aseptic loosening in cemented THR [84]. Radiographic assessment of cement mantles is guided by the Barrack classification. Grade A is defined as complete filling of the medullary canal (a so-called white-out), Grade B involves slight radiolucency of the cement-bone interface, Grade C involves 50–99% radiolucency or a defective cement mantle, and Grade D is defined as 100% radiolucency of the cement-bone interface at any projection or an incompletely filled canal (e.g., the tip of the stem was uncovered) [85].

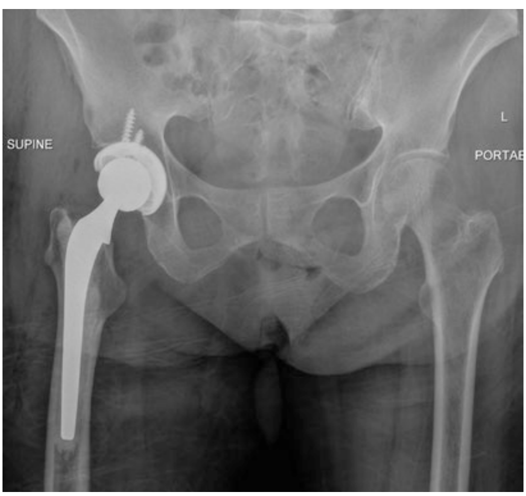


Fig. 8.10 Post-surgical films of the patient shown above with excellent cement fill to the cortices

At this time, there are no studies evaluating cement mantles using the ABMS approach. However, there is some evidence from the direct anterior approach (DAA) to the hip, which follows an anterior approach on the medial side of the TFL muscle. Studies evaluating the DAA have shown the ability to achieve an adequate cement mantle using this technique despite considerations of a less straightforward femoral exposure [86].

Cement mantle quality has been highly associated with the longevity of cemented prostheses, but there is currently little to no data regarding the quality of cement mantles that are achieved using the ABMS approach [87]. In our experience, when adequate femoral exposure is achieved using the ABMS approach, there is no difference between the cement mantle obtained from ABMS and other approaches such as the posterolateral.

Periprosthetic Fractures and the ABMS Approach

Few studies have evaluated the incidence of complications of the muscle-sparing anterolateral THR approaches. One such retrospective analysis of 684 THRs performed using an ABMS approach showed a 4.1% incidence of intraoperative PPFx ($n = 28$) and a 4.2% incidence of fracture within the first 90 days ($n = 29$) for a total of 57 PPFx (8.3%) in the short postoperative evaluation period [88]. Of the 28 intraoperative calcar fractures, 26 were treated with cerclage cables and healed. One greater trochanter fracture was treated with a claw plate and healed. Of the 29 postoperative fractures, 14 required revision surgery with the others adequately treated nonoperatively. Notably, a higher risk of PPFx was observed in the uncemented tapered-wedge and meta-diaphyseal stem group (9.8%) when compared to the cemented and collared stems (0%) ($p = .001$). In this study, cemented and collared stems showed protection when selectively chosen for ABMS THA.

Conclusion

Currently, there is a paucity of literature regarding outcomes of the ABMS approach. This includes a lack of data comparing cemented stems to cementless stems using the ABMS, as well as comparing cemented stems using the ABMS compared to cemented stems using other approaches. The field of arthroplasty has been rapidly evolving, and in order to provide the best care to patients, it is critical that surgeons remain aware of the specific outcomes associated with the plethora of operative approaches, prosthetic devices, and techniques that are currently available. As the total number of patients that have received cemented THR through the ABMS approach increases, it will be important for clinicians to critically evaluate this data to shed light on the specific indications and overall effectiveness of this treatment option.

References

1. Learmonth ID, Young C, Rorabeck C. The operation of the century: total hip replacement. Lancet. 2007;370(9597):1508–19.
2. Charnley J. Arthroplasty of the hip: a new operation. Clin Orthop Relat Res®. 1973;95:4–8.
3. Sutherland CJ, Wilde A, Borden L, Marks K. A ten-year follow-up of one hundred consecutive Müller curved-stem total hip-replacement arthroplasties. J Bone Joint Surg Am. 1982;64(7):970–82.
4. Yamada H, Yoshihara Y, Henmi O, Morita M, Shiromoto Y, Kawano T, et al. Cementless total hip replacement: past, present, and future. J Orthop Sci. 2009;14(2):228–41.
5. Dunbar MJ. Cemented femoral fixation: the North Atlantic divide. Orthopedics. 2009;32(9):662.
6. Clement N, Biant L, Breusch SJ. Total hip arthroplasty: to cement or not to cement the acetabular socket? A critical review of the literature. Arch Orthop Trauma Surg. 2012;132(3):411–27.
7. Gwynne-Jones DP, Gray AR. Cemented or uncemented acetabular fixation in combination with the Exeter Universal cemented stem: long-term survival to 18 years. Bone Joint J. 2020;102(4):414–22.
8. Bedard NA, Callaghan JJ, Stefl MD, Liu SS. Systematic review of literature of cemented femoral components: what is the durability at minimum 20 years followup? Clin Orthop Relat Res. 2015;473(2):563–71. https://doi.org/10.1007/s11999-014-3876-3.
9. Moskal JT, Capps SG, Scanelli JA. Still no single gold standard for using cementless femoral stems routinely in total hip arthroplasty. Arthroplast Today. 2016;2(4):211–8.
10. Wilkerson J, Fernando ND. Classifications in brief: the Dorr classification of femoral bone. Clin Orthop Relat Res®. 2020;478(8):1939–44.
11. Vaishya R, Chauhan M, Vaish A. Bone cement. J Clin Orthop Trauma. 2013;4(4):157–63.
12. Leong JW, Cook MJ, O'neill TW, Board TN. Is the use of antibiotic-loaded bone cement associated with a lower risk of revision after primary total hip arthroplasty? A study of 418,857 total hip arthroplasties in the National Joint Registry for England, Wales, Northern Ireland and the Isle of Man. Bone Joint J. 2020;102(8):997–1002.
13. Springer BD, Etkin CD, Shores PB, Gioe TJ, Lewallen DG, Bozic KJ. Perioperative periprosthetic femur fractures are strongly correlated with fixation method: an analysis from the American Joint Replacement Registry. J Arthroplast. 2019;34(7S):S352–S4. https://doi.org/10.1016/j.arth.2019.02.004.
14. Abdel MP, Watts CD, Houdek MT, Lewallen DG, Berry DJ. Epidemiology of periprosthetic fracture of the femur in 32 644 primary total hip arthroplasties: a 40-year experience. Bone Joint J. 2016;98-B(4):461–7. https://doi.org/10.1302/0301-620X.98B4.37201.
15. Gwam CU, Mistry JB, Mohamed NS, Thomas M, Bigart KC, Mont MA, et al. Current epidemiology of revision total hip arthroplasty in the United States: national inpatient sample 2009 to 2013. J Arthroplast. 2017;32(7):2088–92. https://doi.org/10.1016/j.arth.2017.02.046.
16. Bozic KJ, Kurtz SM, Lau E, Ong K, Vail TP, Berry DJ. The epidemiology of revision total hip arthroplasty in the United States. J Bone Joint Surg Am. 2009;91(1):128–33. https://doi.org/10.2106/JBJS.H.00155.
17. Shields E, Behrend C, Bair J, Cram P, Kates S. Mortality and financial burden of periprosthetic fractures of the femur. Geriatr Orthop Surg Rehabil. 2014;5(4):147–53. https://doi.org/10.1177/2151458514542281.
18. Drew JM, Griffin WL, Odum SM, Van Doren B, Weston BT, Stryker LS. Survivorship after periprosthetic femur fracture: factors affecting outcome. J Arthroplast. 2016;31(6):1283–8. https://doi.org/10.1016/j.arth.2015.11.038.
19. Boylan MR, Riesgo AM, Paulino CB, Slover JD, Zuckerman JD, Egol KA. Mortality following periprosthetic proximal femoral fractures versus native hip fractures. J Bone Joint Surg Am. 2018;100(7):578–85. https://doi.org/10.2106/JBJS.17.00539.
20. Duncan CP, Masri BA. Fractures of the femur after hip replacement. Instr Course Lect. 1995;44:293–304.
21. Greidanus NV, Mitchell PA, Masri BA, Garbuz DS, Duncan CP. Principles of management and results of treating the fractured femur during and after total hip arthroplasty. Instr Course Lect. 2003;52:309–22.

22. Berry DJ. Epidemiology: hip and knee. Orthop Clin North Am. 1999;30(2):183–90. https://doi.org/10.1016/s0030-5898(05)70073-0.
23. Lowenhielm G, Hansson LI, Karrholm J. Fracture of the lower extremity after total hip replacement. Arch Orthop Trauma Surg. 1989;108(3):141–3. https://doi.org/10.1007/BF00934256.
24. Fitzgerald RH Jr, Brindley GW, Kavanagh BF. The uncemented total hip arthroplasty. Intraoperative femoral fractures. Clin Orthop Relat Res. 1988;235:61–6.
25. Lindberg-Larsen M, Jorgensen CC, Solgaard S, Kjersgaard AG, Kehlet H, Lunbeck Foundation Centre for Fast-track Hip and Knee Replacement, et al. Increased risk of intraoperative and early postoperative periprosthetic femoral fracture with uncemented stems. Acta Orthop. 2017;88(4):390–4. https://doi.org/10.1080/17453674.2017.1302908.
26. Kelley SS. Periprosthetic femoral fractures. J Am Acad Orthop Surg. 1994;2(3):164–72. https://doi.org/10.5435/00124635-199405000-00005.
27. Sharkey PF, Hozack WJ, Callaghan JJ, Kim YS, Berry DJ, Hanssen AD, et al. Acetabular fracture associated with cementless acetabular component insertion: a report of 13 cases. J Arthroplast. 1999;14(4):426–31. https://doi.org/10.1016/s0883-5403(99)90097-9.
28. Bozic KJ, Lau E, Ong K, Chan V, Kurtz S, Vail TP, et al. Risk factors for early revision after primary total hip arthroplasty in Medicare patients. Clin Orthop Relat Res. 2014;472(2):449–54. https://doi.org/10.1007/s11999-013-3081-9.
29. Sidler-Maier CC, Waddell JP. Incidence and predisposing factors of periprosthetic proximal femoral fractures: a literature review. Int Orthop. 2015;39(9):1673–82. https://doi.org/10.1007/s00264-015-2721-y.
30. Sarvilinna R, Huhtala H, Pajamaki J. Young age and wedge stem design are risk factors for periprosthetic fracture after arthroplasty due to hip fracture. A case-control study. Acta Orthop. 2005;76(1):56–60. https://doi.org/10.1080/00016470510030328.
31. Foster AP, Thompson NW, Wong J, Charlwood AP. Periprosthetic femoral fractures--a comparison between cemented and uncemented hemiarthroplasties. Injury. 2005;36(3):424–9. https://doi.org/10.1016/j.injury.2004.07.023.
32. Davidson D, Pike J, Garbuz D, Duncan CP, Masri BA. Intraoperative periprosthetic fractures during total hip arthroplasty. Evaluation and management. J Bone Joint Surg Am. 2008;90(9):2000–12. https://doi.org/10.2106/JBJS.H.00331.
33. Lee SR, Bostrom MP. Periprosthetic fractures of the femur after total hip arthroplasty. Instr Course Lect. 2004;53:111–8.
34. Jones LC, Hungerford DS. Cement disease. Clin Orthop Relat Res. 1987;225:192–206.
35. Blankstein M, Lentine B, Nelms NJ. The use of cement in hip arthroplasty: a contemporary perspective. J Am Acad Orthop Surg. 2020;28(14):e586–e94. https://doi.org/10.5435/JAAOS-D-19-00604.
36. Gulati A, Manktelow ARJ. Even "cementless" surgeons use cement. J Arthroplast. 2017;32(9S):S47–53. https://doi.org/10.1016/j.arth.2017.02.044.
37. Emara AK, Ng M, Krebs VE, Bloomfield M, Molloy RM, Piuzzi NS. Femoral stem cementation in hip arthroplasty: the know-how of a "lost" art. Curr Rev Musculoskelet Med. 2021;14(1):47–59. https://doi.org/10.1007/s12178-020-09681-5.
38. McCaskie AW, Barnes MR, Lin E, Harper WM, Gregg PJ. Cement pressurisation during hip replacement. J Bone Joint Surg Br. 1997;79(3):379–84. https://doi.org/10.1302/0301-620x.79b3.7301.
39. Kim YH. Bilateral cemented and cementless total hip arthroplasty. J Arthroplast. 2002;17(4):434–40. https://doi.org/10.1054/arth.2002.31073.
40. Kim YH, Park JW, Kim JS, Kim IW. Twenty-five- to twenty-seven-year results of a cemented vs a cementless stem in the same patients younger than 50 years of age. J Arthroplast. 2016;31(3):662–7. https://doi.org/10.1016/j.arth.2015.09.045.
41. Fenelon C, Murphy EP, Pomeroy E, Murphy RP, Curtin W, Murphy CG. Perioperative mortality after cemented or uncemented hemiarthroplasty for displaced femoral neck fractures—a systematic review and meta-analysis. J Arthroplast. 2021;36(2):777–87.e1.
42. Lamb JN, King SW, van Duren BH, West RM, Pandit HG. Comparison of cementless versus cemented stem survival: an analysis of 2934 patients with bilateral hip arthroplasties in the National Joint Registry of England and Wales. Bone Joint J Orthop Proc. 2019;101-B(Supp_6):20.
43. Meding JB, Ritter MA, Davis KE, Hillery M. Cemented and uncemented total hip arthroplasty using the same femoral component. Hip Int. 2016;26(1):62–6. https://doi.org/10.5301/hipint.5000296.
44. Vidalain JP. Twenty-year results of the cementless corail stem. Int Orthop. 2011;35(2):189–94. https://doi.org/10.1007/s00264-010-1117-2.
45. McLaughlin JR, Lee KR. Total hip arthroplasty with an uncemented tapered femoral component in patients younger than 50 years of age: a minimum 20-year follow-up study. J Arthroplast. 2016;31(6):1275–8. https://doi.org/10.1016/j.arth.2015.12.026.
46. Kim YH, Oh SW, Kim JS. Prevalence of fat embolism following bilateral simultaneous and unilateral total hip arthroplasty performed with or without cement : a prospective, randomized clinical study. J Bone Joint Surg Am. 2002;84(8):1372–9. https://doi.org/10.2106/00004623-200208000-00012.
47. Donaldson AJ, Thomson HE, Harper NJ, Kenny NW. Bone cement implantation syndrome. Br J Anaesth. 2009;102(1):12–22. https://doi.org/10.1093/bja/aen328.
48. Christie J, Robinson CM, Singer B, Ray DC. Medullary lavage reduces embolic phenomena

and cardiopulmonary changes during cemented hemi-arthroplasty. J Bone Joint Surg Br. 1995;77(3):456–9.
49. Ereth MH, Weber JG, Abel MD, Lennon RL, Lewallen DG, Ilstrup DM, et al. Cemented versus noncemented total hip arthroplasty--embolism, hemodynamics, and intrapulmonary shunting. Mayo Clin Proc. 1992;67(11):1066–74. https://doi.org/10.1016/s0025-6196(12)61121-5.
50. Parvizi J, Holiday AD, Ereth MH, Lewallen DG. The Frank Stinchfield Award. Sudden death during primary hip arthroplasty. Clin Orthop Relat Res. 1999;369:39–48. https://doi.org/10.1097/00003086-199912000-00005.
51. Kallos T, Enis JE, Gollan F, Davis JH. Intramedullary pressure and pulmonary embolism of femoral medullary contents in dogs during insertion of bone cement and a prosthesis. J Bone Joint Surg Am. 1974;56(7):1363–7.
52. Lafont ND, Kalonji MK, Barre J, Guillaume C, Boogaerts JG. Clinical features and echocardiography of embolism during cemented hip arthroplasty. Can J Anaesth. 1997;44(2):112–7. https://doi.org/10.1007/BF03012997.
53. Tryba M, Linde I, Voshage G, Zenz M. Histamine release and cardiovascular reactions to implantation of bone cement during total hip replacement. Anaesthesist. 1991;40(1):25–32.
54. Sierra RJ, Timperley JA, Gie GA. Contemporary cementing technique and mortality during and after Exeter total hip arthroplasty. J Arthroplast. 2009;24(3):325–32. https://doi.org/10.1016/j.arth.2008.01.301.
55. Byrick RJ, Bell RS, Kay JC, Waddell JP, Mullen JB. High-volume, high-pressure pulsatile lavage during cemented arthroplasty. J Bone Joint Surg Am. 1989;71(9):1331–6.
56. Munro NA, Nicol M, Selvaraj S, Hussain SM, Finlayson DF. Femoral cement pressurization in hip arthroplasty: a comparison of 3 systems. J Arthroplast. 2007;22(6):893–901. https://doi.org/10.1016/j.arth.2006.09.014.
57. Ritter MA. Acetabular options. J Arthroplast. 2003;18(3 Suppl 1):80–1. https://doi.org/10.1054/arth.2003.50071.
58. Toossi N, Adeli B, Timperley AJ, Haddad FS, Maltenfort M, Parvizi J. Acetabular components in total hip arthroplasty: is there evidence that cementless fixation is better? J Bone Joint Surg Am. 2013;95(2):168–74. https://doi.org/10.2106/JBJS.K.01652.
59. Hailer NP, Garellick G, Karrholm J. Uncemented and cemented primary total hip arthroplasty in the Swedish Hip Arthroplasty Register. Acta Orthop. 2010;81(1):34–41. https://doi.org/10.3109/17453671003685400.
60. Laupacis A, Bourne R, Rorabeck C, Feeny D, Tugwell P, Wong C. Comparison of total hip arthroplasty performed with and without cement : a randomized trial. J Bone Joint Surg Am. 2002;84(10):1823–8. https://doi.org/10.2106/00004623-200210000-00013.
61. Murray P, Rorabeck H. Bilateral femoral component breakage in total hip replacement: a case report. Can J Surg. 1998;41(3):236–8.
62. Wechter J, Comfort TK, Tatman P, Mehle S, Gioe TJ. Improved survival of uncemented versus cemented femoral stems in patients aged < 70 years in a Community Total Joint Registry. Clin Orthop Relat Res. 2013;471(11):3588–95. https://doi.org/10.1007/s11999-013-3182-5.
63. Warth LC, Callaghan JJ, Liu SS, Klaassen AL, Goetz DD, Johnston RC. Thirty-five-year results after Charnley total hip arthroplasty in patients less than fifty years old: a concise follow-up of previous reports. JBJS. 2014;96(21):1814–9.
64. Haynes JA, Stambough JB, Sassoon AA, Johnson SR, Clohisy JC, Nunley RM. Contemporary surgical indications and referral trends in revision total hip arthroplasty: a 10-year review. J Arthroplast. 2016;31(3):622–5. https://doi.org/10.1016/j.arth.2015.09.026.
65. Charnley J. The reaction of bone to self-curing acrylic cement. A long-term histological study in man. J Bone Joint Surg Br. 1970;52(2):340–53.
66. Charnley J, Follacci FM, Hammond BT. The long-term reaction of bone to self-curing acrylic cement. J Bone Joint Surg Br. 1968;50(4):822–9.
67. Charnley J. The bonding of prostheses to bone by cement. J Bone Joint Surg Br. 1964;46:518–29.
68. Harris WH, Schiller AL, Scholler JM, Freiberg RA, Scott R. Extensive localized bone resorption in the femur following total hip replacement. J Bone Joint Surg Am. 1976;58(5):612–8.
69. Jacobs JJ, Roebuck KA, Archibeck M, Hallab NJ, Glant TT. Osteolysis: basic science. Clin Orthop Relat Res. 2001;393:71–7. https://doi.org/10.1097/00003086-200112000-00008.
70. Campbell P, Ma S, Yeom B, McKellop H, Schmalzried TP, Amstutz HC. Isolation of predominantly submicron-sized UHMWPE wear particles from periprosthetic tissues. J Biomed Mater Res. 1995;29(1):127–31. https://doi.org/10.1002/jbm.820290118.
71. Kim YH, Kook HK, Kim JS. Total hip replacement with a cementless acetabular component and a cemented femoral component in patients younger than fifty years of age. J Bone Joint Surg Am. 2002;84(5):770–4. https://doi.org/10.2106/00004623-200205000-00011.
72. Strom H, Kolstad K, Mallmin H, Sahlstedt B, Milbrink J. Comparison of the uncemented cone and the cemented Bimetric hip prosthesis in young patients with osteoarthritis: an RSA, clinical and radiographic study. Acta Orthop. 2006;77(1):71–8. https://doi.org/10.1080/17453670610045713.
73. Karrholm J, Malchau H, Snorrason F, Herberts P. Micromotion of femoral stems in total hip arthroplasty. A randomized study of cemented, hydroxyapatite-coated, and porous-coated stems with roentgen stereophotogrammetric analysis. J Bone Joint Surg Am. 1994;76(11):1692–705. https://doi.org/10.2106/00004623-199411000-00013.

74. Grant P, Aamodt A, Falch JA, Nordsletten L. Differences in stability and bone remodeling between a customized uncemented hydroxyapatite coated and a standard cemented femoral stem a randomized study with use of radiostereometry and bone densitometry. J Orthop Res. 2005;23(6):1280–5. https://doi.org/10.1016/j.orthres.2005.03.016.1100230607.
75. Bozic KJ, Katz P, Cisternas M, Ono L, Ries MD, Showstack J. Hospital resource utilization for primary and revision total hip arthroplasty. J Bone Joint Surg Am. 2005;87(3):570–6. https://doi.org/10.2106/JBJS.D.02121.
76. Ong KL, Lau E, Suggs J, Kurtz SM, Manley MT. Risk of subsequent revision after primary and revision total joint arthroplasty. Clin Orthop Relat Res. 2010;468(11):3070–6. https://doi.org/10.1007/s11999-010-1399-0.
77. Ramanath SK, Shah RH, Patil S, Umesh S. Reconstruction of neglected patellar tendon rupture using tendoachilles' allograft with transosseous tunnels: a case report. J Orthop Case Rep. 2020;10(5):27–9. https://doi.org/10.13107/jocr.2020.v10.i05.1824.
78. Holt G, Hook S, Hubble M. Revision total hip arthroplasty: the femoral side using cemented implants. Int Orthop. 2011;35(2):267–73. https://doi.org/10.1007/s00264-010-1167-5.
79. Malahias MA, Mancino F, Agarwal A, Roumeliotis L, Gu A, Gkiatas I, et al. Cement-in-cement technique of the femoral component in aseptic total hip arthroplasty revision: a systematic review of the contemporary literature. J Orthop. 2021;26:14–22. https://doi.org/10.1016/j.jor.2021.06.002.
80. Lee RR. Interaction of bone and hydroxyapatite filled 4-META/MMA-TBB bone cement in in vitro and in vivo environments. J Philipp Dent Assoc. 1996;48(1):5–12.
81. Duncan WW, Hubble MJ, Howell JR, Whitehouse SL, Timperley AJ, Gie GA. Revision of the cemented femoral stem using a cement-in-cement technique: a five- to 15-year review. J Bone Joint Surg Br. 2009;91(5):577–82. https://doi.org/10.1302/0301-620X.91B5.21621.
82. Bertin KC, Röttinger H. Anterolateral mini-incision hip replacement surgery: a modified Watson-Jones approach. Clin Orthop Relat Res. 2004;429:248–55.
83. Kelley SS, Seyler TM, Hallows RK. Total hip replacement: anterior-based, muscle-sparing approach without use of a fracture table. In: Lieberman JR, Berry DJ, editors. AAOS advanced reconstruction hip 2. Rosemont: AAOS; 2015. p. 185–93.
84. Harvey EJ, Tanzer M, Bobyn JD. Femoral cement grading in total hip arthroplasty. J Arthroplast. 1998;13(4):396–401. https://doi.org/10.1016/s0883-5403(98)90004-3.
85. Barrack RL, Mulroy RD Jr, Harris WH. Improved cementing techniques and femoral component loosening in young patients with hip arthroplasty. A 12-year radiographic review. J Bone Joint Surg Br. 1992;74(3):385–9. https://doi.org/10.1302/0301-620X.74B3.1587883.
86. McGoldrick NP, Fischman D, Nicol GM, Kreviazuk C, Grammatopoulos G, Beaule PE. Cementing a collarless polished tapered femoral stem through the anterior approach : evaluation of cement mantle quality and component alignment. Bone Joint J. 2021;103-B(7 Supple B):46–52. doi: 10.1302/0301-620X.103B7.BJJ-2020-2394.R1.
87. Sanghrajka AP, Whittingham-Jones P, Higgs D, Caruana J, Blunn G, Briggs TW. Anterior or posterior: does the surgical approach to the hip influence the quality of the femoral cement mantle? Hip Int. 2006;16(2):67–74. https://doi.org/10.5301/hip.2008.3541.
88. Herndon CL, Nowell JA, Sarpong NO, Cooper HJ, Shah RP, Geller JA. Risk factors for Periprosthetic femur fracture and influence of femoral fixation using the mini-anterolateral approach in primary Total hip arthroplasty. J Arthroplast. 2020;35(3):774–8. https://doi.org/10.1016/j.arth.2019.10.011.

Implant Selection in ABMS Surgery

9

Brian J. McGrory

Key Points

- Choice of implant is not limited in anterior-based muscle-sparing (ABMS) total hip arthroplasty (THA).
- Successful results after arthroplasty depend on accurate component positioning, achieved safely and efficiently so as to reconstruct appropriate hip joint mechanics.
- The improved surgical stability achieved with this approach allows routine usage of any size femoral head as well as realizes a decreased effect of abnormal spinopelvic motion on the risk of instability.
- Examples of implants used at an institution with a successful ABMS THA program are given.
- Slight variations in technique that may be of interest to the novice as well as the experienced ABMS surgeon when considering usage of different implants.

Introduction

Choosing implants for total hip arthroplasty may be a complex process based on availability, cost, surgeon training, experience, or even institutional tradition and/or administrative mandates. Nonetheless, a well-fixed, accurately placed implant should be the ultimate goal so as to reconstruct appropriate hip joint mechanics. Recently, some surgeons have espoused implant choice based on surgical exposure, with limited, minimally invasive (MIS) and so-called "less-invasive" exposure techniques [1] because of the risk of potential implant malpositioning with more minimally invasive surgical exposures [2–4]. Some of these offerings include short stems; bone-sparing, curved stems; modular necks; or limited fixation types and implant categories [1, 5]. Further, offset reamers and impaction tools may be required for bony preparation and implantation through these specific surgical approaches [6]. Despite the availability of modified insertion techniques and implants, component malposition remains a challenge in some MIS techniques [3]. One significant benefit of the ABMS approach is that this approach to THA can be used with cemented and cementless fixation alike [7, 8], and all commercially available acetabular and femoral components can be used safely and straightforwardly. In fact, this approach was used historically with one of the first metal-on-metal (MoM) implants, the McKee-Farrar, in 1966 [9]. Custom or modified reamers and offset impaction tools may at times be helpful but are likewise not required.

In addition to femoral stem versatility, the ABMS approach also affords the surgeon femoral head and acetabular component optionality.

B. J. McGrory (✉)
Department of Orthopedic Surgery, Tufts University School of Medicine and Maine Medical Center, Falmouth, ME, USA
e-mail: mcgrob1@mmc.org

J. A. Geller, B. J. McGrory (eds.), *The Anterior-Based Muscle-Sparing Approach to Total Hip Arthroplasty*, https://doi.org/10.1007/978-3-031-02059-9_9

Joint registry data has shown inferior mid-term outcomes with femoral heads size 36 and greater [10].

In terms of dislocation and instability, spino-pelvic motion concerns are also of concern in modern hip arthroplasty [11]. The stability afforded by the ABMS approach allows primary usage of 32-mm femoral heads in the vast majority of cases [7, 12] and therefore may offer both short- and long-term advantages to some patients. In this chapter we will discuss the reasoning behind why the ABMS approach allows universal implant application and offer an example of implants used at a successful ABMS program.

Acetabular Implant Selection

The ABMS approach affords excellent visualization of the acetabulum and therefore is an ideal approach for cementless hemispherical components with or without screws. Likewise, enhanced shells, offset liners, lipped liners, and cemented acetabular components are easily implanted with appropriate visualization of acetabular landmarks [13]. Dual-mobility constructs and ceramic liners are similarly easily placed, as complete seating can be directly visualized. Hemiarthroplasty heads (either bipolar or unipolar) without acetabular reconstruction can also be successfully performed but may be difficult to reduce and may require capsulectomy and increased patient muscular relaxation.

There may be a difference in implantation bias for the acetabular component in relation to the patient position during the AMBS approach [14]. As previously mentioned, the ABMS approach may be performed with the patient in either the lateral or supine position, although there does not appear to be a difference in patient outcomes at 3 months. Using a non-cemented hemispherical shell, ABMS surgery with the patient in the lateral position was less accurate for acetabular cup inclination but similar in regard to anteversion compared with the patient in the supine position.

Acetabular Preparation

Contemporary acetabular preparation techniques using hemispherical or truncated reamers may be achieved with the ABMS approach. Pre-operative anteroposterior and direct lateral radiographs [15] are very helpful to assess osteophyte presence and allow for anticipation of accurate acetabular preparation. Slight Trendelenburg positioning of the operating room table and adducting the operative leg allow easy visualization of the appropriate landmarks when the patient is in the lateral position. Protection of the reflected head of the rectus femoris as well as terminal branches of the superior gluteal nerve (SGN) should be prioritized during acetabular exposure and reaming. Because the surgeon stands anterior for this technique (if the patient is in the lateral position), care should be exercised to guide the reamer slightly anterior as the reconstruction is medialized. In difficult cases with limited access to the joint, the reamer head may be placed by hand, and the reamer shaft and drill motor attached separately. Likewise, an offset reamer shaft may be used if this is the surgeon's preference.

Implantation

Implantation of the acetabular component is not different than in traditional THA, but a few tips may be helpful in considering the ABMS approach. When inserting the cup while it is attached the impaction shaft, hyperflexion to place the inferior component above the inferior capsule may be helpful. Likewise, flexing and extending the shell next in the implantation sequence allows for direct scratch fit without soft tissue interposition. This sequence may not be necessary for cemented implantation.

At our center, we impact the shell based on the position anticipated from the pre-operative templating. Other than bony landmarks, we also use the transverse acetabular ligament (TAL) for abduction and anteversion parameters [13]. Care to make sure that the metallic edge of a cementless component is not proud anteriorly minimizes the risk of iliopsoas impingement and postoperative groin pain [16]. In cases of anterior bony insufficiency or patients with pelvic extension from abnormal spinopelvic mechanics, a high wall or augmented polyethylene liner may be useful. Finally, an intraoperative radiograph or use of fluoroscopy may aid in component positioning, as may surgical navigation.

Femoral Implant Selection

The ABMS approach also allows excellent visualization of the femoral neck and therefor allows the use of any implant type or shape (Fig. 9.1). Cementless and cemented application is equally straightforward, and proximal or fully coated ingrowth stems appear to work equivalently well. Modular neck stems are contraindicated in my experience, because of corrosion and neck fracture issues [17].

There may be some evidence to suggest that patient positioning on the OR table may lead to differences in femoral component position using the ABMS approach [18]. With the patient in the lateral position, there was a lower incidence of stem flexion malpositioning, but higher likelihood of increased stem anteversion than ABMS with the patient in the supine position. Of note,

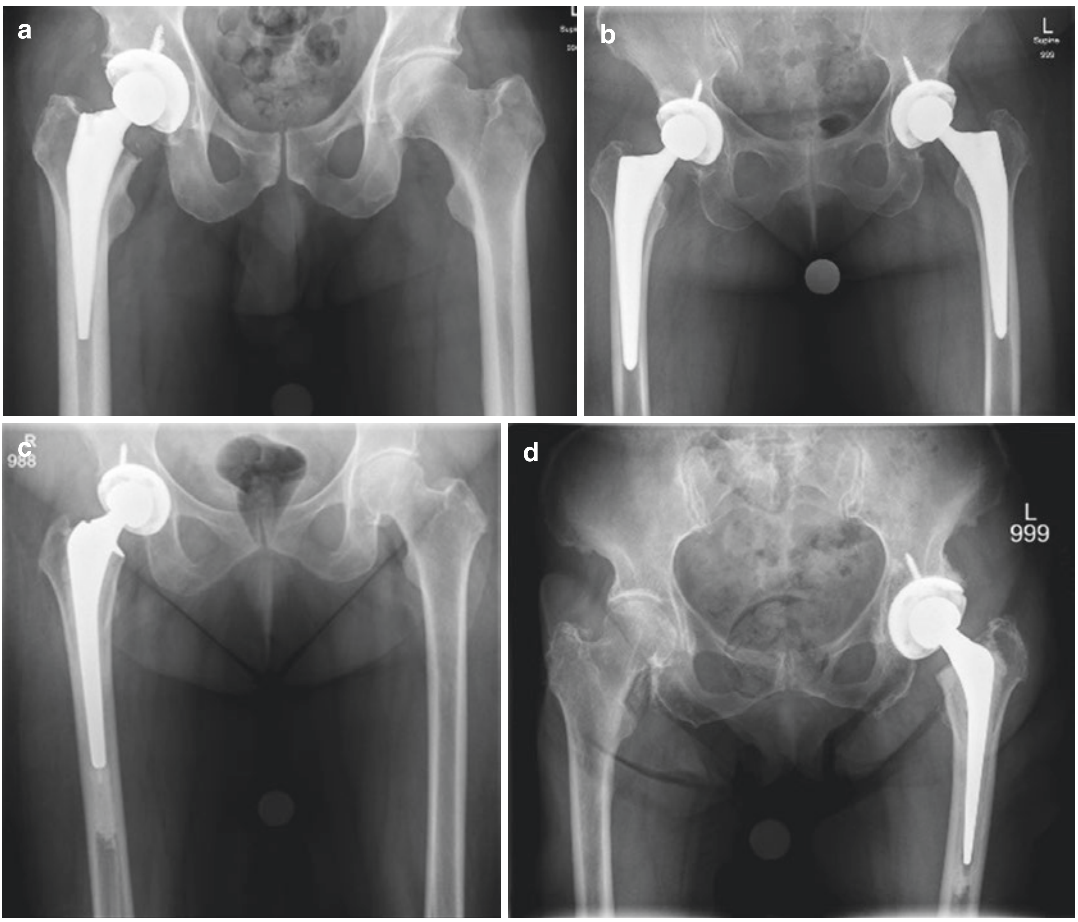


Fig. 9.1 Anteroposterior (AP) pelvis radiographs of femoral implant types implanted with a non-cemented hemispherical acetabular component using the anterior-based muscle-sparing (ABMS) approach. (**a**) Blade-style, single-taper, metaphyseal ingrowth stem (Anthology AFIT, Smith and Nephew, Memphis, TN, USA). (**b**) Double-taper, full ingrowth stems (Polarstem, Smith and Nephew, Memphis, TN, USA). (**c**) Fit and fill style cemented stem (Synergy, Smith and Nephew, Memphis, TN, USA). (**d**) Highly polished taper slip-style cemented stem (CPCS, Smith and Nephew, Memphis, TN, USA)

coronal femoral component placement was similar in both patient positions.

Cemented femoral application varies by geography [19, 20] and is often based on surgeon preference. Surgeons may use registry data, bone morphology, patient demands, or other factors in their decision-making for implant fixation [21]. Though there is no absolute consensus, patients older than age 75 with Dorr type C bone are often more ideal candidates for cemented application.

Uncemented implant choice is important for clinical success as it is the most commonly utilized mode of femoral component fixation in many parts of the world. In order to improve the chance for clinical success using cementless implants, pre-operative templating is critical to achieve successful implant matching and sizing. Specifically, ingrowth femoral components rely on a secure initial fixation to achieve osseointegration. Malposition or undersizing may affect this fixation and therefore compromise clinical results [22]. Contemporary registry data also supports using a calcar collar to protect against early femoral fracture as well as subsidence, and to a lesser extent, grit-blasted finish and a triple-tapered design are important also [23].

We have used a metaphyseal ingrowth blade style stem predominantly at our hospital's joint replacement program. In my practice, most patients who receive non-cemented components are candidates for a variation of this style stem with a decreased distal medial/lateral profile (Anthology AFIT stem, Smith and Nephew, Memphis, TN, USA) (Fig. 9.1a). This maximizes metaphyseal fit in the coronal plane and avoids poor osseointegration from distal "potting," particularly in patients with thicker femoral cortices (Dorr type A femoral morphology [24]) [25] (Fig. 9.2).

Femoral Preparation

Preparation of the femur is best achieved after an appropriate posterior capsular release to allow visualization of the proximal metaphysis and clearance of the soft tissues. With the patient in the lateral position, slight operating table Trendelenburg position allows for excellent femoral positioning as it helps deliver the proximal femur out of the surgical incision with improved visibility. The surgical assistant, on the opposite

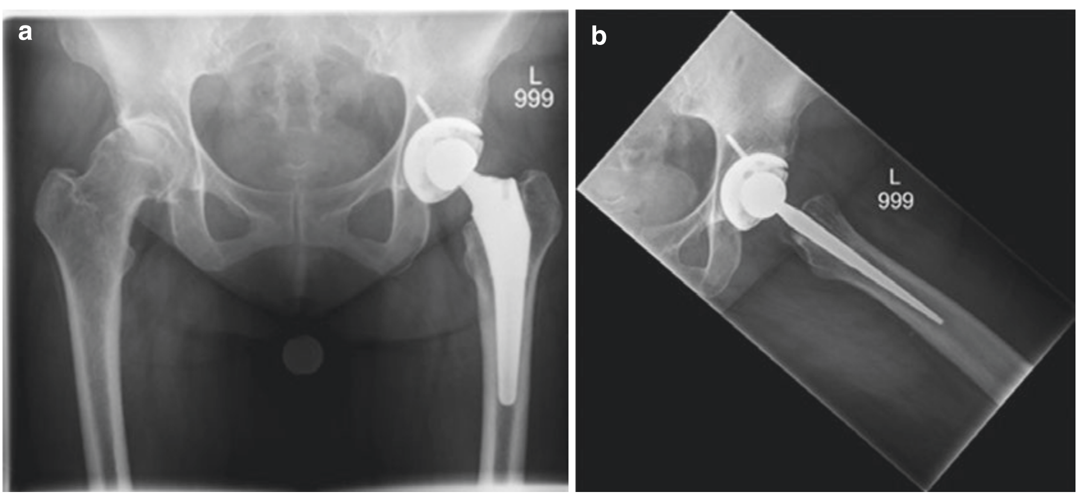


Fig. 9.2 AP (**a**) and frog lateral (**b**) radiographs of a patient with a painful left total hip replacement and evidence of fibrous ingrowth at follow-up. Note the intimate contact of the distal stem (Anthology, Smith and Nephew, Memphis, TN, USA) in the coronal plane on the AP radiograph. This part of the stem does not have a microstructure for ingrowth nor is it hydroxyapatite coated and by binding may prevent proximal osseointegration. On the frog lateral view (**b**), anterior and posterior lucency is noted, consistent with fibrous ingrowth

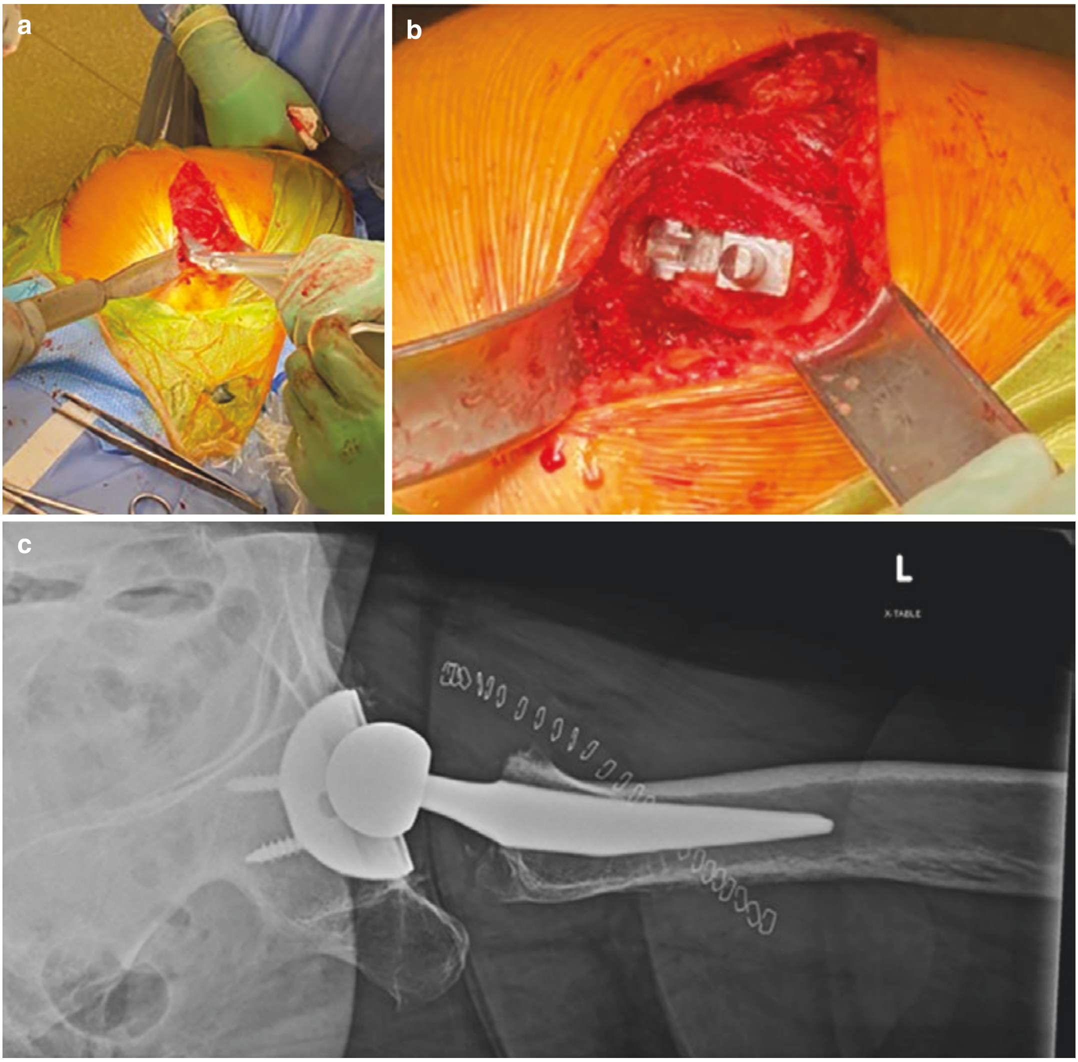


Fig. 9.3 Example of a left hip replacement, with appropriate posterior and lateral starting point for the femoral broach. (**a**) The surgical patient is in the right lateral decubitus position, and left leg is extended and externally rotated. The broach tip is touching the area of the osteotomized femur where the broaching is started. (**b**) The broached femur with the trial broach in place. Note the excellent cancellous bone surrounding the broach and the posterior placement of the implant channel. (**c**) Postoperative direct lateral radiograph showing femoral bow and placement of this blade style stem in the femur

side of the table than the surgeon, manipulates the leg and offers femoral bone stabilization during the broaching/preparation process. Positioning the tibia orthogonal to the floor allows the surgeon to place the stem in accurate anteversion, although once appropriate version is noted, the leg may be adjusted slightly for exposure. For a patient in a supine position, the surgical limb is placed under the contralateral leg in a figure four position (abduction and external rotation of the femur, with flexion of the knee). Further dropping of the leg off of the table may also improve proximal femoral exposure.

Notably, the entrance for broaching and reaming should be posterior and lateral to account for the anterior bow of the femur (Fig. 9.3). Additionally, posterolateral cortical bone in the region of the shoulder (junction of the lateral femoral neck and medial trochanter) should be debrided/rasped to avoid varus broach placement;

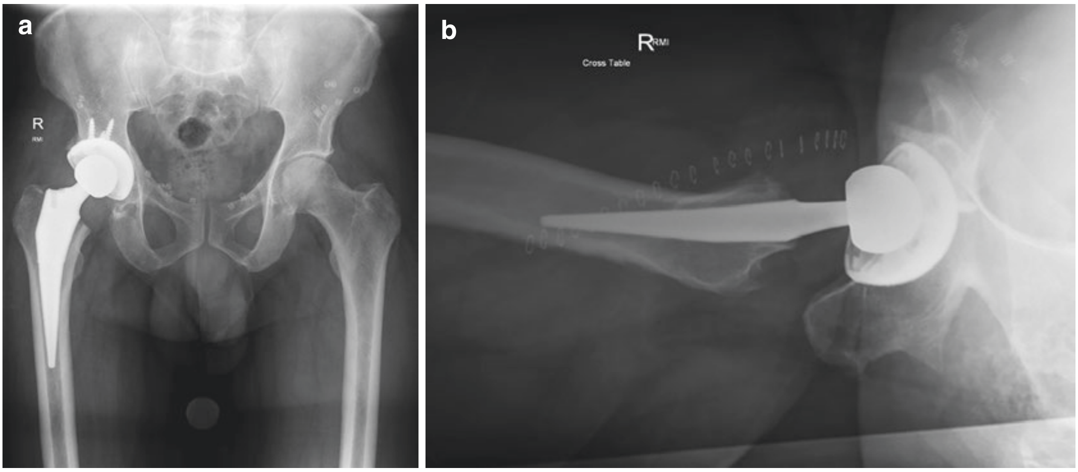


Fig. 9.4 AP (**a**) pelvis and direct lateral (**b**) radiographs of a patient with a right total hip replacement. Note slight undersizing of the femoral stem in the coronal plane (**a**) with predominantly 3-point fixation of the stem noted on the lateral (**b**). This may be functional, but is not optimal because settling or fracture may occur. Although 3-point fixation may be desired with wedge style stems, this degree is usually not optimal and may be due in part to anterior broach entrance into the proximal femur

however, care should be taken to avoid rasping cancellous bone out of the greater trochanter as this may weaken the bone and lead to trochanteric fracture. An appropriate starting point for the broach allows for minimal bone loss proximally as progressive sizes of broach are utilized. This is particularly important for a metaphyseal ingrowth tapered blade or wedge stem. An errant anterior starting position may lead to a gap in the bone-prosthesis anteriorly as the larger broach sizes fit well in the coronal plane but migrates posteriorly during the broaching process. Additionally, if a more anterior entrance is utilized, a predominant 3-point fixation of the stem will occur with undersizing in the coronal plane (Fig. 9.4). This may be functional, but is not optimal because settling or fracture may occur.

Cemented stems and ream/broach stems may require slightly more access proximally; however the ABMS approach easily allows for either of these types of stem designs. Tips for implantation include meticulous abductor muscle protection, careful medial trochanteric bone removal, and measured lateral pressure with reaming and broaching. Offset broach handles may be helpful to be sure the cement-stem composite is neutral in the coronal plane.

Implantation

Implantation of the stem is routine with the ABMS approach. Some find that an offset stem impactor may be helpful to clear the abductors and trochanteric prominence. Stem fit and stability vary based more on stem type, geometry, and implant coating. It is important to reiterate that excess posterolateral cortical bone at the junction of the femoral metaphysis and medial trochanter may cause implant impingement (even if the broach fits appropriately), and this may lead to trochanteric fracture or incomplete stem seating.

Special Circumstances: THA for Fracture

Implant selection for revision and periprosthetic fracture application are discussed elsewhere in this book and are beyond the scope of this chapter.

ABMS surgery is ideal for those patients whom have high functioning prior to a displaced femoral neck fracture and whom are candidates for THA. Implant selection may be similar to that for arthritis care, but in these clinical scenarios, the surgeon should consider cemented femoral fixation due to the high prevalence of osteoporosis in this patient cohort. Additionally, femoral head size and bearing surface type should take into consideration the increased risk of hip instability in patients treated with THA for fracture. In our center, we often opt for options such as a larger-sized femoral head, high-wall liner, and even dual-mobility bearings when appropriate [26, 27].

Experience at Maine Medical Center, Portland, Maine, USA

Implant selection in our practice has been based on surgeon preference, among the three practitioners using the ABMS approach [7]. We all use non-cemented, hemispherical acetabular components with screw fixation on the acetabular side, and each uses a cross-linked, ultra-high-molecular-weight polyethylene bearing surface with 32-mm or 36-mm internal diameter (based primarily on acetabular diameter). Each of us agrees on cemented femoral fixation for selected patients with poor bone strength and poor balance/function (i.e., those at risk for periprosthetic fracture). For non-cemented femoral fixation, we each use variations of the taper-wedge design. The design rationale for this class of stems is to achieve fixation by a tapered fit into the proximal femoral metaphysis in one or two planes. This may even include 3-point fixation [28]. Further, metaphyseal force transmission to the proximal femur may reduce long-term osteopenia [29]. Radiographic and clinical success relies on implant osteointegration and graduated proximal to distal stress transfer [30, 31].

One surgeon predominantly uses a fully coated, dual-taper, titanium alloy stems (Polarstem, Smith and Nephew, Memphis, TN, USA), and another prefers a proximal-ingrowth single-taper style stem (Anthology, Smith and Nephew, Memphis, TN, USA). Personally, I have evolved to use a specific single-taper style stem (Anthology AFIT, Smith and Nephew, Memphis, TN, USA) for most patients. The AFIT style anthology stem minimizes risk if distal binding or so-called potting and maximizes proximal metaphyseal fit. With these varying implant choices, we have achieved high clinical success with a minimal risk of failure.

In a white paper describing our combined experience, Rana and co-authors share the results with the ABMS approach between January 2013 and August 2020 at Maine Medical Center, Portland, Maine. Over this 7-year period, 6, 251 primary unilateral hip replacements were performed. Overall, 0.29% of patients sustained an intraoperative fracture, 0.11% sustained a dislocation, 0.19% had a deep joint infection, and 0.11% had a superficial infection requiring surgical debridement. Overall, results were comparable to the best results reported in the literature for any hip arthroplasty [7].

Specifically reviewing my experience with the Anthology AFIT stem (Fig. 9.5), I have per-

Fig. 9.5 Photograph of single-taper Anthology (left) and Anthology AFIT (right) femoral stems (Smith and Nephew, Memphis, TN, USA). The AFIT style stem allows for enhanced proximal fit with less chance for distal binding or so-called potting

formed 605 implants with the ABMS technique between February 2018 and June 2021 for conversion and primary THA. Only two THA patients (0.33%) underwent revision, both for early periprosthetic fracture. Three other stems subsided by 2–3 mm but were clinically stable. One patient had fibrous ingrowth, and the other two demonstrated osseointegration on follow-up radiographs.

Conclusion

Anterior-based muscle-sparing (ABMS) total hip arthroplasty (THA) is advantageous for surgeons because they can use familiar implants and fixation techniques that best serve the patient's needs. Using a variety of implants, accurate component positioning may be achieved safely and efficiently. Minor alterations in implant instruments may be beneficial for some surgeons, but are not mandatory. Further, the improved hip stability achieved with this approach allows routine usage of any size femoral head and aids in stability for patients with abnormal spinopelvic motion.

References

1. Gkagkalis G, Goetti P, Mai S, et al. Cementless short-stem total hip arthroplasty in the elderly patient-is it a safe option?: A prospective multicentre observational study. BMC Geriatr. 2019;19(1):112–23.
2. Inmann M, Streit M, Kolb J, et al. Influence of surgical approach on component positioning in primary total hip arthroplasty. BMC Musculoskelet Disord. 2015;18:180.
3. Callanan MC, Jarrett B, Bragdon CR, et al. The John Charnley Award: risk factors for cup malpositioning: quality improvement through a joint registry at a tertiary hospital. Clin Orthop Rel Res. 2011;469(2):319–29.
4. Hailer N, Weiss R, Stark A, Karrholm J. The risk of revision due to dislocation after total hip arthroplasty depends on surgical approach, femoral head size, sex, and primary diagnosis. An analysis of 78,098 operations in the Swedish Hip Arthroplasty Register. Acta Orthop. 2012;83(5):442–8.
5. Luger M, Hipmair G, Schopper C, et al. Low rate of early periprosthetic fractures in cementless short-stem total hip arthroplasty using a minimally invasive anterolateral approach. J Orthop Traumatol. 2021;22(1):19.
6. Howell J, Garbuz D, Duncan C. Minimally invasive hip replacement: rationale, applied anatomy, and instrumentation. Orthop Clin North Am. 2004;35:107–18.
7. Rana A, Babikian G, McGrory BJ, Sturgeon C, Barraud J. ABLE advanced anterior approach for total hip arthroplasty: a single center case series of over 6000 patients. White paper*:* Smith and Nephew. 2021.
8. Herndon CL, Nowell J, Sarpong NO, Cooper HJ, Shah RP, Geller JA. Risk factors for periprosthetic femur fracture and influence of femoral fixation using the mini-anterolateral approach in primary THA. J Arthroplast. 2020;35(3):774–8.
9. McKee G, Watson-Farrar J. Replacement of arthritic hips by the McKee-Farrar prosthesis. J Bone Joint Surg Br. 1966;48(2):245–59.
10. Tsikandylakis G, Karrholm J, Hailer N, et al. No increase in survival for 36-mm versus 32-mm femoral heads in metal-on-polyethylene THA: a registry study. Clin Orthop Rel Res. 2018;476(12):2367–78.
11. Grammatopoulos G, Gofton W, Jibri Z, et al. 2018 Frank Stinchfield Award: Spinoplvic hypermobility is associated with an inferior outcome after THA: examining the effect of spinal arthrodesis. Clin Orthop Rel Res. 2019;477(2):310–21.
12. Mjaaland K, Svenningsen S, Fenstad A, Havelin L, Furnes O, Nordsletten L. Implant survival after minimally invasive anterior or anterolateral vs. conventional posterior or direct lateral approach: an analysis of 21,860 total hip arthroplasties from the Norwegian Arthroplasty Register (2008 to 2013). J Bone Joint Surg. 2017;99(10):840–7.
13. Jain S, Aderinto J, Bobak P. The role of the transverse acetabular ligament in total hip arthroplasty. Acta Orthop Belg. 2013;79(2):135–40.
14. Takada R, Jinno T, Miyatake K, et al. Supine versus lateral position for accurate positioning of the acetabular cup in total hip arthroplasty using the modified Watson-Jones approach: a randomized single-blind controlled trial. Orthop Traum: Surg Res. 2019;105(5):915–22.
15. Kruithoff M, McGrory B. The value of the direct lateral hip radiograph in an adult reconstruction practice. Arthroplasty Today. 2021;8:29–34.
16. Trousdale RT, Cabanela ME, Berry DJ. Anterior iliopsoas impingement after total hip arthroplasty. J Arthroplast. 1995;10(4):546–9.
17. Nawabi DH, Do H, Ruel A, et al. Comprehensive analysis of a recalled modular total hip system and recommendations for management. J Bone Joint Surg Am. 2016;98(1):40–7.
18. Takada R, Jinno T, Miyatake K, et al. Difference in tapered wedge stem alignment between supine and lateral position in cementless THA via modified Watson-Jones anterolateral approach. Eur J Orthop Surg Traumatol. 2021; https://doi.org/10.1016/j.otsr.2019.05.004.
19. Paxton E, Cafri G, Nemes S, et al. An international comparison of THA patients, implants, techniques, and survivorship in Sweden, Australia, and the United States. Acta Orthop. 2019;90(2):148–52.

20. Van Steenbergen L, Makela K, Karrholm J, et al. Total hip arthroplasties in the Dutch Arthroplasty Register (LROI) and the Nordic Arthroplasty Register Association (NARA): comparison of patient and procedure characteristics in 475,685. Acta Orthop. 2021;92(1):15–22.
21. Konan S, Abdel M, Haddad FS. Cemented versus uncemented hip implant fixation. Bone Joint Res. 2019;8(12):604–7.
22. McConnell J, Syed F, Saunders P, et al. Definition and validation of a system for classifying the undersized Corail femoral stem in total hip arthroplasty. Hip Int. 2021; https://doi.org/10.1177/1120700021996001.
23. Lamb J, Baetz J, Messer-Hannemann P, et al. A calcar collar is protective against early periprosthetic femoral fracture around cementless femoral components in primary total hip arthroplasty: a registry study with biomechanical validation. Bone Joint J. 2019;101-B(7):779–86.
24. Wilkerson J, Fernando N. Classifications in brief: the dorr classification of femoral bone. Clin Orthop Rel Res. 2020;478(8):1939–44.
25. Nitin G, Engh CA. Cementless femoral stems: is there an optimum? Sem Arthroplasty. 2013;24(2):61–7.
26. Hoskins W, Griffin X, Hatton A, de Steiger R, Bingham R. THA for fractured femoral neck: comparing the revision and dislocation rates of standard-head, large-head, dual-mobility and constrained liners. Clin Orthop Rel Res. 2021;479(1):72–81.
27. Cobb T, Morrey B, Ilstrup D. The elevated-rim acetabular liner in total hip arthroplasty: relationship to postoperative dislocation. J Bone Joint Surg. 1996;78(1):80–6.
28. Froimson MI, Garino JP, Machenaud A, Vidalain JP. Minimum 10-year results of a tapered, titanium, hydroxyapatite-coated hip stem: an independent review. J Arthroplast. 2007;22(1):1–7.
29. Karachalios T, Tsatsaronis C, Efraimis G, Papadelis P, Lyritis G, Diakoumopoulos G. The long-term clinical relevance of calcar atrophy caused by stress shielding in total hip arthroplasty: a 10-year, prospective, randomized study. J Arthroplast. 2004;19(4):469–75.
30. Kim YH. The results of a proximally-coated cementless femoral component in total hip replacement: a five- to 12-year follow-up. J Bone Joint Surg Br. 2008;90(3):299.
31. Lee G, Srivastava A, D'lima DD, Pulido P, Colwell CW. Hydroxyapetite-coated femoral stem survivorship at 10 years. J Arthroplast. 2005;20(7 Suppl 3):57.

10 Tips and Tricks to Overcome the Learning Curve of the ABMS Approach to the Hip

Johannes F. Plate, Nicholas M. Hernandez, and Scott S. Kelley

Learning Points

- Implementation of an anterior-based muscle-sparing approach to total hip replacement has been shown to be prone to a learning curve in the first several cases.
- The anterior-based muscle-sparing (ABMS) approach to total hip replacement has shown a faster learning curve compared to the direct anterior (DA) approach, but certain points may improve the difficulty encountered during that learning curve.
- The authors recommend to place the fascial incision more anterior in obese patients to allow for tissue retraction.
- Identification of the gateway vessels helps identify the deep surgical interval between the gluteus medius (GMed) and tensor fascia latae (TFL) muscles.
- Femoral mobilization can be achieved by releasing the anterior inferior and posterior superior capsule including the obturator externus tendon from the piriformis fossa.
- To avoid femoral nerve palsy, the authors recommend to maintain approximately 1 cm of TFL attached to the muscle belly to protect the femoral nerve.

Introduction

The anterior-based muscle-sparing (ABMS) approach to the hip is a viable alternative to other current approaches [1–4] with a comparatively short learning curve [5]. The surgical tips discussed here are meant to help further shorten the learning curve for surgeons adopting this approach and to provide possible solutions for more experienced surgeons to further enhance their surgical technique.

Skin Incision

With the patient in the lateral position, the authors make the incision approximately 1–2 cm anterior to the greater trochanter in line with the femur [2, 3]. The middle of the incision intersects a line between the anterior superior iliac spine (ASIS) and the midportion of the greater trochanter (Fig. 10.1). The overall length of the incision varies with the body habitus of the patient. The authors routinely

J. F. Plate (✉)
Department of Orthopaedic Surgery, University of Pittsburgh, Pittsburgh, PA, USA
e-mail: Johannes.Plate@Pitt.edu

N. M. Hernandez
Department of Orthopaedics and Sports Medicine, University of Washington School of Medicine, Seattle, WA, USA

S. S. Kelley
North Carolina Orthopaedic Clinic, Duke University, Durham, NC, USA
e-mail: scott.kelley@duke.edu

J. A. Geller, B. J. McGrory (eds.), *The Anterior-Based Muscle-Sparing Approach to Total Hip Arthroplasty*, https://doi.org/10.1007/978-3-031-02059-9_10

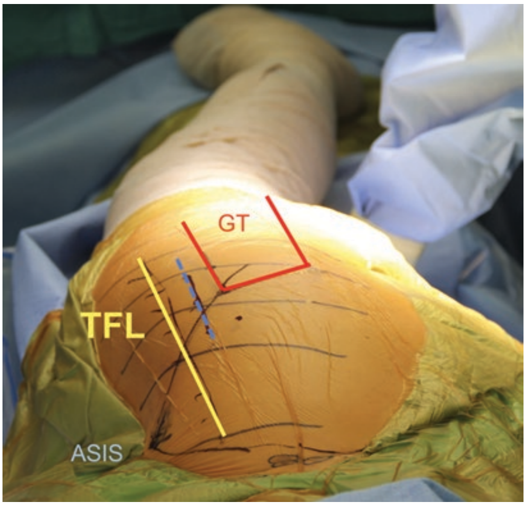


Fig. 10.1 In the lateral patient position, the skin incision (blue-dashed line) is placed approximately 1–2 cm anterior to the greater trochanter (GT) and posterior to the tensor fascia latae muscle (TFL). The incision can be centered over a line from the anterior superior iliac spine (ASIS) to the middle of the GT and extended proximal or distal

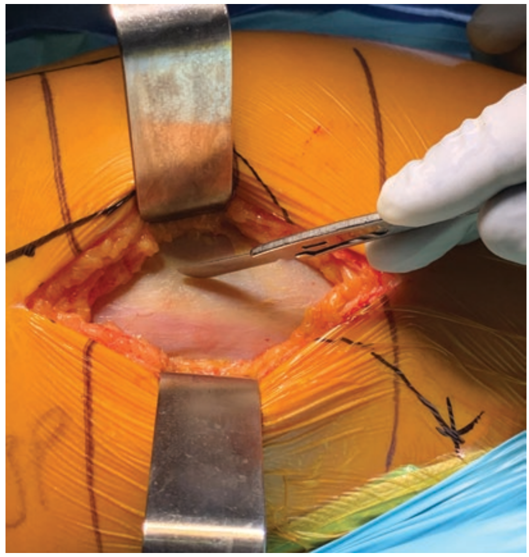


Fig. 10.2 Following the skin incision, the blue hue of the TFL muscle belly can be observed anteriorly. The fascial incision is made 1–2 cm posterior to the boarder of the TFL

start with a 6–8 cm skin incision centered over the tip of the greater trochanter. The incision is then extended proximal or distal once the tip of the greater trochanter has been identified within the incision. The incision may range anywhere from 8 cm to 16 cm in length. When using a mobile window through a smaller exposure, the placement of the incision is of greater importance.

Surgical Tips

Incision Length The incision length may be varied from proximal to distal. Extending the incision more proximally may improve femoral exposure and mobilization. Extending the incision more distally may improve acetabular exposure and allow an adequate angle for acetabular reaming and instrumentation.

Placing the incision too anterior makes identification of the proper tissue planes more difficult. In most cases, the TFL muscle appears as a blue hue through the fascia anteriorly (Fig. 10.2).

Position An incision too anterior may lead to a fascial incision within the TFL muscle.

Placing the skin incision too posterior makes retraction of the anterior tissues more difficult while instrumenting the acetabulum and femur. Soft tissue tension may feel increased giving the impression of overall increased hip tightness.

Obese and/or Muscular Patients In patients with an obese body habitus, the anterior border of the femur is difficult to identify. In these cases, the authors preferentially place the incision further anterior.

Incision Shape The proximal part of the skin incision can be altered based on the preferred femoral stem system. A straight incision gives more direct in-line access to the femur preferred for ream and broach systems. Directing the proximal portion of the skin incision slightly anterior in the shape of a "hockey-stick" allows for improved access to the femur when using a broach-only femoral stem system. The authors routinely use a double-offset femoral broach handle, which allows femoral instrumentation with less femoral exposure.

Fascial Incision

The authors identify the interval for the fascial incision between the anterior aspect of the proximal femur and the TFL muscle belly [2, 3]. Based on the location of the skin incision, the TFL muscle belly appears in the anterior third of the skin incision as a blue hue underneath the fascia. The fascial incision is approximately made 1–2 cm posterior to the lateral border of the TFL muscle belly which is generally halfway between the TFL muscle belly and the greater trochanter (Fig. 10.3a). This allows for more substantial tissue to suture together during the closure at the conclusion of the procedure.

Surgical Tips

Identification The authors use a Beaver blade to make a small stab incision through the fascia first to ensure the correct location. A small amount of subfascial fat is expected to appear when the fascial incision is in the correct location. If muscle tissue appears, the fascial incision is likely *too anterior*.

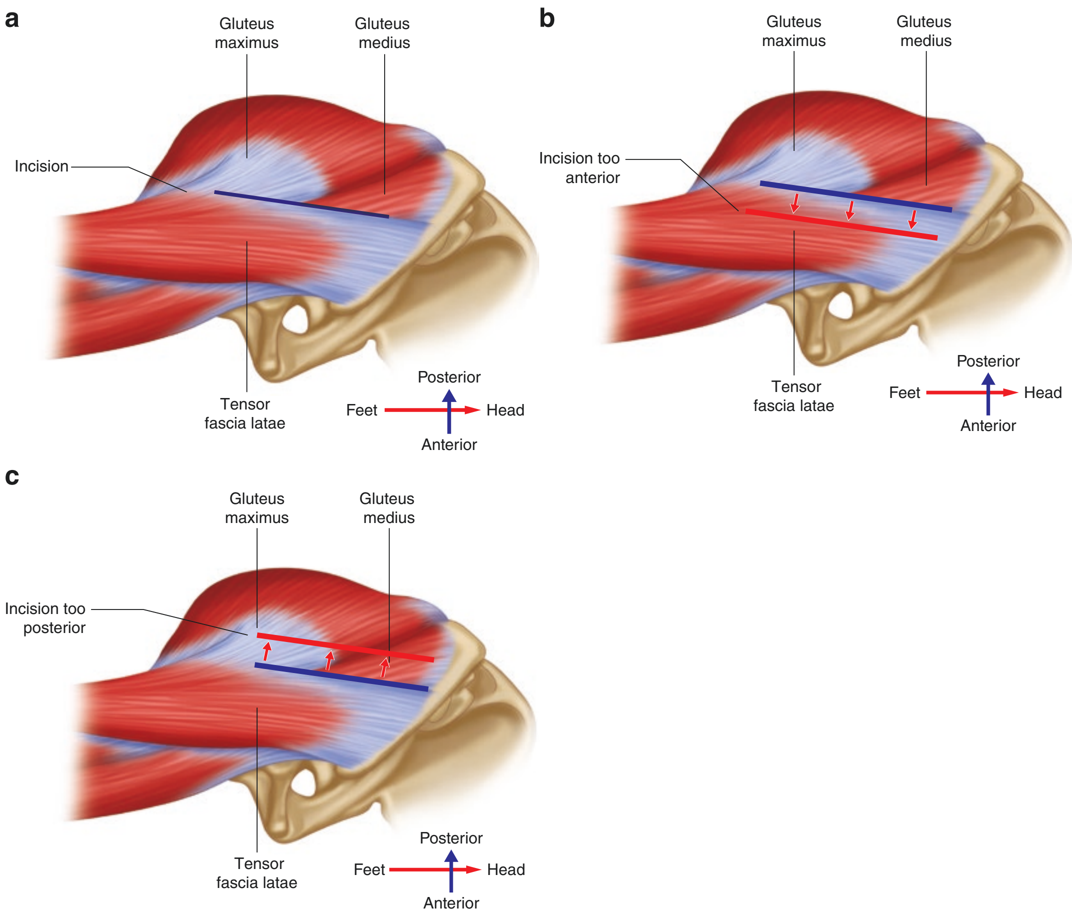


Fig. 10.3 (**a**) The 6–8-cm skin incision is placed lateral/posterior to the tensor fascia latae muscle belly and anterior/medial to the abductor musculature. (**b**) Placing the incision too anterior makes identification of the tissue planes more difficult. This may lead to a fascial incision within the tensor fascia latae muscle belly. (**c**) Placing the incision too posterior may lead to increased difficulty retracting anterior tissues during acetabular and femoral instrument

While there is moderate variation in the size of the TFL and the fascial interval, a common and consistent landmark is a vessel that penetrates the fascia from the TFL muscle. The fascial incision should be placed posterior to this penetrating vessel.

Location Too Anterior If the fascial incision is made too anterior and muscle tissue appears following the small stab incision, another stab incision can be made more posterior to identify subfascial fat. The anterior stab incision can then be closed with a suture to preserve TFL integrity. An anterior fascial incision places the surgeon inside the TFL muscle belly (Fig. 10.3b). If no clear tissue plans can be identified, the authors recommend that the surgeon reevaluates the location of the fascial incision before proceeding.

Location Too Posterior If the fascial incision is made too posterior and too close to the femur, retraction of the anterior tissues becomes difficult (Fig. 10.3c). This can lead to tearing of the TFL fascia. The authors recommend that the surgeon extends the fascial incision proximally and distally in case it appears to be too close to the femur to allow for increased retraction.

Identification of Deep Surgical Interval

The gateway vessels are a leash of vessels between the TFL and gluteus medius, representing the terminal transverse branches of the lateral femoral circumflex vessel. Identification of these vessels helps identify the surgical interval between the TFL anteriorly and the gluteus medius (GMed) posteriorly (Fig. 10.4) [2, 3]. There is a small leash of crossing veins superficially upon the initial split between the muscle intervals, but failure to identify and ligate the deeper transverse branch of the lateral femoral circumflex artery may lead to increased bleeding during exposure.

Surgical Tips

The vessels are identified by sliding the index finger distally underneath the leash of vessels and the thumb of the other hand proximally to the leash of vessels down to the capsule. The thumb is then located underneath the abductors which can be released from the TFL anteriorly, and a cobra retractor can be slid over the superior neck.

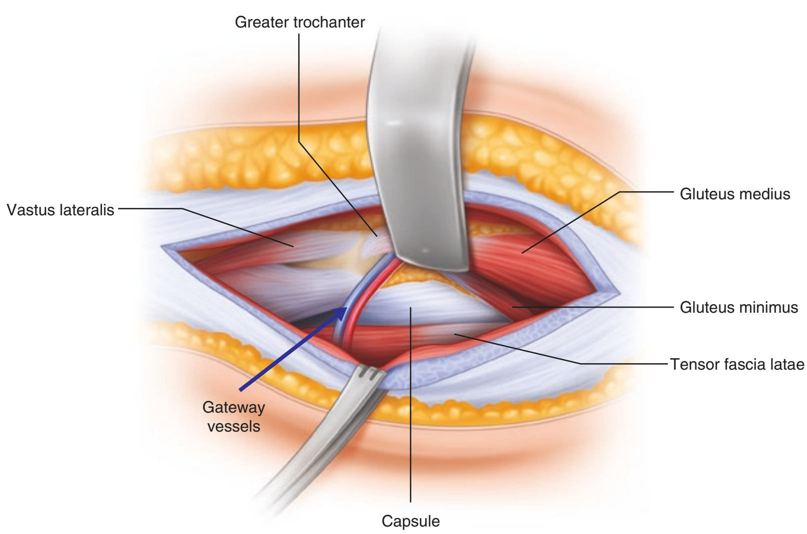


Fig. 10.4 The gateway vessels are located within a fascial bridge between the tensor fascia latae and gluteus medius. While the leash of vessels may help with identification of the deep surgical interval, ligation may not be necessary in the majority of cases

Once the vessels have been identified and the surgical interval has been established, the vessels may be ligated to allow further opening of the surgical interval distally. This may help femoral mobilization in cases of tight anterior structures.

If these vessels are severed prior to ligation, the vessels may retract and continue to hemorrhage. The vessels should then be identified and ligated prior to proceeding.

Working distal to proximal, once the vessels are ligated, the terminal nerve branches of the superior gluteal nerve may be encountered. These nerve branches should be preserved and are best manipulated proximally out of the surgical field.

Capsular Incision

The authors perform the capsular incision with a Beaver blade. The authors identify the superior neck, and a capsular incision is made in line with the femoral neck at approximately one-third of the superior neck (Fig. 10.5) [2, 3]. The first limb of the L-shaped incision is performed all the way to the intertrochanteric ridge. The capsule is then elevated sharply off the intertrochanteric ridge distally in line with the anterior femur. This establishes a robust capsular flap. The authors tag the capsular flap at the apex with a 5-0 Ethibond suture for retraction.

Surgical Tips

Capsulotomy When performed in the lateral position, the capsular flap helps with anterior retraction and is usually not detrimental for visualization. At the end of the case, the capsule is closed with #5 Ethibond suture which may decrease the risk for anterior dislocation with using this capsular flap.

Capsulectomy A capsulectomy may be performed in a similar fashion. The superior neck is identified and a capsular incision made along the superior neck toward the intertrochanteric ridge. The capsule is then sharply elevated off the intertrochanteric ridge distally. The capsular incision may be then brought back toward the acetabulum along the inferior neck, thereby excising the anterior capsule. A capsulectomy may be helpful in patients with thickened anterior capsule and in revision surgery, although some surgeons using this surgical approach perform a capsulectomy routinely without any complications.

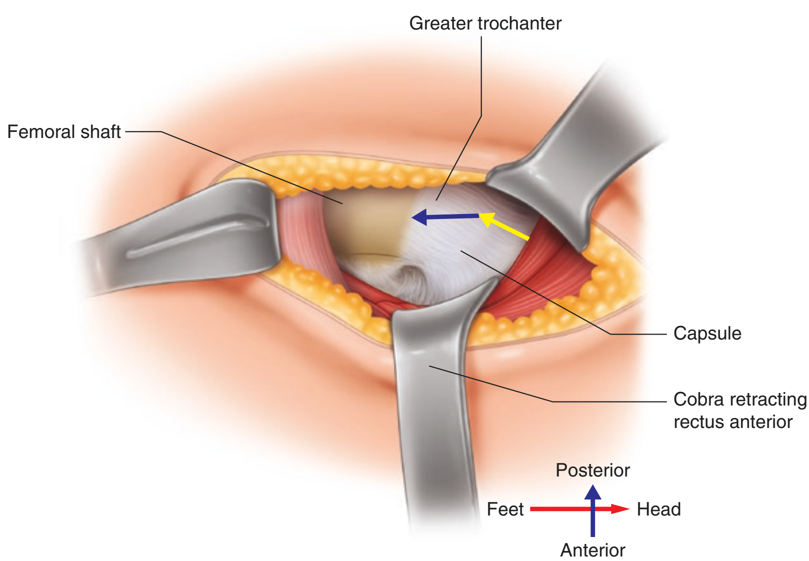


Fig. 10.5 The capsular incision is made in an L-shape starting from the anterior-superior aspect of the acetabulum along the superior femoral neck to the intertrochanteric ridge of the femur. The capsular incision in then extended distally along the femur. The capsule can be tagged for retraction

Inferior Capsular Release Following the femoral neck cut, the femur is brought into the figure-of-four position to release the inferior capsule. While retracting the anterior capsule, the inferior neck is palpated to assess whether a tight inferior capsule is present. The inferior capsule may then be released with electrocautery. An osteotome can also be slid along the inferior neck and gently tapped to release any tight capsule. This allows for further external rotation of the femur during femoral exposure as well as visualization of the acetabulum.

Femoral Neck Cut

The authors find that in the lateral position, two femoral neck cuts allow for improved femoral head removal. The initial neck cut is performed along the femoral neck/cartilage junction [2, 3]. Then an osteotome is first introduced anteriorly and next posteriorly to free the femoral head from the neck. While gently pushing on the osteotome, the remaining femoral neck is elevated onto the femoral head.

The shoulder of the greater trochanter is then exposed. The second neck cut is made from the shoulder of the greater trochanter toward the anterior medial femoral neck based on preoperative templating. The authors template the femoral neck cut from the tip of the greater trochanter in line with the femur and a perpendicular line toward the medial neck where the proximal aspect of the femoral stem is expected to be seated.

Following the second neck cut, the remaining napkin ring of the femoral neck is removed. This allows for improved visualization of the remaining femoral head and improved exposure for femoral head removal. Alternatively, a single femoral neck cut can be made while the femoral head remains located.

Surgical Tips

Angle of the First Cut Rather than making the first cut perpendicular to the femoral neck, a slight proximal to distal angulation (of just a few degrees) of the neck cut will allow for more easy and efficient delivery of the femoral neck remnant into the surgical field.

Planning Second Cut The determining factor for the level of the second neck cut is the length of the center of the femoral head to the base of the trial neck. If the first cut is begun medially at the femoral head-neck junction, then the second cut can be made a short distance from the medial cut edge as opposed to determining a variable distance from the lesser trochanter.

Alternatively, the level of the second neck cut can be determined on a preoperative template measured from the tip of the greater trochanter. Intraoperatively, a ruler can be used to mark the level of the second neck cut.

Saw Blade The authors prefer a single-sided reciprocating saw blade for the femoral neck cuts. This type of saw blade allows for improved control while protecting the posterior soft tissues. Alternatively, an oscillating saw may be used while protecting the posterior soft tissues and greater trochanter.

Single Neck Cut The hip may be dislocated prior to the femoral neck cut. A bone hook may be used along the femoral neck to aid in hip dislocation. The shoulder of the greater trochanter is then identified, and the femoral neck cut made in a perpendicular fashion toward the medial femoral neck.

Femoral Head Removal

Several ways have been described to remove the femoral head during this approach. The authors prefer to make a preliminary neck cut followed by the second definitive neck cut based on preoperative templating. The resultant napkin ring following the definitive neck cut can be removed with a rongeur or Kocher in a medial to lateral fashion. The leg is then brought into the figure-of-four position, and a corkscrew style reamer is advanced into the femoral head. The authors aim to spin the femoral head with the corkscrew reamer to tear the remaining ligamentum teres.

A T-handle is then attached to the reamer, and the femoral head is gently levered out of the acetabulum. The vector of the T-handle is against the remaining femoral neck in the posterior-distal direction.

Further release of the capsule along the anterior rim of the acetabulum may be necessary for adequate removal if a tight anterior capsule is present.

Surgical Tips

Femoral Head Removal Placement of a cobra retractor inside the acetabulum posterior to the femoral head may improve femoral head mobilization. The femoral head can be removed with the leg in extension and external rotation or in the figure-of-four position. The figure-of-four position is recommended in patients with difficult femoral head mobilization.

Removal with Acetabular Retractors in Place The femoral head may also be removed with acetabular retractors in place. This may aid in overall visualization and may aid in femoral head removal. Initially the authors place a cobra retractor between the anterior labrum and capsule. This is followed by placing a cobra retractor over the posterior acetabular rim. The femoral head is then identified, and a corkscrew style reamer is used to remove the femoral head.

Femoral Head Mobilization In cases with significant capsular adhesions, femoral head deformity, or femoral head and neck osteophytes, removal of the femoral head can be difficult. In these cases, the authors recommend a preliminary neck cut followed by a final neck cut. If further difficulty is encountered, the surgeon should inspect to see if there are any remaining soft tissue adhesions limiting head removal.

Femur Mobilization

Adequate femoral mobilization is necessary to allow visualization of the femoral neck as well as allow for proper elevation of the femur from the pelvis. The initial step has been described earlier and consists of elevating the inferior capsule off the femur. The inferior capsule may be elevated further once the femoral head has been removed. This can be assessed immediately after femoral head removal in the figure-of-four position.

Further assessment of the inferior capsule is performed when the leg is brought into the position for femoral instrumentation with the leg fully externally rotated, brought behind the patient with the knee bent. Retractors are placed over the greater trochanter underneath the abductors, and double-pronged Mueller retractor is placed along the inferior neck. The inferior capsule can be further removed medially all the way to the lesser trochanter if necessary. This can be done with electrocautery or with an osteotome slit along the inferior neck while gently tapping toward the lesser trochanter.

Surgical Tips

Posterior Femoral Release Releasing soft tissue along the posterior femur allows for greater external rotation of the femur as well as further elevation of the femur out of the field for later preparation of the femur. A straight Hohmann retractor is placed along the posterior superior femur putting the posterior capsule under tension.

The posterior capsule is then elevated off the femur with electrocautery starting medial and moving more posterior and lateral (Fig. 10.6). This release can be performed toward the piriformis fossa, thereby releasing the obturator externus while keeping the remaining external rotators intact.

Release of Obturator Externus A complete posterior capsular release and release of the obturator externus may not be necessary in all cases. Once the leg is put into the femoral instrumentation position, the authors assess whether the femur has been appropriately mobilized and perform this posterior lateral release if necessary at this time.

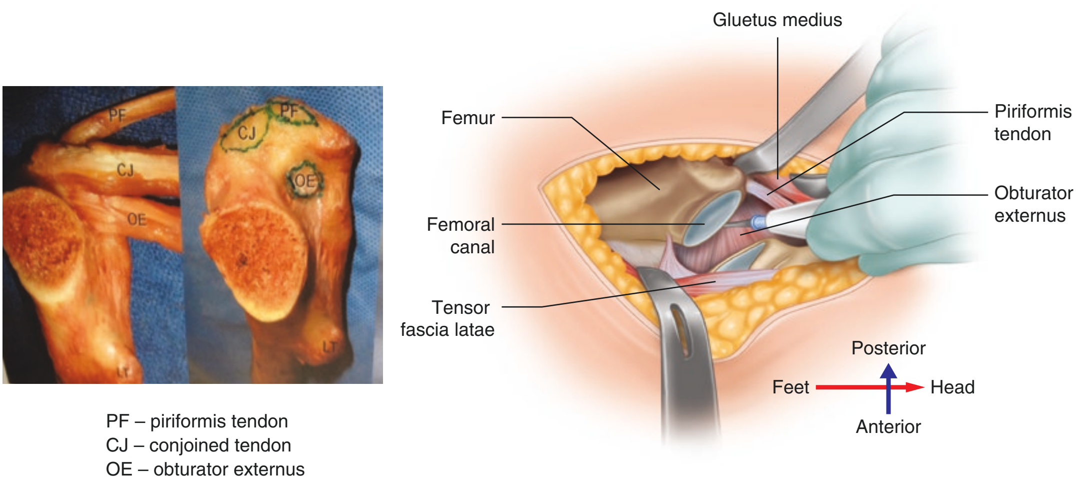


Fig. 10.6 The posterior femoral release can be performed in the figure-of-four position. A straight Hohmann retractor is placed along the posterior-superior femur to identify the obturator externus tendon which is then elevated from the femur toward the piriformis fossa with electrocautery

This posterior lateral release may also be performed after acetabular instrumentation. However, the authors have found that following an appropriate femoral release, visualization of the acetabulum is generally improved.

Timing of Releases for Femoral Mobilization For obese patients, the authors recommend to perform all femoral releases prior to acetabular exposure. The femur will eventually need to be fully mobilized in this group of patients, and the added mobilization can be beneficial for instrumentation of the acetabulum. In obese patients, release of the obturator externus will be of significant value throughout the case.

Acetabular Exposure

A sharp Cobra retractor is first placed posteriorly [2, 3]. The retractor is first inserted into the acetabulum and then brought over the posterior wall under the posterior capsule. The retractor is placed perpendicular to the femoral neck cut allowing further retraction of the femur posteriorly (Fig. 10.7).

The authors place an anterior retractor between the anterior labrum and capsule [2, 3]. Initially, a Cobb elevator is gently introduced between the anterior labrum and anterior capsule. An opening can be made in the capsule by gently tapping the Cobb elevator by hand. A blunt bent cobra retractor is then placed into this opening. If the anterior capsule is thick and an opening can-

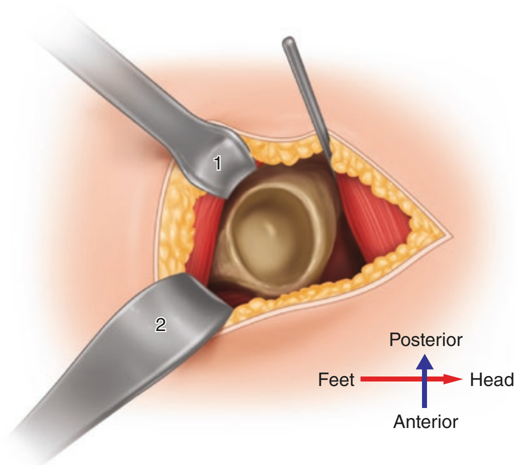


Fig. 10.7 Acetabular exposure is obtained by first placing a sharp cobra retractor over the posterior wall of the acetabulum. A Cobb elevator is then introduced between the capsule and labrum in the anteriorly followed by a blunt cobra retractor. A threaded or smooth pin can be inserted superiorly to aid in capsular retraction and visualization. Retractor placement should be avoided along the anterior superior acetabulum to protect the femoral nerve

not be made with a Cobb elevator, an anterior capsular incision can be made with electrocautery. This is then further widened with a Cobb elevator, followed by inserting the anterior cobra retractor. The anterior retractor rests just distal to the ASIS. The authors recommend using a blunt retractor to decrease the risk of vascular injury.

In general, the retractor is placed along the distal third of the posterior wall. If the retractor is placed too distal, the tip will be prevented from fully seating and blocked by the ischium and remain unstable during retraction (and potentially partially avulse the acetabular rim). Similarly, if the retractor is placed too proximal, it will remain unstable during retraction. Care should be taken to ensure close contact between the tip of the retractor and the posterior wall during insertion to limit the risk for sciatic nerve injury with aberrant retractor placement. Forceful retraction should be avoided to prevent avulsion of the acetabular rim or fracture of the posterior wall.

Surgical Tips

Capsular Retraction Acetabular visualization may be improved through superior capsular retraction. This may be achieved with a short-threaded or smooth 4.5-mm Schanz pin. The short-threaded pin has the advantage of the tactile feedback of the threads pulling the pin into the bone and a stop point as soon as the threads are fully buried into the lateral ileum. The disadvantage is that the pin needs to be backed out under power. This pin can be placed superiorly between the capsule and labrum.

The partially (short) threaded 4.5-mm Schanz pin has a blunted tip and can be maneuvered on the pelvis, when powered on reverse. The pin is first introduced through the capsule, and while drilling in reverse, the surgeon's hand is raised 90 degrees perpendicular to the pelvis. The pin is then drilled into the superior pelvis.

Alternatively, a smooth Schanz pin can be placed and impacted with a mallet. The pin can then be bent superiorly for improved access to the acetabulum.

Other Capsular Retraction Options A 90-degree sharp Hohmann or the Hibbs retractor can also be placed along the superior capsule to enhance visualization of the acetabulum.

Teardrop Identification The authors generally identify the cotyloid fossa or teardrop prior to reaming. A blunt cobra tractor may be placed inferiorly along the teardrop and underneath the transverse acetabular ligament. Inferior osteophytes may then be removed with an osteotome perpendicular to the teardrop. Often the transverse ligament is partially or completely ossified and needs to be removed in order to insert the inferior cobra. The pulvinar can be cut and coagulated with bipolar electrocautery followed by removal with a rongeur. Once the teardrop and medial wall of the acetabulum have been identified, a reamer is used for medialization. In general, the authors use a reamer that is approximately 2 mm less than the diameter of the removed femoral head. Medialization is facilitated by reaming perpendicular to the acetabulum. The goal is to remove the cartilage along the teardrop and remove adequate medial bone based on preoperative templating.

Following medialization a larger reamer is then used for centralization. This consists of reaming in the position of the future acetabular component and raising the reamer slightly to accommodate for the diameter of the templated cup size.

The authors have found that this stepwise reaming (medialize, centralize, and then ream to size) progression allows for consistent cup placement without raising the hip center.

Femur Preparation

To obtain femoral exposure for instrumentation in the lateral patient position, the leg is fully externally rotated posterior (behind the patient) with the knee bent underneath the operating room table. When performing the procedure in the supine position, the leg is externally rotated with adduction in a figure-of-four position and placed underneath the contralateral leg. The authors place a cobra retractor over the greater trochanter under the abductor muscles and tendon. A double-pronged Muller retractor is then placed along the medial calcar to elevate the proximal femur. It is important to continue to be vigilant about the location of the double-pronged retractor during femoral preparation as the retractor can slide and one prong can perforate the proximal femur.

Surgical Tips

Broach-Only System During femoral preparation with any femoral component design, there is a risk for cortical perforation. When using a broach-only system, the author prefers to use an angled canal finder followed by a smallest broach. This broach is used to lateralize the femoral component by applying lateral pressure while impacting the broach with a mallet. Alternatively, the broach can be used like a rasp to remove lateral cancellous bone for lateralization of the femoral component and rasp down any remaining lateral cortical bone from the femoral neck cut. It is important to broach in line with the femoral canal. Insertion of the broach at a steep angle can lead to impingement on the posterior cortex and femoral component undersizing or cortical breach. Therefore, starting the initial broach insertion lateral and posterior accommodates for the anterior bow of the femur and assures excellent fit. Cortical bone near the piriformis fossa may be removed using a rongeur to minimize the risk of varus broaching.

Ream and Broach System The ABMS approach is versatile, allowing for the use of a ream and broach system based on surgeon preference. Using a ream and broach system, the authors use ball-tipped, side-cutting reamer first. This is advanced with the reamer on reverse. If the femoral canal is difficult to locate, a curved, rounded canal finder can be used along the medial femoral calcar. This is advanced into the femoral canal along the anterior-medial cortex. A ball-tipped guide wire is then inserted through the same path as the canal finder. A cannulated reamer can then be used and advanced. Similarly, a curved curette can be used to remove cortical bone along the medial femoral calcar locating the femoral canal.

Tips to Reduce Complications

The authors will discuss complications that appear to be unique to a learning curve with the ABMS approach (femoral nerve palsy, femoral fracture, and abductor muscle trauma) [3, 5–7]. This discussion will be followed by complications not unique to ABMS, specifically the relationship between hip stability and leg length. We feel instability with ABMS is quite low, even while a surgeon is still in the learning curve; however, this complication can be reduced even further with a few technical considerations.

Preventing Femoral Nerve Palsy

While nerve palsy is a dreaded complication following total hip arthroplasty, it usually recovers over the course of approximately 6 months. With ABMS THA the femoral nerve is at increased risk for partial or complete palsy given its proximity to the intermuscular interval and positioning of the retractors. This is a devastating complication for the patient, but there are many precautions that can almost eliminate its occurrence [4].

Maintain Fascial Band It is important to leave at least a 1 cm band of fascia latae attached to the TFL. Throughout the case there will be retraction against the TFL. In addition to protecting the TFL muscle belly from injury, the remaining fascial sleeve also protects the femoral nerve from stretch injury.

Hypermobile Patients Hypermobile individuals, often women with a lower body mass index, are at risk for femoral nerve stretch injury when mobilizing the femur. In these patients, it is much easier to mobilize the femur without doing the aggressive releases performed in the heavier patients. Specifically, this involves minimizing the posterior lateral release of the obturator externus. Aggressive soft tissue release to mobilize the femur can cause the femur to be over-distracted and place undue tension on the femoral nerve.

Femoral Elevation The assistant can push in and up on the femur as the surgeon prepares the femur, to minimize this distraction and stretch to the nerve [2].

Acetabular Retractor Placement The anterior acetabular retractor should be placed just outside the joint at the capsulolabral junction, with a blunt retractor, at the 3:30 to 5:30 range (for a right THR) and 6:30 to 8:30 range (for a left THR), based on the face of a clock.

Electrocautery The surgeon should minimize the use of a bipolar sealer or excess electrocautery to deep anterior structures. Excess bipolar sealer use around the deep anterior structures may cause thermal injury to the femoral nerve. By employing these steps, the risk of femoral nerve injury can be minimized.

Preventing Femoral-Sided Complications

Both the DA and ABMS approaches are unique in that they position the leg/femur in extension and external rotation. The ABMS approach has the advantage of spinning the leg on the rotators rather than releasing them. A potential disadvantage of both anterior approaches is the steep learning curve associated with preventing femoral fractures and early femoral loosening. Patients with an elevated body mass index or who are osteoporotic are at increased risk for greater trochanter avulsions. This can be prevented by doing a thorough release of the posterior capsule and obturator externus. In patients with greater body mass index, one may consider partial release of the undersurface of the conjoined tendon to decrease the chance of the trochanteric hook from avulsing. Proper placement of a double-offset retractor (Fig. 10.8) or cobra retractor over the anterolateral aspect of the greater trochanter can also prevent trochanteric injury [2, 8]. This retractor should go in without resistance. If resistance is met, then the tip of the retractor may be in bone and make a stress riser for fracture.

Calcar fractures with or without extension to the femoral diaphysis are not common. Paying attention to the femoral morphology and choosing an appropriate stem can minimize the risk of calcar fracture. In those who are osteoporotic, consideration should be given for a cemented femoral stem, and in those with Dorr A bone, consideration should be given to a ream and broach style stem. There is typically no limitation to stem design with this approach. Careful inspection of the calcar should be a routine part of the final checks before relocation of the femoral head into the acetabulum, before closure. And if there

Fig. 10.8 Double-offset retractors that are placed over the greater trochanter. One is right sided and one is left sided

is any concern for calcar fracture, a cerclage cable may be placed.

Preventing Muscle Damage

The anterior undersurface of the abductors is at risk to damage, especially in muscular male patients. This can be limited by following several key steps. The abductors should be manually dissected off the tensor fascia latae as far proximally as possible. By palpating the anterior superior iliac spine, the surgeon can be confident that this interval has been developed. Not developing this interval, places undue tension on the abductor muscle making it susceptible to tearing. After retractors are placed over the superior femoral neck or greater trochanter, the surgeon should ensure that the assistant is not placing more pressure than is needed on the retractors. Further, the retractors should be angled to be parallel to the muscle as opposed to perpendicular to the muscle belly. Holding the retractor perpendicular with excess force can lead to muscle damage, and the surgeon will need to periodically check that this is not the case.

Prevent Dislocation and Leg Length Discrepancies

A reduced dislocation rate is one of the major benefits of ABMS THA, and special attention to several key steps can help minimize the risk further [4, 5, 8]. Excessive force for reduction is not necessary and may alert the surgeon that the hip may be over-lengthened. The authors routinely use a manual shuck once the hip has been reduced with trial components. A 3-mm shuck is typical of a well-balanced THA with the ABMS approach. Posterior stability is then assessed with internal rotation at 90 degrees of hip flexion. Posterior dislocation is to be avoided, and the authors recommend placing an Ethibond suture in the trial femoral head for possible need of retrieval. Anterior stability is assessed with full extension and external rotation of the leg. Palpation of the inferior poles of the patella and/or medial malleoli can be used to assess intraoperative leg lengths. Intraoperative radiographs may also be used in assessing leg lengths during the early learning curve. The senior author has had to use only two dual-mobility constructs in the first 3000 hips using the ABMS approach. The ABMS approach has such consistent stability that it rarely requires over-lengthening to obtain stability.

The authors advocate for a capsulotomy instead of a capsulectomy when performing the ABMS in the lateral position. By repairing the anterior capsule at the end of the case, the surgeon provides one more restraint toward anterior dislocation.

Next, it is important to preserve the short external rotators. The first muscle to be released in this approach for femoral exposure is the obturator externus. The piriformis and conjoined tendon very seldomly need release and should be identified and protected. By preserving the short external rotators, the patient has both a static and dynamic check rein to posterior dislocation.

The acetabular component does not need to be over-anteverted to prevent posterior dislocation. Assuming a neutral pelvis without hip spine pathology, the cup can be placed in a more natural range for anteversion, approximately 15 degrees. By medializing the cup to the medial wall, anterior soft tissue irritation can be minimized. Lastly, it is important to trial with the implants in place. One of the advantages of the ABMS in the lateral position is that the surgeon can trial for both anterior and posterior stability. If there is any instability, this can be addressed in the operating room.

Conclusion

The surgical tips discussed in this chapter have evolved from the authors' experience with challenging cases. As the ABMS surgical technique becomes increasingly used and accepted, the authors hope that these tips can provide solutions for other surgeons that may face intraoperative challenges and to enhance the success of this surgical approach.

References

1. Bertin KC, Röttinger H. Anterolateral mini-incision hip replacement surgery: a modified Watson-Jones approach. Clin Orthop Relat Res. 2004;429:248–55.
2. Plate JF, Hallows RK, Kelley SS, Messersmith J, Seyler TM. Primary total hip arthroplasty: ABMS (anterior-based muscle-sparing approach). AAOS Video Theater. 2017. https://www.aaos.org/videos/video-detail-page/18254__Videos
3. Hansen BJ, Hallows RK, Kelley SS. The Röttinger approach for total hip arthroplasty: technique and review of the literature. Curr Rev Musculoskelet Med. 2011;4:132–8.
4. Civinini R, Cozzi Lepri A, Carulli C, Matassi F, Villano M, Innocenti M. The anterior-based muscle-sparing approach to the hip: the "other" anterior approach to the hip. Int Orthop. 2019;43:47–53.
5. Kagan RP, Greber EM, Richards SM, Erickson JA, Anderson MB, Peters CL. Advantages of an anterior-based muscle-sparing approach in transitioning from a posterior approach for total hip arthroplasty: minimizing the learning curve. J Arthroplast. 2019;34:2962–7.
6. Delanois RE, Sultan AA, Albayar AA, Khlopas A, Gwam CU, Sodhi N, Lamaj S, Newman JM, Mont MA. The Röttinger approach for total hip arthroplasty: technique, comparison to the direct lateral approach and review of literature. Ann Transl Med. 2017;5:S31.
7. D'Arrigo C, Speranza A, Monaco E, Carcangiu A, Ferretti A. Learning curve in tissue sparing total hip replacement: comparison between different approaches. J Orthop Traumatol Off J Ital Soc Orthop Traumatol. 2009;10:47–54.
8. Hansen E, Bs MT, Bs BZ, Valle DCJ, Parvizi J, Haddad FS, Hozack WJ. Outcome of one-stage cementless exchange for acute postoperative periprosthetic hip infection. Clin Orthop Relat Res. 2013;471:3214–22.

11 Surgical Navigation in the ABMS Approach to Total Hip Replacement (THR)

M. Giraud, J. Aebi, and J. Cabezas-Davalos

Learning Points

- The anterior-based muscle-sparing (ABMS) approach was reintroduced in the orthopedic landscape in the early 2000s, just as surgical navigation began to be increasingly used in operating theaters. The use of computer-assisted surgery (CAS) for total knee replacement (TKR) since 1999 allowed us to consider the CAS as a routine activity, assimilating the computer to a standard surgical instrument.
- We have routinely used ABMS approach since 2005.
- A less invasive surgery could then be associated with more accurate results despite reduced exposure of the anatomical structures.
- CAS can improve accuracy of placement, stability of the prosthetic joint, and traceability of our procedures.

Introduction

Authors' team was trained in the use of surgical navigation in 1999 and has used it in their surgical practice since that time. Trained in the use of two dimensional (2D) planning according to the precepts of Maurice Muller [8], we have followed the evolution of imaging techniques, and digitization has allowed us to go from 2D planning on standard radiographs to digital planning in 2D and then on 3D CT-based or biplanar reconstruction (EOS)-based planification. We quickly realized that systematic postoperative evaluation could be achieved with the same technique. The possibility of checking the quality of placement of our total hip replacements (THRs) and thus correcting our errors in real time appeared to us as a very important progression.

Our intraoperative verifications with computer-assisted surgery (CAS) from our preoperative planning were regularly satisfactory concerning the size of the implants but quite often disappointing in terms of restoration of limb length and offset. The appearance on the market of implant ranges that take into account anatomical variations (such as modular necks and stems with more angles and offsets) reflects the surgeons' need to be able to modulate the characteristics of their implants more frequently. We theorized that these additional changes would help with improvement in limb length and offset (Figs. 11.1).

Pre-surgical Planning: Principles

Planning is useful to achieve a goal set in advance in terms of implant size, intraosseous positioning and precision of the result in terms of limb length, and respect or restoration of femoral offset. The

M. Giraud (✉) · J. Aebi · J. Cabezas-Davalos
Traumatologic and Orthopaedic Surgery, clinique du Pont-de-Chaume, Montauban, France

J. A. Geller, B. J. McGrory (eds.), *The Anterior-Based Muscle-Sparing Approach to Total Hip Arthroplasty*, https://doi.org/10.1007/978-3-031-02059-9_11

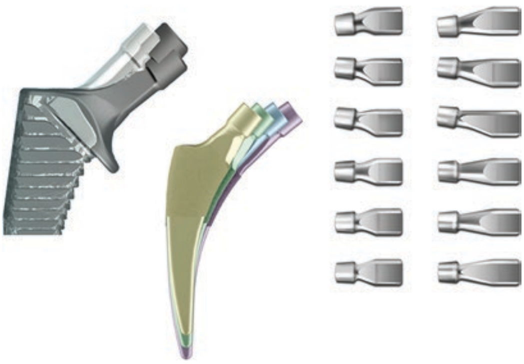


Fig. 11.1 Drawing showing various femoral components of neck mechanical diversity

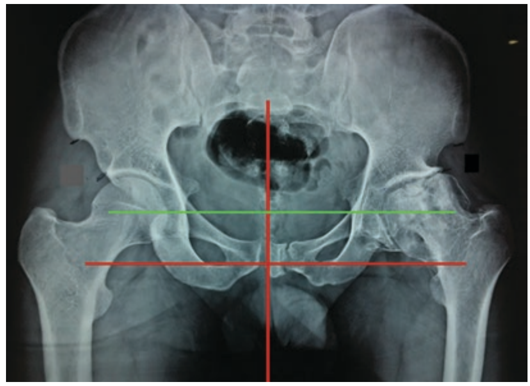


Fig. 11.2 Anteroposterior pelvic radiograph demonstrating the difficulty of defining the head rotation center on the pathological left side

digitization of X-rays has made it possible to obtain reliable magnification coefficients of the images with calibrated markers and to plan directly on digitized images.

Computerized tomography (CT) allows for more accurate, extremely precise, and three-dimensional planning, but with an increase in the cost of the imaging and a significantly higher irradiation [26]. Low-dose stereoradiography (EOS) allows for an accuracy almost equivalent to CT and is performed with the patient standing upright in full weight-bearing. EOS offers a clear reduction in radiation compared with CT and a small variation according to the patient's body weight, but there is an additional cost related to the acquisition of specific equipment.

Lower limb discrepancy is a permanent preoccupation for the orthopedic surgeon; however, limb length and femoral offset are not always predictable. Femoral neck length and offset and rotation head center are not always symmetrical, and this variation might lead to side-to-side differences after surgery [28]. The length or rather the correct balance of the pelvis can be planned on standard X-rays of known magnification, the global offset can be measured, and this correction may be calculated. Acetabular orientation (AO) can be accurately and reliably determined on conventional radiographs and appears to be independent of femoral shape and geometry [19].

The femoral stem offset will be more precise on a 3D planning but will be impacted during operation by intramedullary rotation of the implant and its eventual coronal placement in the varus or valgus which can both influence offset value for several millimeters.

Specification of the real center of rotation of the preoperative hip is also sometimes difficult to define. If the planning of the endomedullary part of the stem is relatively easy, it is quite different for the cervicocephalic portion which depends on the limb rotation, the head sphericity, and the more or less empirical estimation of the center of rotation of the head (assuming that it is unique in a complete loss of sphericity) (Fig. 11.2).

Cup offset may also be difficult to plan because reaming can lead to medialization and cranial migration, as noted by *Dastane* and *Digioia* [6, 7]. Compliance with the anatomical criteria for primary stability remains essential. Without CAS, it is difficult to know the perioperative acetabular migration and to identify causes of impingement or instability (Fig. 11.3).

We were confronted with the problem of carrying out the postoperative control using the same technique as that used to realize preoperative planning. Only the use of this same technique would allow us to evaluate the quality of our results in comparison to preoperative planning [22]. We also had to consider the cost and the level of radiation of these examinations used twice. Therefore, the majority of our postoperative checks are performed with a simple x-ray.

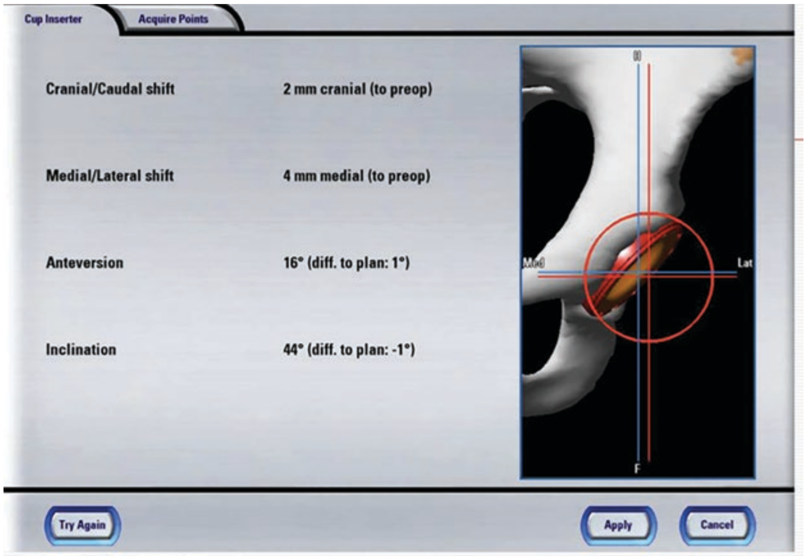


Fig. 11.3 Computer output exemplifying cup migration due to reaming

Some studies emphasize imageless navigation results even describing them as precise as the CT scan planning [10, 23, 27]. Confident in the accuracy provided by imageless navigation techniques, we have started systematic use for all primary total hip replacement procedures.

Preoperative planning and surgical navigation stimulate the surgeon's mind to answer the questions: "Where do we need to go? How do we get there?" [5].

Authors' Choices

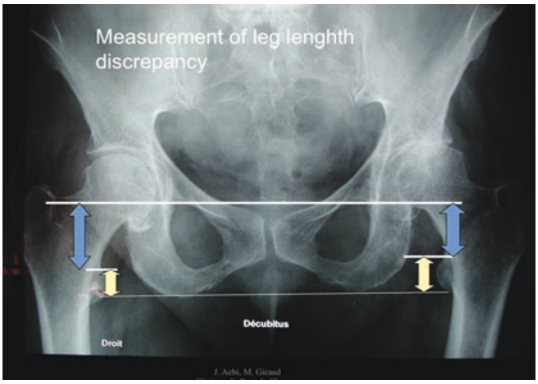
We initially built our experience in CAS with total knee arthroplasty (TKA); more recently, we have worked for 15 years with BrainLab™, orthopedics, computers, and softwares. Since the beginning of our experience, we tried successively different softwares including stem and acetabular navigation, Hip unlimited™, Hip essential™, Hip 6.0™, and Hip Express leg length™.

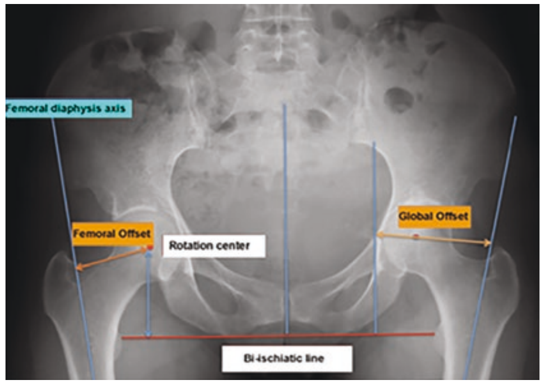
We sought purely imageless procedures to avoid heavy and costly preoperative planning techniques whose post-op control will not be measured routinely by the same methods.

We decided to continue to perform the preoperative planning on conventional 2D digitized radiographs with the scale being ensured by the presence of a marker of known size and the digitization of the images. This planning then allows us to foresee any corrections which may need to be made intraoperatively (Figs. 11.4 and 11.5).

As the global offset and length software stayed the same, we tried acetabular component navigation based upon the transverse acetabular ligament (TAL) and then another procedure using measurement of the *distance* between the left and right anterior superior iliac spines (*ASIS*) with a third acquisition point on the fifth lumbar (L5) vertebrae.

The positioning of the acetabular implant posedmuch less of a problem than respecting the length and the offset, but we had a very low rate of acetabular orientation outliers; however, we often had variations in acetabular cranial and/or medial migration due to reaming. We sometimes had to reorient a correctly positioned navigated acetabular component (based on the safe zone) because of anterior impingement or excessive ante- or retroversion of the femoral neck, sometimes guided by anatomy in the case of uncemented stems. It appears that the functional safe zone is greater than the classic Lewinnek description, and this zone is not a reliable predictor of future stability as previously understood [1, 20, 29]. Conversely, other evidences have not shown significant benefit found at 10 years with CAS acetabular positioning [21]. After 5 years of associated navigation of the





Figs. 11.4 and 11.5 Anteroposterior pelvic radiograph demonstrating length planning (left). Anteroposterior pelvic radiograph demonstrating offset planning (right)

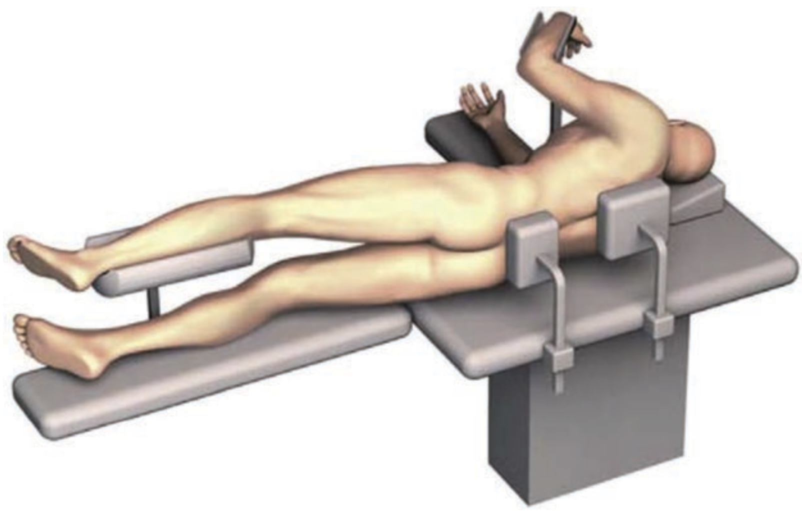


Fig. 11.6 Positioning on the table, with removal of posterior and distal portion of the operating table, for a left hip arthroplasty

stem and the acetabulum, we decided to stop acetabular navigation and to use a software program to define only leg length and hip global offset.

We decided to focus on the concept of global offset, which is easier to obtain and may be more reproductible. There is a strong correlation between femoral offset, abductor lever arm, and hip abductor strength. Hip lateralization is independent of the femoral endomedullary characteristics. The abductor lever arm is highly correlated to the gluteus medius activation angle. Therefore, femoral offset restoration is essential to improve function and longevity of any type of hip arthroplasty [15]. A slight increase of femoral offset can increase efficiency in terms of stability and abductor strength, whereas decreasing femoral offset may impart negative effects such as weakness and possible instability [3].

Technique

We usually perform ABMS THA (total hip arthroplasty) with the patient in lateral decubitus position with leg support (Fig. 11.6).

Two threaded pins are positioned on the iliac crest at the highest accessible point to increase the precision of the navigator calculation and to avoid being hindered during the passage of femoral rasps (Figs. 11.8 and 11.9).

A pinless array plate is then fixed distally to the thigh, positioning the edge of the plate on the

Fig. 11.7 Station installation. We use a BrainLab navigation station (Brainlab, Munich, Germany), in this case for a right hip arthroplasty (Fig. 11.7)

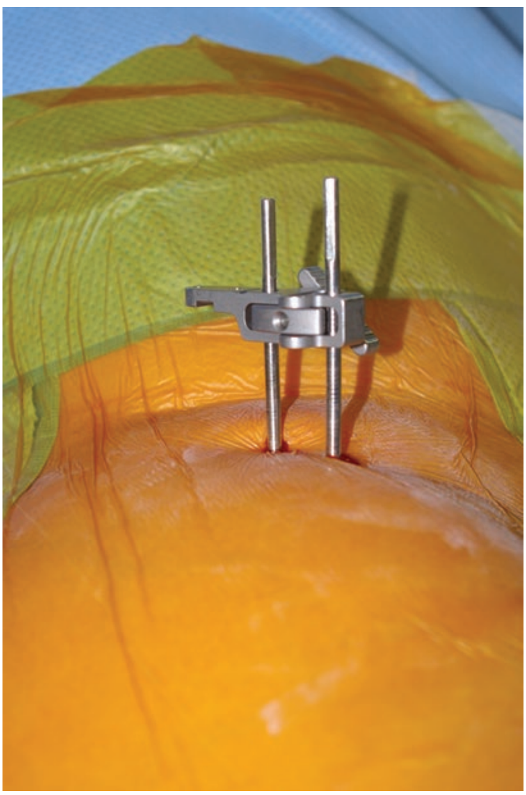


Fig. 11.8 Iliac crest pins

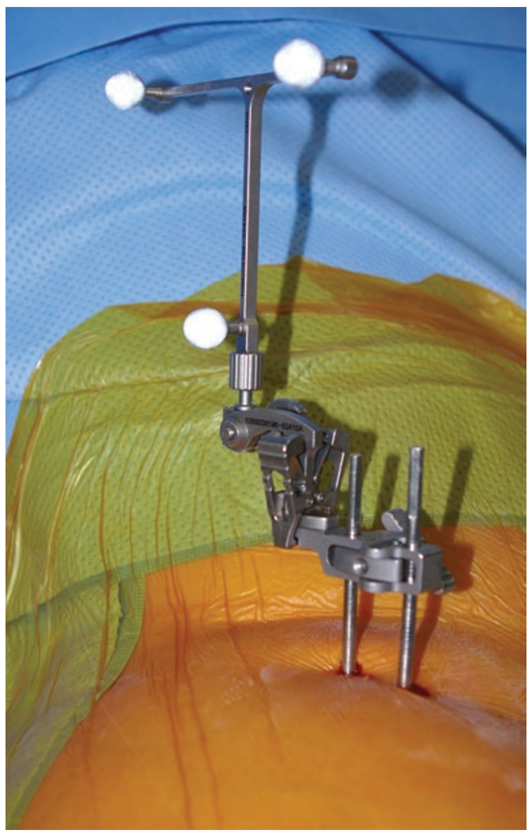
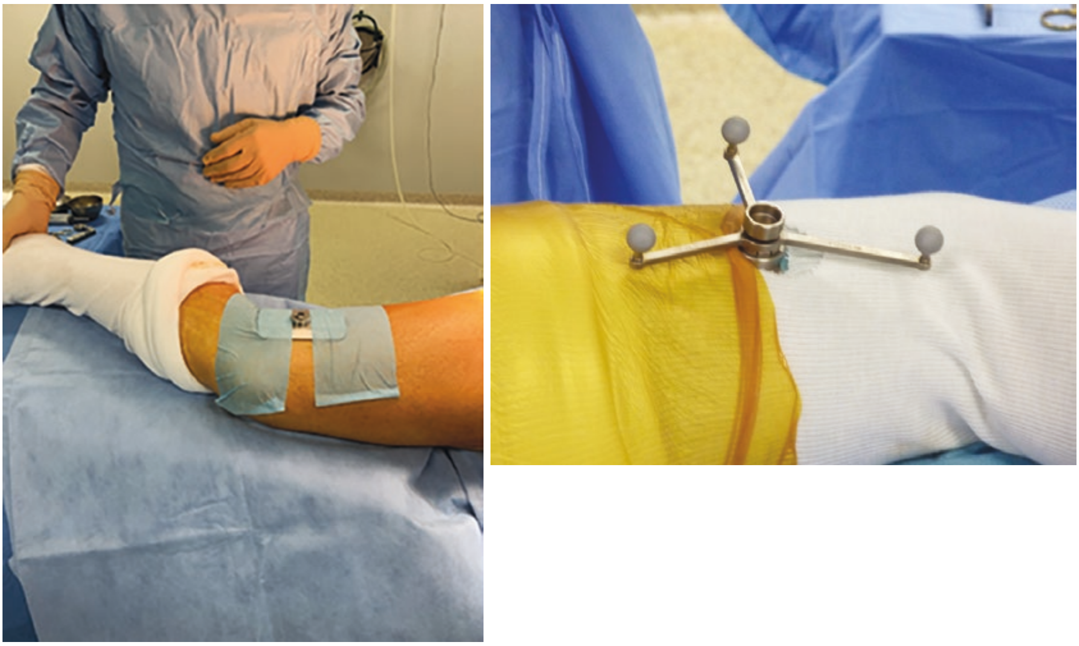


Fig. 11.9 Iliac crest pins and array fixation



Figs. 11.10 and 11.11 Clinical photographs demonstrating fixation (right) and aspect of pinless array (left)

lateral epicondyle and checking its stability when the knee is mobilized (Figs. 11.10 and 11.11). We have moved from the use of femoral pins to a pinless array without any effect on procedure accuracy, which has been previously validated by others [30, 24, 25].

The intermuscular approach is then made by centering it in its lower part to visualize the lateral aspect of the greater trochanter. One single 3.5 cortical screw, length 12 mm, is placed on the most lateral point obtained with rotation of the greater trochanter to maximize the measurable offset (Fig. 11.12).

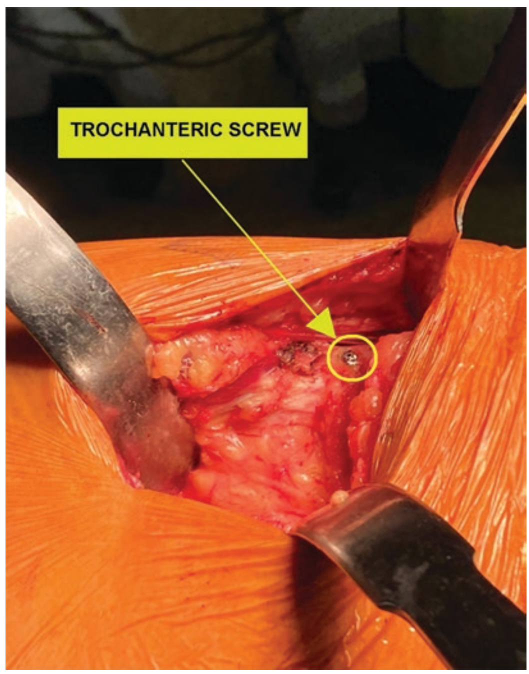


Fig. 11.12 Marking screw on the greater trochanter

The initial *acquisition* can then be performed to define the reference position of the limb. Next, the capsule is exposed, the neck is cut, the head is extracted, and the acetabulum is exposed. The second acquisition can then be made: two equatorial points are taken on the acetabular margin (Fig. 11.13).

The third acquisition is then performed in the initial reference position. The trial implants are in place for this, the first approximation of leg length and offset. Further adaptation of trial necks and heads may be done to approach the preop planning goal (Figs. 11.14 and 11.15).

Upon evaluation of the feedback, adjustments can be made to the neck cut, trial stem size, or both to achieve the preoperative goal.

The most important point with CAS is that the management of the intraoperative compromise regarding stability between offset and length can bemaximized, privileging one of the two parameters. This is not the case when one plays on the simple length of the neck by changing the prosthetic head. Assessment of stability and possible impingement is made by manual mobilizations, whereas analysis of the acetabular orientation is made with the hip in extension and neutral rotation (knee at 90 degrees) by measuring the coverage of the prosthetic head.

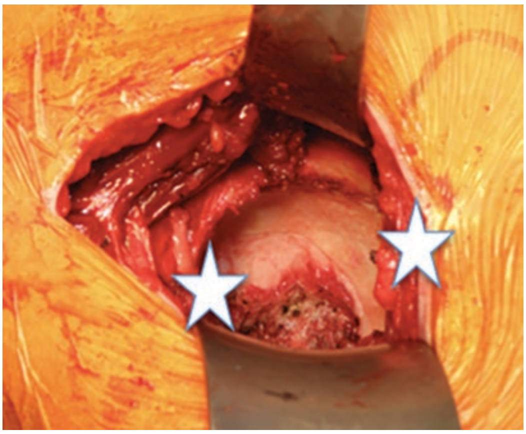
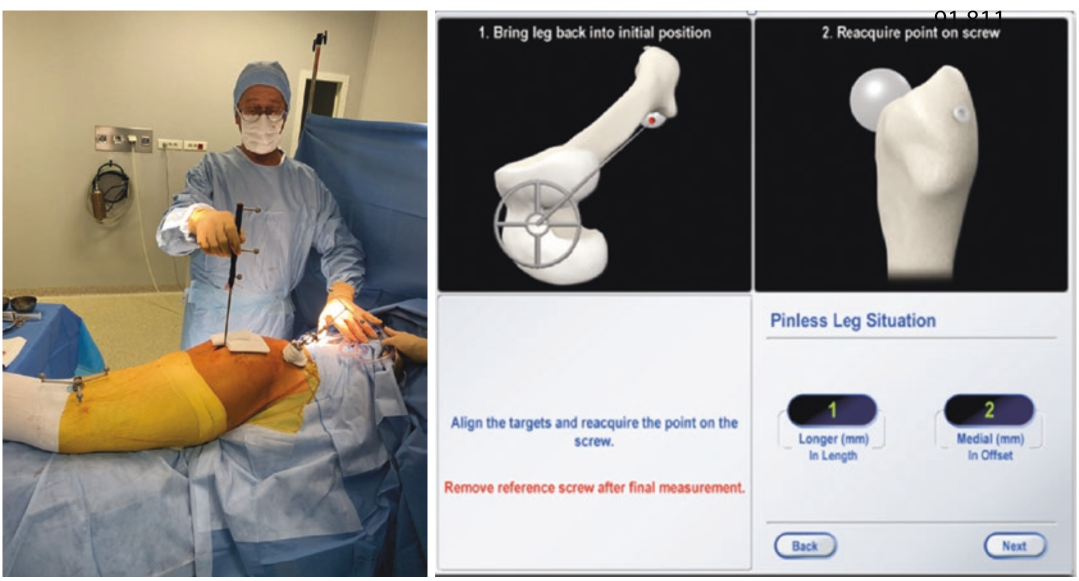


Fig. 11.13 Clinical photograph demonstrating acetabular point acquisition

Goals

We set our parameters for an accuracy to be between a −2 mm and + 5 mm in length and between 0 mm and + 5 mm in global offset value compared to preoperative planning so as not to compromise the periarticular soft tissues, muscles, and ligaments. These length values were chosen with the goal of avoidance of symptoms or clinical disorders postoperatively as described in the literature [12, 16, 18, 31]. The offset values were chosen according to the values classically described as improving (or keeping equal) abductor strength and/or lateral hip pain [2, 4, 9, 32, 17].



Figs. 11.14 and 11.15 Clinical photograph and computer output demonstrating measurement of length and offset in reference position

Results: Findings

We performed a retrospective analysis on a continuous series of 1200 of our patients, from January 2011 to November 2019. All the procedures were performed by our two senior authors. We excluded revision cases and surgeries with severe deformities even when CAS had been utilized. We primarily used two prosthetic stems which allowed versatility in positioning of the femoral head according to the available neck lengths and offsets: CORAIL™ (DePuy Synthes, Warsaw IN) and Fitmore™ (Zimmer Biomet, Warsaw IN). There were multiple variations in the acetabular components.

We studied the post-op length and offset values and the dislocation rate at a 1-year follow-up. Of note, there was no statistical relationship with any medical complications as a result of this technique. We reached our goal in 94% of the cases, that is, for 1128 patients out of 1200. Leg length values were −2 mm/+9 mm and extreme offset values were – 4 mm/10 mm. About 81.7% (980) of the patients were in the 0 mm/+4 mm length and 0 mm/+4 mm offset group. We found a very low dislocation rate of 0.33% (4 out of 1200). Further, we found that since the beginning of our hip navigation experience, there was an increase in our use of extended offset stems.

We compared (with the help of manufacturer's supplied data) the uses of extended offset stems in the French market, and we found a significant increase at our institution: 47% in our facility versus a mean of 27% in all French clinics and hospitals. Our results seem to highlight that surgeons should consider using high offset stems more frequently than is currently being done on a national scale in France. It may be increasingly helpful for reestablishing both stability and abductor muscle strength.

Wasted Time and Morbidity

In our experience, after a short learning curve (<30 cases), the duration of the navigation intervention does not significantly impact the surgery time with an average surgical duration of 55 minutes (range, 40–110 min). The morbidity remains extremely low as described by Kamara [11], at the level of the iliac crest, small scarring or functional inconveniences that resolve in the short term as described by Lambers [13].

Fig. 11.16 Lateral hip radiograph showing a marking screw inadvertently left in place during THA using navigation

We observed only five complications directly related to the use of navigation (0.4%), one fracture of the top of the iliac crest and one infection on pins' site revealed 18 months after the surgery. In addition, in three cases, we found a forgotten screw on the post-op X-ray without any functional consequence (Fig. 11.16).

Conclusion

The combination of an ABMS approach and surgical navigation seems to be a very reliable procedure to ensure limb length, offset, and stability control, as well as contributing to a rapid surgical recovery for THA. We did not observe any significant lengthening in procedure time. We currently try to favor dynamic testing of acetabular component position rather than navigated orientation in the classic safe zone. The future challenge will be to design software with real-time appreciation of relative dynamic femoroacetabular positioning, range of motion, and possible impingement.

With EOS imaging in full weight-bearing, we will further integrate this imaging into our surgical plan to adjust acetabular positioning with pelvic tilt and lumbar spine status considering hip/spine mechanical relationship [14, 20].

References

1. Abdel MP, von Roth P, Jennings MT, Hanssen AD, Pagnano MW. What safe zone? The vast majority of dislocated THAs are within the Lewinnek safe zone for acetabular component position. Clin Orthop Relat Res. 2016;474(2):386–91.
2. Asayama I, Chamnongkich S, Simpson KJ, Kinsey TL, Mahoney OM. Reconstructed hip joint position and abductor muscle strength after total hip arthroplasty. J Arthroplast. 2005;20(4):414–20.
3. Bjørdal F, Bjørgul K. The role of femoral offset and abductors lever arm in total hip arthroplasty. J Othop Traumatol. 2015;16(4):325–30.
4. Cassidy KA, Noticewala MS, Macaulay W, Lee JH, Geller JA. Effect of femoral offset on pain and function after total hip arthroplasty. J Arthroplasty. 2012;27(10):1863–9.
5. Colombi A, Schna D, Castelli CC. Total hip arthroplasty planning. EFORT Open Rev. 2019;4(11):626–32.
6. Dastane M, Dorr LD, Tarwala R, Wan Z. Hip offset in total hip arthroplasty: quantitative measurement with navigation. Clin Orthop Relat Res. 2011;469(2):429–36.
7. Digioia AM 3rd, Jaramaz B, Plakseyvhuk AY, Moody JE Jr, Nikou C, Labarca RS, et al. Comparison of a mechanical acetabular alignment guide with computer placement of the socket. J Arthroplast. 2002;17:359–64.
8. Eggli S, Pisan M, Müller ME. The value of preoperative planning for total hip arthroplasty. J Bone Joint Surg Br. 1998;80(3):382–90.
9. Foy M, Kielminski D, Cavazos D, Hussain A, Sood A, Gonzalez M. Changes in femoral offset is not associated with increased incidence of lateral hip pain following total hip arthroplasty. J Clin Orthop Trauma. 2020;16:132–5.
10. Kalteis T, Handel M, Bathis H, Perlick L, Tingart M, Grifka J. Imageless navigation for insertion of the acetabular component in total hip arthroplasty: is it as accurate as CT-based navigation? J Bone Joint Surg Br. 2006;88:163–7.
11. Kamara E, Berliner ZP, Hepinstall MS, Cooper HJ. Pin site complications associated with computer-assisted navigation in hip and knee arthroplasty. J Arthroplasty. 2017;32(9):2842–284.
12. Konyves A, Bannister GC. The importance of leg length discrepancy after total hip arthroplasty. J Bone Joint Surg Br. 2005;87(2):155–7.
13. Lambers AP, Salim XG, Jennings R, Bucknill AT. Morbidity and safety of iliac crest reference array pins in navigated Total hip arthroplasty: a prospective cohort study. J Arthroplast. 2018;33(5):1557–61.
14. Lazennec JY, Rousseau MA, Rangel A, Gorin M, Belicourt C, Brusson A, Catonné Y. Pelvis and total hip arthroplasty acetabular component orientations in sitting and standing positions: measurements reproductibility with EOS imaging system versus conventional radiographies. Orthop Traumatol Surg Res. 2011;97(4):373–80.
15. Lecerf G, Fessy MH, Philippot R, Massin P, Giraud F, Flecher X, Girard J, Mertl P, Marchetti E, Stindel E. Femoral offset: anatomical concept, definition, assessment, implications for preoperative templating and hip arthroplasty. Orthop Traumatol Surg Res. 2009;95(3):210–9.
16. McWilliams A, Stewart TD, Grainger AJ, O'Connor PJ, White D, Redmond A, et al. Leg length inequality following total hip replacement. Orthop Trauma. 2011;25(1):37–42.
17. Mahmood SS, Mukka SS, Crnalic S, Wretenberg P, Sayed-Noor AS. Association between changes in global femoral offset after total hip arthroplasty and function, quality of life, and abductor muscle strength. A prospective cohort study of 222 patients. Acta Orthop. 2016;87(1):36–41.
18. Maloney WJ, Keeney JA. Leg length discrepancy after total hip arthroplasty. J Arthroplast. 2004;19(4 Suppl 1):108–10.
19. Merle C, Innmann MM, Waldstein W, Pegg EC, Aldinger PR, Gill HS, Murray DW, High GG. Variability of acetabular offset in primary hip osteoarthritis influences acetabular reaming-A computed tomography-based anatomic study. J Arthroplast. 2019;34(8):1808–14.
20. Murphy WS, Yun HH, Hayden B, Kowal JH, Murphy SB. The safe zone range for cup anteversion is narrower than for inclination in THA. Clin Orthop Relat Res. 2018;476(2):325–35.
21. Parratte S, Ollivier M, Lunebourg A, Flecher X, Argenson JN. No benefit after THA performed with computer assisted cup placement : 10 years results of a randomized controlled study. Clin Orthop Relat Res. 2016;474(10):2085–93.
22. Reininga IH, Wagenmakers R, van den Akker-Scheek I, Stant AD, Groothoff JW, Bulstra SK, Zijlstra W, Stevens M. Effectiveness of computer-navigated minimally invasive total hip surgery compared to conventional total hip arthroplasty: design of a ran-

domized controlled trial. BMC Musculoskelet Disord. 2007;8:4. https://doi.org/10.1186/1471-2474-8-4.
23. Renkawitz T, Schuster T, Herold T, Goessmann H, Sendtner E, Grifka J, Kalteis T. Measuring leg length and offset with an imageless navigation system during total hip arthroplasty: is it really accurate? Int J Med Robot. 2009;5:192–7.
24. Renkawitz T, Schuster T, Grifka J, Kalteis T, Sendtner E. Leg length and offset measures with a pinless femoral reference array during THA. CORR. 2010;468:1862–186.
25. Renkawitz T, Sendtner E, Schuster T, Weber M, Grifka J, Woerner M. Femoral pinless length and offset measurements during computer-assisted, minimally invasive total hip arthroplasty. J Arthroplast. 2014;29(5):1021–5.
26. Sariali E, Mauprivez R, Khiami F, Pascal-Mousselard H, Catonné Y. Précision de la planification des prothèses totales de hanche. Étude comparative randomisée de la planification tridimensionnelle et de la planification radiographique. j.rcot. 2012;98(2):142–3.
27. Schmerwitz U. Total hip arthroplasty: first experiences with pinless THA software to determine leg length and offset. Orthopedics. 2007;30(10 suppl):S124–6.
28. Krishnan SP. Common misconceptions of normal hip joint relations on pelvic radiographs. J Arthroplasty. 2006;21(3):409–12.
29. Tezuka T, Heckmann ND, Bodner RJ, Dorr LD. Functional safe zone is superior to the Lewinnek safe zone for total hip arthroplasty: why the Lewinnek safe zone is not always predictive of stability. J Arthroplast. 2019;34(1):3–8.
30. Ulivi M, Orlandini L, Pascale W, Consonni O, Sansone V. Intraoperative validation of navigated limb measurements in THA using a pinless femoral array. J Arthroplast. 2014;29(5):1026–9. https://doi.org/10.1016/j.arth.2013.09.038. Epub 2013 Oct 1
31. Whitehouse MR, StefanovichYLawbuary NS, Brunton LR, Blom AW. The impact of leg length discrepancy on patient satisfaction and functional outcome following total hip arthroplasty. J Arthroplast. 2013;28(8):1408–14.
32. Xu B, Yang D, Aili R, Cao L. Effect of femoral offset change on pain and function after total hip arthroplasty. Chinese J Reparative Reconstruc Surg. 2013;27(7):843–6.

12 Comparison of the ABMS Approach to Other Surgical Approaches for Total Hip Replacement

Eddie S. Wu, Mohamed F. Albana, and Ronald E. Delanois

Learning Points

- Common surgical exposures to the hip including the posterior and direct lateral approach have traditionally involved violation of key muscle and stabilizing structures including the short external rotators, posterior capsule, or abductor complex.
- Anterior muscle-sparing approaches for total hip arthroplasty have recently experienced renewed interest as surgeons and patients continue to search for techniques to accelerate recovery and improve outcomes and patient satisfaction.
- In 2004, Röttinger described an anterior-based muscle-sparing (ABMS) approach utilizing the interval between the gluteus medius and tensor fascia latae (Watson-Jones interval) which has since been modified to be performed in both the supine and lateral position.
- Functional outcomes and patient satisfaction after ABMS total hip arthroplasty have been shown to be at least equivalent, if not superior, to other surgical approaches to the hip.
- The ABMS approach confers all the benefits of other anterior muscle-sparing total hip approaches but with a potentially shorter learning curve and lower complication rate.

E. S. Wu (✉)
Premier Orthopaedic Associates of Southern New Jersey, Vineland, NJ, USA
e-mail: wue@ihn.org

M. F. Albana
Department of Orthopaedic Surgery, Inspira Health, Vineland, NJ, USA
e-mail: Albanam@ihn.org

R. E. Delanois
Rubin Institute for Advanced Orthopedics, Baltimore, MD, USA
e-mail: rdelanoi@lifebridgehealth.org

Introduction

Total hip arthroplasty (THA) is commonly regarded to as one of the most successful surgical procedures in modern medicine. By 2030, it is estimated that there will be approximately 635,000 primary total hip arthroplasties performed annually in the United States alone [1]. Advances in postoperative pain management with multimodal pain protocols, blood conservation strategies, and muscle-sparing surgical approaches have allowed THA to be performed as an outpatient procedure in many cases and improved overall patient satisfaction.

Surgical approaches to THA are generally grouped based on the relationship of the exposure to the greater trochanter. Although extensile, posterior-based approaches require violation of the short external rotators and capsule which play an important role in stability after THA and thus can pose an increased risk of dislocation [2–4]. Anterior-based approaches have traditionally involved some degree of violation of the abductor complex. For example, the direct lateral Hardinge

J. A. Geller, B. J. McGrory (eds.), *The Anterior-Based Muscle-Sparing Approach to Total Hip Arthroplasty*, https://doi.org/10.1007/978-3-031-02059-9_12

and a variation of the classic anterolateral Watson-Jones approach require elevation of a portion of the abductor mechanism which can jeopardize stability and, if not adequately healed, can cause postoperative limp manifesting as a Trendelenburg gait.

Over the last decade, interest in anterior-based muscle-sparing approaches has continued to increase from both patients and surgeons alike largely due to the potential for decreased postoperative pain and accelerated recovery [5–11]. However, most of the current literature involve comparison of the direct anterior approach (DAA) to other traditional approaches. In 2004, Bertin and Röttinger published their technique of an anterior-based muscle-sparing approach utilizing the Watson-Jones interval [12]. Since then, the Röttinger approach has been referred to as the "mini-anterolateral," "minimally invasive anterolateral," "modified Watson-Jones," and most recently anterior-based muscle-sparing or ABMS approach. Modifications to this approach have been described in both the supine and lateral positions [13–15].

Currently, there is a paucity of data showing superiority of one surgical approach over another. In this chapter, we will briefly review the four main surgical approaches to total hip arthroplasty including the posterior, the direct lateral, the direct anterior (DA), and the anterolateral Watson-Jones approach, also known as the anterior-based muscle-sparing (ABMS) approach. The potential advantages and disadvantages of each approach will be highlighted. The ABMS approach will then be compared to the other surgical exposures along with a review of the recent literature comparing the various approaches.

Posterolateral Approach

The posterior, or posterolateral, approach to the hip has traditionally been the most familiar and most commonly used surgical exposure to arthroplasty surgeons in the United States. This utilitarian approach is considered by many to be the technically least demanding of the four major approaches to the hip and seems to be the least technically challenging to become proficient in. The exposure is performed with the patient in the lateral decubitus position and typically involves a curvilinear incision over the posterior aspect of the proximal femur. Once the subcutaneous tissue is dissected down to the level of the iliotibial fascia and gluteus maximus, the iliotibial fascia is incised in line with the skin incision distally, and the gluteus maximus fibers are split with blunt finger dissection. The hip is gently internally rotated to expose the piriformis and short external rotators. The short external rotators are separated from the underlying posterior hip capsule and tagged for later repair. The posterior hip capsule is incised to expose the femoral head and neck and tagged for subsequent repair. The hip is then dislocated posteriorly, and a femoral neck osteotomy is made based on preoperative templating. Preparation of the acetabulum and femur proceeds in a standard fashion.

The posterior approach to the hip provides adequate exposure of the acetabulum and proximal femur and is extensile in both the proximal and distal directions. As a result, this approach can be extremely useful in the setting of revision arthroplasty. Several modifications to this exposure have been made to minimize soft tissue trauma and incision length in an effort to compete with the increasing interest in "minimally invasive" surgery including muscle-sparing anterior hip approaches. Because this exposure is posterior-based, the abductor complex is not involved in the surgical dissection, and thus, the risk of persistent abductor weakness and postoperative limp is minimized. However, care must be taken to identify and protect the sciatic nerve throughout the procedure given its close proximity to the posterior aspect of the greater trochanter.

Perhaps the biggest drawback of the posterior approach is the theoretical increased risk of dislocation due to violation of the posterior stabilizing structures of the hip. The literature has shown mixed results when analyzing dislocation rates after total hip arthroplasty performed through the posterior approach compared to other approaches. In a Norwegian registry study of 21,860 THAs, Mjaaland et al. reported an increased risk of revision due to dislocation with the posterior approach compared with the direct lateral approach (RR = 2.62, 95% CI = 1.53–4.47, $p < 0.001$) [4]. Interestingly, in a recent retrospective study involving 2147 matched pairs of THAs performed through either the DAA or the posterior approach, Maratt et al. were unable to show a difference in dislocation rate based on surgical approach (0.84% DAA vs. 0.79% PA, $p = 0.88$) [16]. Interpretation of large registry studies can be difficult due to the heterogeneity of the subjects and presence of multiple confounding variables including component positioning and quality of the posterior capsular repair. In addition, the increasing interest and understanding of the relationship between spinopelvic kinematics and hip dislocation are also largely unaccounted for in most studies. The recent increased use of larger femoral heads and dual mobility constructs has likely mitigated dislocation rates after posterior approach THA to those of anterior-based approaches.

Direct Lateral Approach

The direct lateral approach, commonly referred to as the "transgluteal" approach or Hardinge modification of the anterolateral approach, is a versatile anterior-based exposure that is still commonly used for primary and revision total hip arthroplasty. The approach was popularized by Hardinge in 1982 [17] and involves dissecting off the anterior 30–40% of the abductor complex from the underlying anterior hip capsule. The approach can be performed with the patient in either the supine or lateral position and does not require any type of specialized operating room table. The longitudinal skin incision is generally centered over the greater trochanter in line with the femur. The gluteus medius and vastus lateralis are exposed after the iliotibial band has been split in line with the skin incision. A flap involving the anterior 30–40% of the abductor complex is then developed either sharply or with electrocautery. Once the hip capsule is dissected off the abductor complex, an anterior capsulectomy or capsulotomy is performed to expose the femoral head and neck. The hip is dislocated anteriorly, and the femoral neck osteotomy is performed based on preoperative templating. Exposure and preparation of the acetabulum and femur proceed in a standard fashion.

There are several advantages associated with the direct lateral approach including excellent visualization of the acetabulum and femur which allows this approach to be used in most revision settings. The incision can be easily extended distally for full exposure of the entire femur. However, because the superior gluteal nerve innervates the gluteus medius approximately 3–4 cm proximal to the tip of the greater trochanter, care must be taken when extending the exposure proximally so as not to denervate the abductor complex. Because it is an anterior-based approach, the posterior stabilizing structures of the hip are not violated which minimize the risk of dislocation after total hip arthroplasty. In addition, if the approach is performed in the supine position, the use of intraoperative fluoroscopy is easily facilitated to assess component positioning and leg lengths.

Violation of the abductor complex is the main disadvantage of the direct lateral Hardinge approach as improper repair, and/or inadequate healing of the abductor complex can result in persistent weakness and limp. The incidence of residual lateral hip pain, abductor weakness, and limp has been reported to occur in 10–25% of patients undergoing THA performed through the lateral approach [18, 19]. In an effort to protect the repair during the early postoperative period, some surgeons may even prescribe a 4–6-week course of toe-touch weight-bearing to minimize stress across the repair site. In a Norwegian registry study, Amlie et al. reported worse outcomes 1–3 years after surgery in patients undergoing the direct lateral approach compared to any of the other approaches. More specifically, adjusted hip disability and osteoarthritis outcome scores (HOOS) for pain, other symptoms, activities of daily living (ADLs), sport/recreation, and quality of life were significantly worse in the lateral approach group compared to the other groups ($p < 0.03$). This was likely attributable to more patient-reported limping in the lateral approach group [18]. In a prospective randomized controlled trial comparing 21 ABMS approaches to 16 direct lateral approaches, Muller et al. reported higher Harris hip and patient satisfaction scores along with less residual pain in the ABMS group at 3 and 12 months although this did not reach statistical significance. Similar to the findings of Amlie et al., Muller et al. noted significantly higher rates of Trendelenburg gait at a 12-month follow-up ($p = 0.029$) [20]. In addition to persistent lateral hip pain and weakness, the direct lateral approach has also been associated with a higher incidence of developing heterotopic ossification compared to other approaches [21–25].

Direct Anterior Approach

Over the last 10–15 years, the direct anterior approach (DAA) has continued to gain interest among arthroplasty surgeons. Anterior muscle-sparing approaches to the hip can be traced back to 1881 when Carl Hueter first described them. Currently, modifications to the Smith-Peterson approach through the Hueter interval are commonly regarded as the direct anterior approach (DAA) to the hip as popularized by Matta [26]. An internervous and intermuscular approach, the surgical dissection, utilizes the plane between the sartorius and tensor fascia latae. The approach is performed with the patient in the supine position with or without a specialized operating room table and typically begins with an 8–10 cm longitudinal incision which begins 1–2 cm distal and lateral to the ASIS (anterior superior iliac spine). The lateral femoral cutaneous nerve (LFCN) remains superficial to the tensor fascia latae and is at risk for iatrogenic neurapraxia during superficial dissection and with overzealous retraction during deep exposure. Although several branching patterns of the LFCN have been described, the dominant branch may cross the Hueter interval in up to 84% of cases [27]. The fascia over the tensor muscle is opened longitudinally, and the muscle belly is then gently swept off the underlying anteromedial deep fascial layer. Once the rectus femoris muscle is retracted medially, a thin band of the fascia is encountered which connects the rectus and tensor muscle. It is here where the transverse ascending branches of the lateral circumflex vessels are encountered which should be cauterized. Once the femoral neck is adequately exposed, a napkin ring osteotomy is often required as the femoral neck is cut in situ. Preparation and cup insertion proceed in a routine fashion although the use of offset reamers and cup inserters can help navigate around the wound edges. The use of intraoperative fluoroscopy to assess cup positioning and leg lengths is easily facilitated since the patient is in a supine position.

Exposure and preparation of the proximal femur are the most technically demanding portions of the case. The operative extremity is adducted, externally rotated, and extended to expose the posteromedial capsule in the wound. This can be done by an assistant on the opposite side if using a regular radiolucent table or with the aid of a fracture boot or leg holder if using a specialized table. The goal is to perform an adequate release of the posteromedial capsular structures around the greater trochanter and occasionally partial release of the short external rotators to allow for adequate elevation and translation of the proximal femur out of the wound. Inadequate release of the proximal femur during this stage has been associated with femoral perforation, greater trochanter fractures, and varus positioning of the femoral component likely due to inadequate visualization. Once adequate exposure of the proximal femur is obtained, femoral broaching and stem insertion proceed in a routine fashion. Again, the use of specialized offset instruments can be very helpful at this stage.

There are several potential benefits of performing THA through the DAA. For example, the DAA has often been associated with a faster recovery compared to the other traditional approaches to the hip due to the muscle-sparing exposure although the literature supporting this claim has been mixed [5–10]. In addition, the use of intraoperative fluoroscopy is easily facilitated to assess component sizing and leg lengths and to recreate any type of fixed pelvic tilt deformities for accurate functional positioning of the acetabular component.

Several disadvantages have been associated with the DAA including a steep learning curve, a high incidence of neurapraxia to the LFCN, intraoperative proximal femoral fracture, difficulty with exposure in revision arthroplasty, the need for special operating room tables, and wound healing complications. It is commonly accepted that the learning curve for mastering the DAA requires over 100 cases to minimize intraoperative complications and operative time [28, 29]. Due to the proximity of the incision to the LFCN, traction neurapraxia and, in some instances, meralgia paresthetica are commonly reported to range between 2% and 81% after THA performed through the DAA [30–32]. In a recent cadaveric study by Thaler et al., the authors described three patterns of how the LFCN branches including a sartorius-type, a posterior-type, and a fan-type. Regardless of branching pattern, the authors found that the LFCN was encountered 100% of the time during longitudinal extension of the DAA approach which places this sensory nerve at an even higher risk during revision procedures where distal extension of the incision is required [27]. Inadequate release of the posteromedial structures around the greater trochanter has been associated with iatrogenic fractures from overzealous retraction, as well as with femoral perforation of the posteromedial proximal femur from poor exposure. Because the DAA requires anterior displacement of the proximal femur, many surgeons advocate for the use of specialized radiolucent tables with the ipsilateral foot fixed in a boot to help maneuver the operative extremity during surgery, particularly into hyperextension and external rotation. Placing the operative limb in extreme positions with the foot fixed in a boot without adequate release proximally has resulted in fractures to the ankle during the DAA. In a study by Matta et al., the authors reported 3 ankle fractures and 3 greater trochanter fractures in their series of 494 THAs performed through the DAA on a Judet (Tasserit, Sens, France) or ProFix table (Orthopedic Systems, Inc., Union City, CA) [26]. Finally, due to the relative proximity of the incision to the groin and abdominal pannus, local wound complications have been commonly associated with the DAA [31, 33].

Anterior-Based Muscle-Sparing Approach (ABMS) via Watson-Jones Interval

The anterolateral approach, commonly referred to as the Watson-Jones approach, utilizes the intermuscular plane between the gluteus medius and the tensor fascia latae. The approach can be performed with the patient in either the supine or lateral position. The skin incision is generally a 10–15 cm longitudinal incision centered over the posterior border of the tensor fascia latae muscle belly. The subcutaneous tissue is dissected down to the level of the iliotibial fascia. The iliotibial fascia is incised in a slightly anterior sloping fashion proximally toward the ASIS and in line with the skin incision distally to expose the gluteus medius and vastus lateralis. At this point, the tensor fascia muscle belly is retracted medially and gluteus medius laterally to enter the Watson-Jones interval. Collateral vessels from the ascending branches of the lateral circumflex artery are commonly encountered in this interval and should be ligated. The incision can be extended in line with the femur and thus is considered to be extensile distally. However, because the innervation of the superior gluteal nerve enters the gluteus medius approximately 3–4 cm proximal to the greater trochanter, an anterior curvilinear incision proximally may be required if proximal extension is necessary. The terminal branch of the superior gluteal nerve enters the tensor fascia latae at the proximal aspect of the dissection and should be preserved.

Once the deep fascia in the Watson-Jones interval has been incised, retractors are placed into the saddle of the superior neck (junction of the femoral neck and greater trochanter), along the medial femoral neck, and over the anterior acetabular rim to expose the pericapsular fat over the hip capsule. Hip flexion can help facilitate placing the anterior acetabular retractor deep to the rectus tendon to minimize iatrogenic injury to the femoral nerve. The pericapsular fat is cleared off the capsule with a Cobb elevator, and an anterior capsulectomy or capsulotomy is performed. A femoral neck osteotomy is performed in situ at the level determined from preoperative templating. A napkin ring osteotomy can be helpful at this stage to remove the femoral head. Acetabular exposure, preparation, and final cup insertion proceed in a routine manner although the use of offset reamers can be helpful, especially in heavier and/or muscular patients.

Similar to the DAA, adequate release of the posteromedial capsule and femoral exposure is the most technically demanding portion of the approach. However, because exposure of the femur is in a more anterolateral rather than an anterior direction, adequate visualization of the proximal femur can usually be obtained without hyperextension of the hip. The operative extremity is externally rotated and adducted by an assistant on the opposite side of the table to facilitate anterolateral translation of the proximal femur. With a retractor placed posterior to the greater trochanter and anterior to the abductor complex, a controlled release of the posteromedial and inferior capsule is performed to expose the proximal femur in an anterolateral direction. Femoral broaching and stem insertion proceed in a routine fashion although the use of offset instruments can be helpful.

This approach provides excellent visualization of both the acetabulum and femur. If being performed in the supine position, the use of intraoperative fluoroscopy is easily facilitated to assess component positioning and leg lengths. Dislocation rates with this anterior-based surgical approach have also traditionally been reported to be lower when compared to posterior approaches to the hip. The reason for this is likely related to the preservation of the posterior capsule and short external rotators. In addition, the improved exposure of the acetabulum compared to the posterior approach may also minimize the risk of placing the cup in a neutral and/or retroverted position.

How Does ABMS Differ from Other Approaches?

As described in previous chapters, the ABMS approach can be performed with the patient in either the lateral or supine position. The procedure is commonly performed on a regular radiolucent table if the patient is positioned supine or on an operating room table with a detachable posterior leg if the patient is in the lateral decubitus position (Jupiter Table, TRUMPF Inc., Charleston, SC). This avoids the need for any type of specialized operating room tables with leg holders which can be costly. An anterior intermuscular approach, the deep dissection, utilizes the plane between the gluteus medius and tensor fascia latae (Watson-Jones interval) and avoids any violation of key muscle attachments including the abductor complex and short external rotators. As a result, the incidence of persistent abductor weakness and limp is minimized. In addition to sparing key muscle attachments, the ABMS approach also avoids violating the posterior hip capsule which may contribute to a lower risk of posterior dislocation.

The ABMS approach typically begins as a longitudinal or curvilinear incision over the posterior aspect of the tensor fascia muscle belly. The anterolateral location of the incision avoids the inguinal and abdominal regions where moisture can accumulate which can predispose to bacterial and fungal infections. Since the LFCN typically lies over the sartorius muscle belly, iatrogenic injury to the sensory nerve is minimized compared to the DAA. Both Delanois et al. and Mandereu et al. reported only a 2% incidence of self-limiting LFCN palsy in their series of 100 and 103 patients, respectively, who underwent THA with the ABMS approach [34, 35]. This is in comparison to the 2–81% incidence of LFCN neurapraxia commonly reported after the DAA [30, 32, 33]. The more lateral location of the incision compared to the DAA can also facilitate easier exposure of the proximal femur. Since the ABMS exposure approaches the hip through the Watson-Jones interval rather than the more anterior Hueter interval, exposure of the proximal femur during THA is often in an anterolateral direction. Although an adequate release of the posteromedial structures is still required to expose the femur during the ABMS approach, less anterior translation is required compared to the DAA, thus minimizing the risk of iatrogenic fracture and femoral perforation during broaching. The avoidance of excessive anterior translation of the femur can be especially helpful when exposing the proximal femur in younger males with large muscle mass in the thigh.

Learning curves for the ABMS approach have also been reported though not as steep when compared to the DAA [36–38]. D'Arrigo et al. reported a statistically significant higher operative time in their first ten cases of THA using the ABMS approach compared to the second ten cases [36]. Similarly, in a prospective randomized study of 42 patients undergoing THA through the ABMS approach, Martin et al. did not report a significant difference in mean operative time between the first 21 cases and last 21 cases which supports a relatively shorter learning curve compared to other muscle-sparing approaches to the hip [39]. Similar to the DAA, the ABMS approach also has the advantage of easily utilizing intraoperative fluoroscopy which can mitigate some of the common complications seen early on in the learning curve including femoral perforation and component malpositioning.

Although comparative studies are relatively scarce in the literature, several authors have compared the ABMS approach to other surgical approaches [4, 8, 18, 20, 31, 37, 40, 41]. In a Norwegian registry database study, Mjaaland et al. found that the 2–5-year implant survival rates did not differ when analyzing 2087 ABMS THAs compared to other total hip approaches ($p = 0.187$). Similarly, the relative risk (RR) of revision for any cause also did not differ among any of the approaches (0.95 ABMS vs. 0.90 direct lateral and posterior) [4]. However, the inherent flaws of large registry database studies, as well as the short follow-up period (mean 4.3 years), should be taken into consideration when interpreting these results.

In a prospective randomized study of 52 patients with the ABMS approach compared to 50 patients with the direct lateral Hardinge approach, Inaba et al. found a faster recovery of abduction strength at 6 weeks in the ABMS group ($p < 0.01$) but no difference at 3, 6, or 12 months. However, no significant differences in Harris hip score (HHS), visual analog score (VAS), or SF-36 ($p < 0.01$) score were found throughout the study period between the two cohorts [8]. Several other authors have also failed to show significant differences in patient-reported outcome measures between the ABMS approach and other approaches. In a prospective randomized controlled study of 42 cemented ABMS THAs compared to 41 direct lateral THAs, Martin et al. did not find any significant differences in Postel and Merle d'Aubigne, HHS, or SF-36 scores at 1 year although there was a nonsignificant trend for more patients in the ABMS group to rate their hip as "silent" compared to the direct lateral cohort (60%, 24 out of 40, vs. 44%, 18 out of 40, $p = 0.178$) [39]. In a multicenter prospective randomized study of 69 cementless ABMS THAs compared to 66 cementless THAs performed through either the direct lateral or posterolateral approach, Greidanus et al. did not report any significant differences in WOMAC, SF-36, Paper Adaptive Test in 5 Domains of Quality of Life in Arthritis Questionnaire (PAT5D), or patient satisfaction scores at a minimum 2-year follow-up (mean, 30 months; range, 24–42 months). Similarly, Lafosse et al. did not find any significant differences in pain scores, modified HHS, or WOMAC scores at 6 weeks, 3 months, or 6 months postoperatively in their single surgeon prospective study of 35 THAs performed through the ABMS approach compared to 43 THAs performed through the posterolateral approach. In addition, patient satisfaction scores did not differ between the two cohorts at 6 months. However, the authors reported a significantly higher incidence of intraoperative complications ($p = 0.003$) and duration of surgery ($p = 0.045$) in the ABMS cohort [38].

Most recently, Herndon et al. retrospectively compared reoperation rates for any reason of 170 ABMS to 170 DAA THAs. Within 1 year, 3.5% (6 out of 170) of patients in the ABMS group underwent reoperation compared to 1% (2 out of

170) from the DAA group. Of the six revisions in the ABMS cohort, three were for femoral stem subsidence. The authors attributed this higher rate of femoral component subsidence on the absent use of fluoroscopy in the laterally positioned ABMS group. However, there were 13 patients (8%) in the DAA cohort who experienced wound complications compared to only 6 patients (4%) in the ABMS cohort ($p = 0.036$) [30].

Conclusion

Muscle-sparing anterior approaches to the hip have recently gained a renewed interest as surgeons and patients continue to search for novel interventions to accelerate recovery, optimize functional outcomes, improve patient satisfaction, and minimize complications. Over the last several decades, surgical approaches to the hip have been modified with the goal of leaving key soft tissue structures intact including the posterior capsule, short external rotators, and abductor complex. Although there has been an accelerated interest in muscle-sparing hip replacement over the last 15–20 years, there has been a paucity of high-level evidence to strongly suggest superiority of one surgical approach over the other. Each surgical approach carries its own risk-benefit profile which should be discussed with the patient during the informed consent process. In 2004, Bertin and Röttinger published their modification of the muscle-sparing Watson-Jones approach to total hip arthroplasty. Since its inception, the approach has been referred to in the literature in several ways including the “Röttinger,” “mini-anterolateral,” “minimally invasive anterolateral,” “modified Watson-Jones,” and most recently anterior-based muscle-sparing or ABMS approach. The inconsistent nomenclature in the literature serves as a source of confusion for surgeons and patients alike and may be a barrier to more widespread knowledge and adoption of this approach [42].

In summary, the ABMS approach has been shown to provide all the muscle-sparing advantages of the DAA but with less risk of complications and a shorter learning curve. Recent modifications to the ABMS approach allow this approach to be performed in either the supine or lateral decubitus position. Functional outcome measures and patient satisfaction have shown to be at least equivalent to, if not superior, when compared to other anterior- and posterior-based surgical approaches. As surgeons continue to adopt this relatively new surgical approach, standardization of terminology when describing the ABMS approach will be key to being able to critically analyze comparative data about different THA approaches in future studies.

References

1. Sloan M, Premkumar A, Sheth NP. Projected volume of primary total joint arthroplasty in the U.S., 2014 to 2030. J Bone Joint Surg Am 2018;100(17):1455–1460. https://doi.org/10.2106/JBJS.17.01617. PMID: 30180053.
2. DeWal H, Su E, DiCesare PE. Instability following total hip arthroplasty. Am J Orthop (Belle Mead NJ). 2003;32(8):377–82. PMID: 12943337.
3. Woo RY, Morrey BF. Dislocations after total hip arthroplasty. J Bone Joint Surg Am. 1982;64(9):1295–306. PMID: 7142237.
4. Mjaaland KE, Svenningsen S, Fenstad AM, Havelin LI, Furnes O, Nordsletten L. Implant survival after minimally invasive anterior or anterolateral vs. conventional posterior or direct lateral approach: an analysis of 21,860 total hip arthroplasties from the Norwegian Arthroplasty Register (2008 to 2013). J Bone Joint Surg Am. 2017;99(10):840–7. https://doi.org/10.2106/JBJS.16.00494. PMID: 28509824.
5. Sun X, Zhao X, Zhou L, Su Z. Direct anterior approach versus posterolateral approach in total hip arthroplasty: a meta-analysis of results on early post-operative period. J Orthop Surg Res. 2021;16(1):69. https://doi.org/10.1186/s13018-021-02218-7. PMID: 33468181; PMCID: PMC7816494.
6. Sugano N, Takao M, Sakai T, Nishii T, Miki H, Nakamura N. Comparison of mini-incision total hip arthroplasty through an anterior approach and a posterior approach using navigation. Orthop Clin North Am. 2009;40(3):365–70. https://doi.org/10.1016/j.ocl.2009.04.003. PMID: 19576404.
7. Alecci V, Valente M, Crucil M, Minerva M, Pellegrino CM, Sabbadini DD. Comparison of primary total hip replacements performed with a direct anterior approach versus the standard lateral approach: perioperative findings. J Orthop Traumatol. 2011;12(3):123–9. https://doi.org/10.1007/s10195-011-0144-0. Epub 2011 Jul 12. PMID: 21748384; PMCID: PMC3163771.

8. Inaba Y, Kobayashi N, Yukizawa Y, Ishida T, Iwamoto N, Saito T. Little clinical advantage of modified Watson-Jones approach over modified mini-incision direct lateral approach in primary total hip arthroplasty. J Arthroplast. 2011;26(7):1117–22. https://doi.org/10.1016/j.arth.2011.04.002. Epub 2011 May 23. PMID: 21602025.
9. Lakhani K, Mimendia I, Porcel JA, Martín-Domínguez LA, Guerra-Farfán E, Barro V. Direct anterior approach provides better functional outcomes when compared to direct lateral approach in hip hemiarthroplasty following femoral neck fracture. Eur J Orthop Surg Traumatol. 2021; https://doi.org/10.1007/s00590-021-02941-1. Epub ahead of print. PMID: 33760998.
10. Elstad ZM, Buckner JF, Taunton MJ, Sherman CE, Ledford CK, Wilke BK. Outcomes of total hip arthroplasty via the direct anterior vs alternative approaches for acute femoral neck fractures. Arthroplast Today. 2021;8:92–5. https://doi.org/10.1016/j.artd.2021.02.003. PMID: 33732832; PMCID: PMC7943958.
11. Rivera F, Bardelli A, Giolitti A. Promising medium-term results of anterior approach with an anatomical short stem in primary hip arthroplasty. J Orthop Traumatol. 2021;22(1):8. https://doi.org/10.1186/s10195-021-00567-x. PMID: 33675436; PMCID: PMC7936996.
12. Bertin KC, Röttinger H. Anterolateral mini-incision hip replacement surgery: a modified Watson-Jones approach. Clin Orthop Relat Res. 2004;429:248–55. PMID: 15577495.
13. Civinini R, Cozzi Lepri A, Carulli C, Matassi F, Villano M, Innocenti M. The anterior-based muscle-sparing approach to the hip: the "other" anterior approach to the hip. Int Orthop. 2019;43(1):47–53. https://doi.org/10.1007/s00264-018-4190-6. Epub 2018 Oct 4. PMID: 30284607.
14. Jerosch J, Theising C, Fadel ME. Antero-lateral minimal invasive (ALMI) approach for total hip arthroplasty technique and early results. Arch Orthop Trauma Surg. 2006;126(3):164–73. https://doi.org/10.1007/s00402-006-0113-x. Epub 2006 Mar 8. PMID: 16523344.
15. Wu ES, Cherian JJ, Delanois RE. Minimally invasive anterolateral (Watson-Jones) approach in the supine position. In: Scuderi G, Tria A, editors. Minimally invasive surgery in orthopedics. Cham: Springer; 2015.
16. Maratt JD, Gagnier JJ, Butler PD, Hallstrom BR, Urquhart AG, Roberts KC. No difference in dislocation seen in anterior vs posterior approach total hip arthroplasty. J Arthroplast. 2016;31(9 Suppl):127–30. https://doi.org/10.1016/j.arth.2016.02.071. Epub 2016 Mar 15. PMID: 27067754.
17. Hardinge K. The direct lateral approach to the hip. J Bone Joint Surg Br. 1982;64(1):17–9. https://doi.org/10.1302/0301-620X.64B1.7068713. PMID: 7068713.
18. Amlie E, Havelin LI, Furnes O, Baste V, Nordsletten L, Hovik O, Dimmen S. Worse patient-reported outcome after lateral approach than after anterior and posterolateral approach in primary hip arthroplasty. A cross-sectional questionnaire study of 1,476 patients 1–3 years after surgery. Acta Orthop. 2014;85(5):463–9. https://doi.org/10.3109/17453674.2014.934183. Epub 2014 Jun 23. PMID: 24954494; PMCID: PMC4164862.
19. Mulliken BD, Rorabeck CH, Bourne RB, Nayak N. A modified direct lateral approach in total hip arthroplasty: a comprehensive review. J Arthroplast. 1998;13(7):737–47. https://doi.org/10.1016/s0883-5403(98)90024-9. PMID: 9802658.
20. Müller M, Tohtz S, Springer I, Dewey M, Perka C. Randomized controlled trial of abductor muscle damage in relation to the surgical approach for primary total hip replacement: minimally invasive anterolateral versus modified direct lateral approach. Arch Orthop Trauma Surg. 2011;131(2):179–89. https://doi.org/10.1007/s00402-010-1117-0. Epub 2010 May 20. PMID: 20490520.
21. Bischoff R, Dunlap J, Carpenter L, DeMouy E, Barrack R. Heterotopic ossification following uncemented total hip arthroplasty. Effect of the operative approach. J Arthroplast. 1994;9(6):641–4. https://doi.org/10.1016/0883-5403(94)90118-x. PMID: 7699377.
22. Harwin SF. Trochanteric heterotopic ossification after total hip arthroplasty performed using a direct lateral approach. J Arthroplast. 2005;20(4):467–72. https://doi.org/10.1016/j.arth.2004.12.047. PMID: 16124962.
23. Iorio R, Healy WL, Warren PD, Appleby D. Lateral trochanteric pain following primary total hip arthroplasty. J Arthroplast. 2006;21(2):233–6. https://doi.org/10.1016/j.arth.2005.03.041. PMID: 16520212.
24. Pai VS. Heterotopic ossification in total hip arthroplasty. The influence of the approach. J Arthroplast. 1994;9(2):199–202. https://doi.org/10.1016/0883-5403(94)90069-8. PMID: 8014651.
25. Alijanipour P, Patel RP, Naik TU, Parvizi J. Heterotopic ossification in primary total hip arthroplasty using the direct anterior vs direct lateral approach. J Arthroplast. 2017;32(4):1323–7. https://doi.org/10.1016/j.arth.2016.11.030. Epub 2016 Nov 22. PMID: 28024885.
26. Matta JM, Shahrdar C, Ferguson T. Single-incision anterior approach for total hip arthroplasty on an orthopaedic table. Clin Orthop Relat Res. 2005;441:115–24. https://doi.org/10.1097/01.blo.0000194309.70518.cb. PMID: 16330993.
27. Thaler M, Dammerer D, Hechenberger F, Hörmann R, Van Beeck A, Stofferin H. The anatomical course of the lateral femoral cutaneous nerve in relation to various skin incisions used for primary and revision total hip arthroplasty with the direct anterior approach. J Arthroplast. 2021;36(1):368–73. https://doi.org/10.1016/j.arth.2020.07.052. Epub 2020 Jul 28. PMID: 32826147.
28. Anterior Total Hip Arthroplasty Collaborative Investigators, Bhandari M, Matta JM, Dodgin D,

Clark C, Kregor P, Bradley G, Little L. Outcomes following the single-incision anterior approach to total hip arthroplasty: a multicenter observational study. Orthop Clin North Am. 2009;40(3):329–42. https://doi.org/10.1016/j.ocl.2009.03.001. PMID: 19576400.
29. Masonis J, Thompson C, Odum S. Safe and accurate: learning the direct anterior total hip arthroplasty. Orthopedics. 2008;31(12 Suppl 2) orthosupersite.com/view.asp?rID=37187. PMID: 19298019.
30. Herndon CL, Drummond N, Sarpong NO, Cooper HJ, Shah RP, Geller JA. Direct anterior versus mini-anterolateral approach for primary total hip arthroplasty: early postoperative outcomes and complications. Arthroplast Today. 2020;6(2):257–61. https://doi.org/10.1016/j.artd.2020.02.009. PMID: 32577474; PMCID: PMC7303493.
31. Jewett BA, Collis DK. High complication rate with anterior total hip arthroplasties on a fracture table. Clin Orthop Relat Res. 2011;469(2):503–7. https://doi.org/10.1007/s11999-010-1568-1. PMID: 20886324; PMCID: PMC3018203.
32. Restrepo C, Parvizi J, Pour AE, Hozack WJ. Prospective randomized study of two surgical approaches for total hip arthroplasty. J Arthroplasty. 2010;25(5):671–9.e1. https://doi.org/10.1016/j.arth.2010.02.002. Epub 2010 Apr 8. PMID: 20378307.
33. Berend KR, Lombardi AV Jr, Seng BE, Adams JB. Enhanced early outcomes with the anterior supine intermuscular approach in primary total hip arthroplasty. J Bone Joint Surg Am. 2009;91(Suppl 6):107–20. https://doi.org/10.2106/JBJS.I.00525. PMID: 19884418.
34. Delanois RE, Sultan AA, Albayar AA, Khlopas A, Gwam CU, Sodhi N, Lamaj S, Newman JM, Mont MA. The Röttinger approach for total hip arthroplasty: technique, comparison to the direct lateral approach and review of literature. Ann Transl Med. 2017;5(Suppl 3):S31. https://doi.org/10.21037/atm.2017.11.21. PMID: 29299478; PMCID: PMC5750259.
35. Mandereau C, Brzakala V, Matsoukis J. Functional recovery, complications and CT positioning of total hip replacement performed through a Röttinger anterolateral mini-incision. Review of a continuous series of 103 cases. Orthop Traumatol Surg Res. 2012;98(1):8–16. https://doi.org/10.1016/j.otsr.2011.10.005. Epub 2011 Dec 29. PMID: 22209043.
36. D'Arrigo C, Speranza A, Monaco E, Carcangiu A, Ferretti A. Learning curve in tissue sparing total hip replacement: comparison between different approaches. J Orthop Traumatol. 2009;10(1):47–54. https://doi.org/10.1007/s10195-008-0043-1. Epub 2009 Jan 31. PMID: 19384637; PMCID: PMC2657353.
37. Greidanus NV, Chihab S, Garbuz DS, Masri BA, Tanzer M, Gross AE, Duncan CP. Outcomes of minimally invasive anterolateral THA are not superior to those of minimally invasive direct lateral and posterolateral THA. Clin Orthop Relat Res. 2013;471(2):463–71. https://doi.org/10.1007/s11999-012-2603-1. PMID: 23073706; PMCID: PMC3549154.
38. Laffosse JM, Chiron P, Molinier F, Bensafi H, Puget J. Prospective and comparative study of the anterolateral mini-invasive approach versus minimally invasive posterior approach for primary total hip replacement. Early results. Int Orthop. 2007;31(5):597–603. https://doi.org/10.1007/s00264-006-0247-z. Epub 2006 Oct 12. PMID: 17053875; PMCID: PMC2266652.
39. Martin R, Clayson PE, Troussel S, Fraser BP, Docquier PL. Anterolateral minimally invasive total hip arthroplasty: a prospective randomized controlled study with a follow-up of 1 year. J Arthroplast. 2011;26(8):1362–72. https://doi.org/10.1016/j.arth.2010.11.016. Epub 2011 Mar 23. PMID: 21435823.
40. Martz P, Maczynski A, Elsair S, Labattut L, Viard B, Baulot E. Total hip arthroplasty with dual mobility cup in osteonecrosis of the femoral head in young patients: over ten years of follow-up. Int Orthop. 2017;41(3):605–10. https://doi.org/10.1007/s00264-016-3344-7. Epub 2016 Nov 25. PMID: 27888294.
41. Takada R, Jinno T, Miyatake K, Hirao M, Kimura A, Koga D, Yagishita K, Okawa A. Direct anterior versus anterolateral approach in one-stage supine total hip arthroplasty. Focused on nerve injury: a prospective, randomized, controlled trial. J Orthop Sci. 2018;23(5):783–7. https://doi.org/10.1016/j.jos.2018.05.005. Epub 2018 Jun 20. PMID: 29935972.
42. Lepri AC, Villano M, Matassi F, Carulli C, Innocenti M, Civinini R. "Anterolateral" approach to the hip: a systematic review of the correct definition of terms. Hip Int. 2020;30(2_suppl):13–9. https://doi.org/10.1177/1120700020966800. PMID: 33267690.

13 Periprosthetic Hip Infection Treatment Through the ABMS Approach

Michael Müller

Learning Points
- Periprosthetic hip infection may be a catastrophic complication after total hip replacement surgery.
- Adequate treatment generally consists of aggressive surgical debridement and at time one- or two-stage revision procedures for eradication.
- Surgical treatment of periprosthetic joint infections (PJI) in the hip may be successfully performed through the ABMS (anterior-based muscle-sparing) approach.
- The ABMS approach may afford better exposure to the hip joint than other anterior-based approaches.

Introduction

Periprosthetic joint infections of the knee and hip are one of the most serious complications in the field of arthroplasty. They occur in primary total knee and hip arthroplasty with a frequency of 0.5–2% [1]. The infections may occur either acutely (usually early postoperatively) and hematogenously or chronically (late postoperatively) [2]. In the first year, the infection is usually related to the primary operation; in the later course, it most likely is due to a hematogenous spread such as a urinary tract infection or an infected pacemaker, but rarely also per communication through a psoas abscess [3]. An infection is considered acute if it occurs within 4 weeks after implantation of the prosthesis or after a hematogenous index infection leading to symptomatic bacteremia or sepsis. Chronic infections are all infections that persist for more than 4 weeks after the onset of symptoms [4]. This definition results from the duration of the biofilm formation on the prosthesis and the associated surgical procedure. It can be assumed that a biofilm has developed completely and irreversibly within 4 weeks [5].

Correspondingly, it is no longer possible to eradicate the infection while preserving the prosthesis, since the bacteria are protected by the biofilm and likely permanently adherent to the joint implants. In the case of an acute infection, either acute postoperatively or acute late hematogenously, the prosthesis can still be preserved using the DAIR (debridement, antibiotics, and implant retention) procedure by changing the mobile parts. As already mentioned, this is possible because the bacteria adhering to the prosthesis can be surgically and antimicrobially eradicated due to a still incomplete biofilm. In the case of a chronic infection, it is necessary to completely remove the infected prosthesis. This is usually performed in a two-stage procedure with a prosthesis-free interval, with or without a spacer.

M. Müller (✉)
Charite University Medicine Berlin, Centre for Musculoskeletal Surgery, Department of Orthopaedics, Berlin, Germany
e-mail: michael.mueller@charite.de

J. A. Geller, B. J. McGrory (eds.), *The Anterior-Based Muscle-Sparing Approach to Total Hip Arthroplasty*, https://doi.org/10.1007/978-3-031-02059-9_13

Alternatively, there is mounting evidence that, in certain types of infections, this can also be done with a one-stage revision, that is, the removal of the prosthesis and the reimplantation are carried out in a single operative procedure.

The use of the ABMS approach for septic revision has the advantage of sparing the periarticular hip muscles, especially the abductors. This results in verifiable good postoperative mobilization and functionality, which is significantly better than, for example, using an intramuscular Hardinge (lateral) approach, especially after multiple revision surgery [6]. It may also afford improved surgical stability compared to a posterior approach which may involve significant posterior soft tissue disruption.

DAIR Procedure Via an ABMS Approach

The DAIR procedure is indicated in the case of an acute infection in which the prosthesis can still be preserved because the biofilm has not yet fully formed on the surface of the prosthesis. Therefore, the DAIR procedure should be carried out up to a maximum of 3–4 weeks after the onset of symptoms. Accordingly, the procedure includes irrigation, debridement, and changing the modular components (head and acetabular liner), while retaining the cup and stem in situ. The exchange of the mobile parts is promoted mainly due to the fact that the polyethylene is colonized by bacteria the earliest due to its surface structure and therefore the polyethylene (PE) liner should be exchanged in the event of an acute infection [7]. Femoral head revision allows access to the trunnion, as well as aiding in acetabular exposure. The purpose of the DAIR procedure is the maximum operative reduction of pathogens and the subsequent antibiotic therapy with the aim of infection eradication. The earlier DAIR procedure is carried out after the primary infection, the better the chances of successful infection cleanup [8].

The ABMS approach is well appropriated for the DAIR procedure. The approach offers excellent, and extensile, muscle-sparing access to the joint, which enables detailed debridement and irrigation of the joint (Fig. 13.1). This approach also makes it very easy to prepare and dislocate the prosthesis and to exchange the head and PE inlay.

The entire acetabulum can be viewed and debrided very easily, and the liner can be changed safely and straightforwardly. Overall, the dislocation rate after a liner exchange is slightly higher [9] when using an ABMS approach but still lower than, for example, via a dorsolateral approach [10].

In general, the surgical approach to the hip is similar in scope to the descriptions of ABMS in other parts of the textbook. However, particular attention should be paid to finding the same initial surgical plane as the original hip surgery,

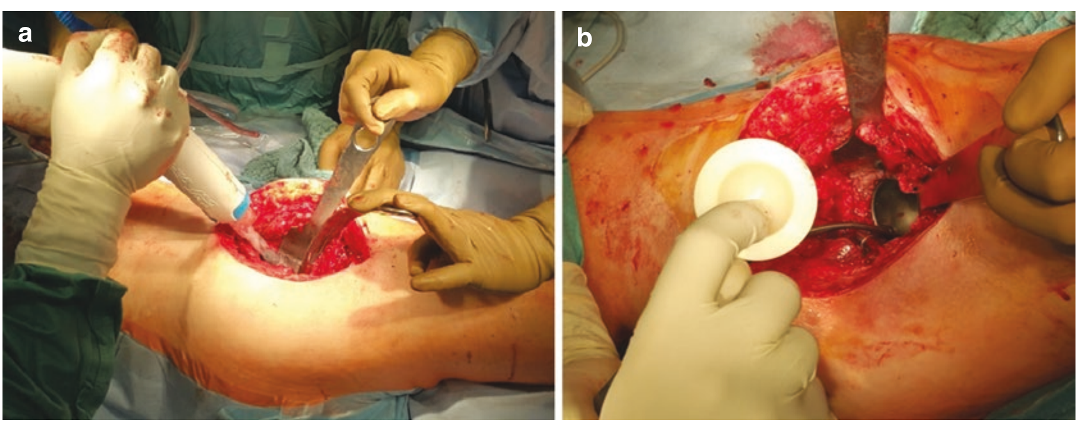


Fig. 13.1 Intraoperative photographs of a DAIR (debridement, antibiotics, and implant retention) procedure with headliner exchange: (**a**) exposure and pulse lavage via ABMS approach and (**b**) placement of new ultrahigh-molecular-weight polyethylene liner after debridement

excising any infected looking parts of the incision, a thorough synovectomy upon entry into the joint space, and protection of the vital structures medial to the joint, such as the neurovascular bundle of the femoral nerve, artery, and vein.

One- or Two-Stage Revision Via ABMS Approach

The goal of the one- or two-stage exchange is the complete removal of the infected prosthesis and all foreign materials, the subsequent extensive debridement and irrigation of the joint, and the reimplantation of a new prosthesis, either directly in the same session or with an interval of a several weeks. In principle, this procedure can be carried out well via an ABMS approach. The ABMS approach is certainly a very good option for removing the acetabular component and debridement and reimplantation of a new socket. All relevant regions of the acetabulum can be easily reached via the approach. The roof of the acetabulum, the entire acetabular rim, the ilium, or the ischium can be viewed and prepared very easily. Almost the entire spectrum of current revision implants can be used via an ABMS approach. With an ABMS approach, regular cemented or cementless revision cups with and without screws, augments, reconstruction rings with and without ischial flanges, or cup-cage constructs can be safely implanted without restrictions. The ABMS approach also allows a safe and multidirectional screw placement of the acetabular implants. It should be pointed out that in the most cranial area of the intermuscular interval, the terminal branches of the superior gluteal nerve run from dorsal to ventral into the tensor fasciae latae (TFL) muscle and can be injured if it is dissected too far cranially. This can also damage the TFL [11].

For stem revision, most primary short or standard stems can also be easily addressed through an ABMS approach, both in terms of explantation, debridement, and pulse lavage and for reimplantation (Fig. 13.2). However, a good

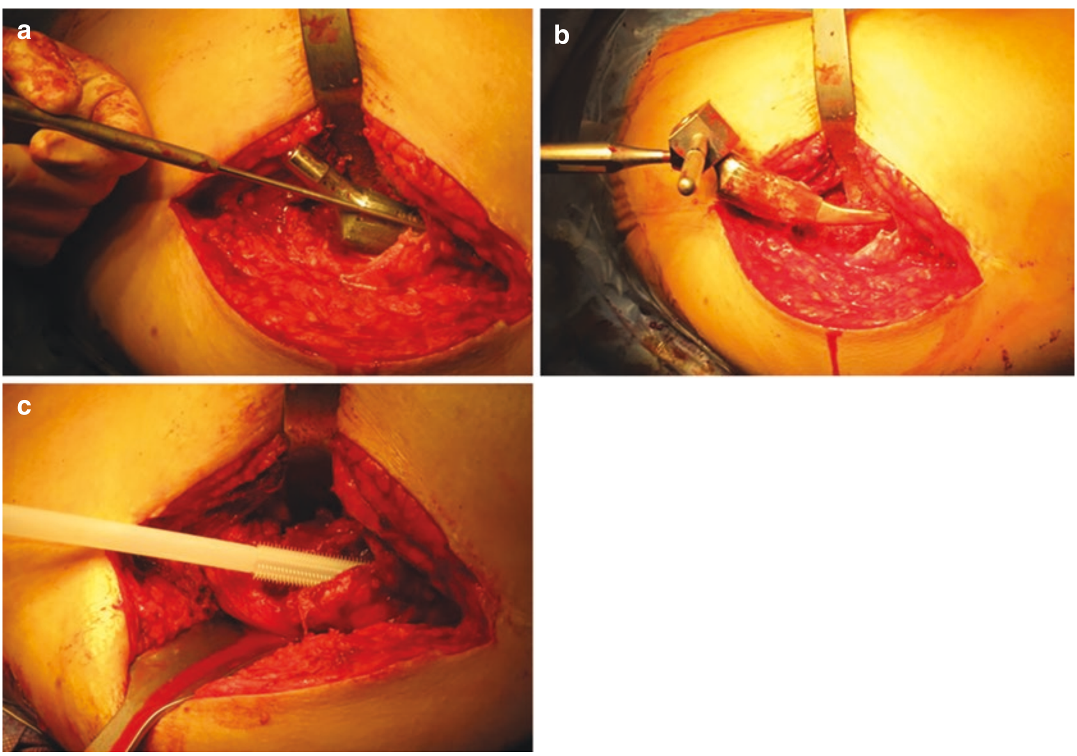


Fig. 13.2 Femoral component explantation (**a**, **b**) and pulse lavage with debridement (**c**) via the ABMS approach

release of the surrounding soft tissue, the dorsolateral capsule, and the tendon attachments, especially those of the gluteal medius, minimus, and piriformis muscles on the proximal femur, should be ensured so that a good mobilization and exposure of the proximal femur are possible. This is especially important to avoid muscular and bony damage or fractures when removing or installing components or when debriding the medullary canal with long curettes. In particular, care should be taken to protect the greater trochanter, as there can be an increased risk of a trochanteric fracture when using an ABMS approach [12].

The use of an ABMS approach should be carefully considered when removing or implanting larger, modular, or non-modular revision stems or when the removal of distal cement residue is necessary. The risk of irreversible damage to the gluteal muscle and tendon including the bony structure is then significantly increased. Usually, a dorsal approach and an extended transtrochanteric osteotomy are better suited, especially with regard to the protection of muscular and bony structures. It is therefore recommended, if the stem removal is initially planned via an ABMS approach, to begin with the patient in a lateral position. In the case of a difficult stem preparation, an extended transtrochanteric osteotomy can be carried out relatively easily. This possibility of expandability into more of an extensile exposure is also an advantage of the ABMS access.

Figure 13.3 demonstrates serial anteroposterior (AP) radiographs of a two-stage septic revision of a 67-year-old patient with an infected hip prosthesis.

Conclusion

In summary, the surgical therapy of periprosthetic hip infections is generally successful and is certainly possible using an ABMS approach. For the acetabulum, there are almost no restrictions with regard to changing the bearing system, component explantation/implantation, and debridement. With appropriate detailed preparation of the proximal femur, the revision of short or standard stems and debridement and irrigation are easily possible for the femoral channel. There may be certain limits to the revision of modular or non-modular revision stems using an ABMS approach. This chapter details some of the surgical aspects of periprosthetic infections around total hip replacement. Further medical management with regard to antibiotic use, timing of replantation, virulence profile of bacteria, and salvage procedures are beyond the scope of this chapter, but should be considered within the latest recommendations contained within the consensus statements on diagnosis and treatment of periprosthetic joint infections [13].

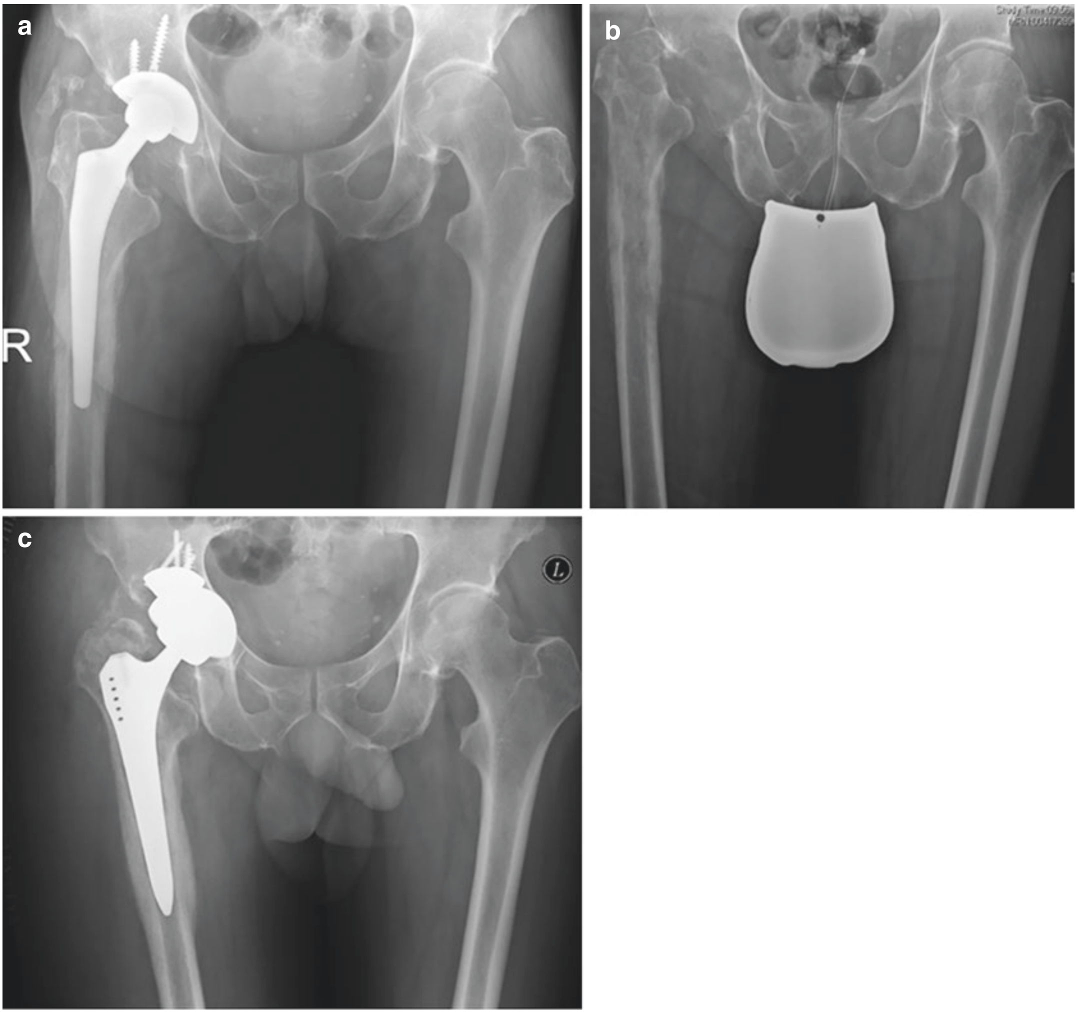


Fig. 13.3 Radiographs showing treatment of a 67-year-old patient with an infected hip prosthesis. Two-stage septic revision via an ABMS approach of an infected left hip prosthesis (Staphylococcus aureus) (**a**) Pelvis radiograph pre-operatively. (**b**) Prosthesis-free interval of six weeks without spacer. (**c**) Reimplantation, also via an ABMS approach, using a non-cemented revision cup in combination with a cranial augment and a non-cemented standard straight stem-type (Zweymüller, Zimmer Biomet, Warsaw, IN, USA)

References

1. Kapadia BH, Berg RA, Daley JA, et al. Periprosthetic joint infection. Lancet. 2016;387:386–94. https://doi.org/10.1016/S0140-6736(14)61798-0.
2. Coughlan A, Taylor F. Classifications in brief: the McPherson classification of Periprosthetic infection. Clin Orthop Relat Res. 2020;478:903–8. https://doi.org/10.1097/CORR.0000000000001133.
3. Izakovicova P, Borens O, Trampuz A. Periprosthetic joint infection: current concepts and outlook. EFORT Open Rev. 2019;4:482–94. https://doi.org/10.1302/2058-5241.4.180092.
4. Parvizi J, Gehrke T, Chen AF. Proceedings of the international consensus on periprosthetic joint infection. Bone Joint J. 2013;95-B:1450–2. https://doi.org/10.1302/0301-620X.95B11.33135.
5. Oliveira WF, Silva PMS, Silva RCS, et al. Staphylococcus aureus and Staphylococcus epidermidis infections on implants. J Hosp Infect. 2018;98:111–7. https://doi.org/10.1016/j.jhin.2017.11.008.
6. von Roth P, Abdel MP, Wauer F, et al. Significant muscle damage after multiple revision total hip replacements through the direct lateral approach. Bone Joint J. 2014;96-B:1618–22. https://doi.org/10.1302/0301-620X.96B12.34256.
7. Barth E, Myrvik QM, Wagner W, et al. In vitro and in vivo comparative colonization of Staphylococcus aureus and Staphylococcus epidermidis on orthopaedic implant materials. Biomaterials. 1989;10:325–8. https://doi.org/10.1016/0142-9612(89)90073-2.

8. Tsang SJ, Ting J, Simpson A, et al. Outcomes following debridement, antibiotics and implant retention in the management of periprosthetic infections of the hip: a review of cohort studies. Bone Joint J. 2017;99-B:1458–66. https://doi.org/10.1302/0301-620X.99B11.BJJ-2017-0088.R1.
9. Dammerer D, Schneider F, Renkawitz T, et al. High risk of hip dislocation following polyethylene liner exchange in total hip arthroplasty-is cup revision necessary? Arch Orthop Trauma Surg. 2020;140:1837–45. https://doi.org/10.1007/s00402-020-03603-3.
10. Kwon MS, Kuskowski M, Mulhall KJ, et al. Does surgical approach affect total hip arthroplasty dislocation rates? Clin Orthop Relat Res. 2006;447:34–8. https://doi.org/10.1097/01.blo.0000218746.84494.df.
11. Ince A, Kemper M, Waschke J, et al. Minimally invasive anterolateral approach to the hip: risk to the superior gluteal nerve. Acta Orthop. 2007;78:86–9. https://doi.org/10.1080/17453670610013466.
12. Laffosse JM, Chiron P, Accadbled F, et al. Learning curve for a modified Watson-Jones minimally invasive approach in primary total hip replacement: analysis of complications and early results versus the standard-incision posterior approach. Acta Orthop Belg. 2006;72:693–701.
13. Parvizi J, Gehrke T, Chen AF. Proceedings of the international consensus on periprosthetic joint infection. Bone Joint J. 2013;95-B(11):1450–2.

14 How to Avoid Complication in the ABMS Total Hip Replacement

Roberto Civinini, Andrea Cozzi-Lepri, Matteo Innocenti, Marco Villano, and Massimo Innocenti

- Three major complication types could be commonly related to the anterior-based muscle-sparing (ABMS) surgical approach: nerve injuries, intraoperative periprosthetic fractures, and postoperative dislocations.
- Nerve injury is a relatively rare, yet potentially devastating, complication: lateral femoral cutaneous nerve (LFCN) and femoral nerve (FN) injuries are potentially more common with the ABMS approach compared with other lateral-/posterior-based approaches.
- Placing the skin incision at the anterior edge of the greater trochanter and firmly positioning the retractor at 12 o'clock without applying too much tension on the underlying soft tissue/muscle structures help surgeons avoid these nerve injuries.
- The ABMS approach dislocation rate is about the same of DAA (direct anterior approach) and therefore improved compared with posterior-based approaches.
- Intraoperative periprosthetic fractures are thought to be more common with the ABMS approach than with posterior-based approaches.
- The greater trochanter is the site prone to fracture with the use of the ABMS approach: accurate planning of prosthesis design/size along with the proper peri-trochanteric soft tissue releases and patient positioning decrease prevalence of these fractures.

Introduction

Total hip arthroplasty (THA) is an effective treatment option for any end-stage painful hip conditions. However, THA may result in severe complications, such as nerve palsy, dislocation, infection, peri-prosthetic fracture, pulmonary thromboembolism, vascular disorder, and so on [1]. Complications and adverse events after THA can compromise patient outcomes, increase hospital readmissions, decrease patient satisfaction, and increase healthcare costs, and finally the occurrence of these complications may result in medical litigation [2]. The Hip Society THA Complications Workgroup proposed a comprehensive list of 19 THA complications [3], but most of them are not directly related to the surgical approach and, for this reason, we will consider only procedure-specific complications where the influence of the approach is more relevant compared to other risk factors; furthermore, all the considerations will be limited to primary THA. We will analyze the impact of the anterior-based muscle-sparing (ABMS) approach on

R. Civinini (✉) · A. Cozzi-Lepri · M. Innocenti
M. Villano · M. Innocenti
Orthopedic Unit, Department of Health Sciences, University of Florence, Florence, Italy
e-mail: Roberto.Civinini@unifi.it; Massimo.Innocenti@unifi.it

J. A. Geller, B. J. McGrory (eds.), *The Anterior-Based Muscle-Sparing Approach to Total Hip Arthroplasty*, https://doi.org/10.1007/978-3-031-02059-9_14

nerve injuries, intraoperative periprosthetic fractures, and postoperative dislocations. The surgical anatomy and the causative factors of the complications will be discussed, and for each of them, tips and tricks to avoid them will be proposed.

Nerve Injuries

Nerve injury is a relatively rare, yet potentially devastating, complication of THA. The clinical incidence of nerve damage following primary THA is reported to range between 0.17% and 3.7%, with a higher risk found in patients receiving revision THA [4]. Apart from patient and surgeon dissatisfaction, nerve palsy is the most common reason that is cited for medical litigation following THA. All of the described techniques and approaches for THA carry at least a small risk of nerve injury; however, each approach has its specific risk of nerve lesion due to the surgical anatomy. A common factor to all the anterior-based approaches is injury to the femoral nerve, lateral femoral cutaneous nerve (LCFN), and superior gluteal nerve. Sciatic nerve injury, which is the most frequent nerve injury in THA, is much less common with anterior-based approaches to THA. Each nerve injury will be discussed in detail below.

Femoral Nerve Injuries

Femoral nerve palsy (FNP) has been recognized as a neurological complication following total hip arthroplasty in 0.01–2.27% of patients. As expected, FNP is more common with anterior approaches; in a large database study, the overall incidence of femoral nerve palsy was found to be 0.21% after THA;, and not surprisingly, the incidence was 14.8-fold higher in patients undergoing anterior-based hip surgeries compared to only 0.045% incidence for the posterior approach and 0.026% incidence for the direct lateral approach [5]. The symptoms of femoral nerve palsy are typically motor disturbance of the quadriceps femoris muscle with an inability to extend the knee and sensory disturbance of the anteromedial part of the thigh and/or medial aspect of the leg. However, FNP has a better prognosis for recovery than other major nerve palsies around the hip, with a majority of patients regaining motor function in the quadriceps muscle [6].

The incidence of FNP has been extensively studied after direct anterior (DA) approach, resulting in the second most commonly injured nerve after LFCN, with a reported incidence ranging from 0.26% to 0.50% [7]. Reports on injuries to the femoral nerve after the ABMS approach are more limited, but the incidence in all the studies is similar to those reported for the DA. In a study of 17,350 consecutive primary THAs, the incidences of FNP for cases performed using the DA and ABMS approaches, respectively, were 0.40% (95% CI 0.27–0.60) and 0.64% (95% CI 0.35–1.2) [5]. In a personal prospective cohort study of 343 hips, our results were similar, with two patients (0.6%) who experienced a self-limited femoral nerve palsy [8].

Clarification of the anatomical course of the femoral nerve in relation to the acetabulum is warranted to understand the risk of nerve palsy in anterior approaches. The femoral nerve originates from the L2–L4 nerve roots of the lumbar plexus and enters the pelvis obliquely, through the fibers of the iliopsoas. As it passes distal to the inguinal ligament, it is in close proximity to the anterior wall of the acetabulum, with the average distance between the anterior lip and the nerve reported to be 1.8–2.2 cm and with only the bulk of iliopsoas lying in between [9].

The cause of femoral nerve palsy following THA is not fully understood but may be due to direct compression, stretching, ischemia, malpositioning of retractors, direct injury, or thermal damage by electrocautery during the procedure or hematoma formation after surgery. However, most authors agree that the vast majority of FNPs likely occur from traction on anterior neurovascular structures by a retractor placed over around the acetabulum or by traction on the nerve due to hyperextension and adduction performed during femoral broaching [5]. The retractor tip may injure the femoral nerve bundle directly, or the retractor may com-press the femoral nerve indirectly through the iliopsoas muscle belly. The risk is increased with anterior retractor placement since the retractor tip is strikingly close to the femoral nerve when placed near the anterior rim of the acetabulum; therefore, the only protection for the femoral nerve is the iliopsoas muscle. This protection is only conferred, however, when the retractor passes deep to the iliopsoas. To guarantee this protection, the tip of the retractor must make contact with the anterior lip of the acetabulum, and this contact must be maintained when moving the retractor into position [10]. A recent study on the proximity of neurovascular structures demonstrated that placing retractors too far medially along the anterior wall substantially increases the risk of injury [11].

Forced hip maneuvers during femoral preparation are another possible cause of femoral nerve palsy after total hip arthroplasty. When the surgery is performed in the lateral position, the femur has to be positioned in hyperextension, adduction, and external femoral rotation, and the prolonged combination of these positions may increase the chance of overstretching the femoral nerve [12]. The same combination of positions may occur when broaching the femur with the patient in supine position, especially if placing the operative leg in hyperextension combined with excessive knee flexion.

Lateral Femoral Cutaneous Nerve Injuries

Lesion of the lateral femoral cutaneous nerve (LFCN) with paresthesia following THA is a known potential sequela which is also more unique to anterior approaches. This malady has been widely described for the DA approach. Although injury to the LFCN does not represent a major neurological complication, as compared with the potentially catastrophic outcomes of sciatic and femoral nerve palsies, its symptoms may be disturbing for many patients. The LFCN exclusively carries afferent sensory fibers. Typically, the main symptoms reported by patients with injury to the LFCN are numbness, which may be associated with a burning sensation on the anterolateral thigh, and, in worst cases, dysesthesias [13]. Previous studies show that these symptoms can affect the quality of life (QOL) of patients independent of the function of their THA [14, 15]. As mentioned previously, despite the soft tissue-preserving nature of the DA approach, this approach has an increased danger of damaging the LFCN; the literature shows a rate of injury of between 0.1% and 81%. This wide variation may be explained by different interpretations or lack of recognition of LFCN injury or by the diversity of skin incisions chosen for this anterior-based approach. Focusing on the six studies which primarily assessed LFCN lesions in DA THA, a total of 345 LFCN lesions in 1113 patients (IQR: 19.4–56.5) were identified corresponding to an average incidence rate of 31%.

On the contrary, injuries to the LFCN are very rarely reported in the literature after the ABMS approach. Even considering the potential bias that the true incidence rate might be underestimated in studies without a strong focus on LFCN lesions, such as those on ABMS approach, the anatomy of LFCN is crucial to understand the potential diminished risk of LFCN injury in ABMS THA. The lateral femoral cutaneous nerve is usually derived from the dorsal branches of the L2 and L3 ventral rami. It appears from under the lateral border of the psoas major and travels toward the notch on the anterior superior iliac spine (ASIS), exiting the lesser pelvis by passing under the inguinal ligament thus providing sensory innervation to the skin of the anterolateral and lateral aspects of the thigh. The most important point as it relates to the ABMS approach is the highly variable branching pattern of the LFCN. More recently, as a result of increasing interest in anterior approaches, this variable branching pattern has been the object of many anatomical studies. Rudin et al. described the following three types of branching pattern of the LFCN [16]:

- *Sartorius type:* a dominant anterior branch of the LFCN coursed along the lateral border of the sartorius muscle (36% of the cases).
- *Posterior type*: a strong posterior branch, equal in thickness to, or thicker than, the anterior branch. The posterior branch of the LFCN consistently branched off laterally and crossed the medial border of the tensor fasciae (32% of the cases).
- *Fan type*: multiple nerve branches of equal thickness spread over the anterolateral region of the proximal aspect of the thigh, crossing over the tensor fasciae latae muscle and the lateral border of the sartorius (32% of the cases).

In the presence of a *posterior*- and moreover of a *fan-type* LFCN pattern, injury to some branches of the LFCN cannot be avoided with DA approach. Even if a surgeon moves the skin incision laterally and distally, with these two anatomical variations, the LCFN remains at significant risk of injury. Because the interval between TFL and sartorius is exploited with blunt dissection, the average 32% rate of lesions found in the literature is justified even if, as noted in a recent study by Thaler et al., the posterior type and fan type are appreciably less frequently encountered than previously reported [17]. On the other hand, the surgical anatomy and interval of dissection of the ABMS approach correlate with a lower incidence of LFCN injury.

Superior Gluteal Nerve

The superior gluteal nerve (SGN) branches to the tensor fascia latae (TFL) are reported to be at risk for injury in both the ABMS and DA approaches [18–21]. The incidence, however, is lower in the ABMS approach compared with the DA [20, 21]. SGN injury can cause postoperative muscle atrophy and fatty infiltration of the TFL and rarely may influence improvement in hip function and gait postoperatively. For these reasons, injuries to the TFL following THA may often remain underdiagnosed. Irrespective of the approach, and apart from a cosmetic defect, most patients with TFL atrophy show no clinical symptoms, and this complication remains undetected [22].

The superior gluteal nerve is a motor nerve, which derives from the posterior branches of the ventral rami of the fourth and fifth lumbar and the first sacral spinal nerves supplying the gluteus medius (GMed), gluteus minimus, and tensor fasciae latae muscles. The roots of the superior gluteal nerve (L4, L5, and S1) arise within the pelvis from the sacral plexus and enter the buttock through the greater sciatic foramen, above the piriformis muscle. The gluteal nerve is the only motor nerve that exits superior to the piriformis muscle and then divides into a superior and an inferior branch [23]. The gluteus medius (GMed) and minimus muscles are both innervated by the superior and inferior branches. The terminal branches of the inferior branch innervate TFL which runs anteriorly to the GMed and minimus [24].

It has been demonstrated that in anterior-based approaches such as the ABMS approach, most of the terminal branches of the SGN enter the TFL muscle in the proximal fourth of the incision. Furthermore, such terminal branches may be damaged by exerting increased force on retractors on the TFL [25]. Fatty atrophy of the TFL as an indirect sign of SGN injury (which consequently can lead to degeneration) has been reported after ABMS approach; Unis et al. found postoperative fatty atrophy of the TFL using magnetic resonance imaging (MRI) in 42% of 26 patients who underwent THA using the ABMS approach [19]. However, these results have not been confirmed by other authors; Muller et al., in 44 patients who were prospectively randomized to receive a cementless THA with ABMS approach, found no increased damage to the TFL with the ABMS approach [26]. In addition, our group investigated this question as well. Using surface electromyography (sEMG), we evaluated a group of 32 patients undergoing ABMSTHA and compared them to a matched group of 32 patients who received a THA using DA approach. In the ABMS cohort, dynamic sEMG signal of TFL showed no alteration in signal amplitude during THA, thus adding further evidence that the ABMS muscle interval may be safer to protect against traction injuries of the SGN compared to the DA approach [8]. Finally, Takada et al. compared the ABMS and the DA approaches in 30 patients who underwent bilateral THA by examining the TFL muscle before and after surgery; with the DA, they found a significantly larger reduction in the cross-sectional area of the TFL muscle. They concluded that the use of the DA approach as compared to the ABMS approach could lead more frequently to injuries to the terminal branches of the SGN and consequently to the TFL [20].

Sciatic Nerve Injury

Sciatic nerve injury is much less common with anterior approach THAs than with the posterior approach; however, it is possible and its incidence during the DA approach has been reported to be up to 0.06%. The sciatic nerve requires consideration during all hip approaches, as posterior retractor placement and/or posterior retraction may lead to possible compression. Another risk factor for indirect injury to the sciatic nerve in anterior-based approaches is the excessive traction, extension, and external rotation of the limb during femoral preparation [7].

Tips and Tricks to Avoid Nerve Complications in ABMS Surgery

- To avoid femoral nerve palsy, anterior retractors should be placed as superiorly as possible in a relative safe zone superior to the 12 o'clock position defined as the intersection of a line from the middle of the femoral neck to the anterior wall of the acetabulum (Fig. 14.1).
- The tip of the retractor must make contact with the anterior lip of the acetabulum, and this contact must be maintained. Pay attention not to remove pressure from the retractor, because retractors released and repositioned by assistants allow the nerve to fall under the retractor tip and ultimately become compressed by the retractor.
- We recommend that the anterior retractor pull should be limited to a necessary minimum. Using the so-called mobile window allows for appropriate relaxation.
- Try to limit hyperextension, adduction, and femoral rotation when broaching the femoral canal. If the surgery is performed in the supine position, do not exceed 60 degrees of knee flexion to release the femoral nerve.
- To avoid LCFN injuries, the skin incision should move laterally approximately through a straight line made at the anterior border of the trochanter, one-third caudal and two-thirds cranial to the trochanter tip; limit the proximal extension of the incision.
- When exploiting the deep layer between the gluteus medius and TFL, the surgeon should start distally and move proximally to protect the SGN. The terminal branches of the lateral femoral circumflex artery are present distally and should be coagulated. Proximally, one or more terminal branches of the SGN will be encountered and should be preserved and manipulated proximally out of the surgical field.

Dislocations

The most common reason for THA failure and indication for early revision is hip dislocation [27–30]. The rate of dislocation after primary THA ranges from 0.2% to 10%. Dislocation after THA represents a major challenge to orthopedic surgeons and the healthcare system [31, 32]. The majority of first-time dislocations occur early, with approximately 60–70% reported within the first 8–12 weeks following the operative procedure [33–35]. Patients suffering an initial dislocation after this early period are at greater risk of

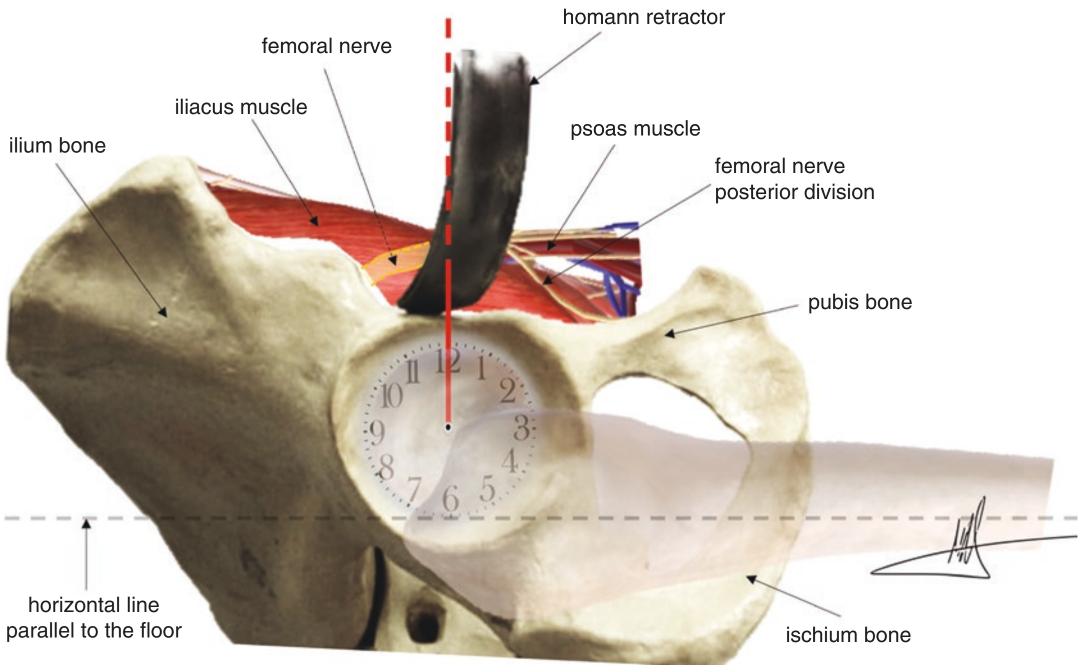


Fig. 14.1 Rendering drawing of the right hip joint. Femoral nerve is located behind the iliac muscle (yellow dashed line). The lateral view of the femoral shaft is parallel to the floor (black dashed line). Hohmann retractor is positioned proximally at 12 o'clock relative to the black horizontal dashed line. (Drawing made by the authors of the chapter, Matteo Innocenti)

experiencing recurrent dislocations. The risk of a recurrent dislocation is highly variable, with two large series [36, 37] showing an incidence of approximately 33%. The risk factors for dislocation include implant design, implant orientation and alignment, impingement, spino-pelvic imbalance (SPI), and surgical approach. Other factors that are intrinsic to the patients – thus not modifiable – have also been implicated: obesity, neurological disability, age, and sex. However, when the choice of implant design is correct and implants are well positioned, surgical approach is the most important factor affecting the risk of dislocation. Modifications of traditional anterior-based surgical approaches were introduced to reduce dislocations and facilitate early rehabilitation after surgery [38–41]. Several recent studies have compared the newer approaches with traditional lateral- and posterior-based approaches [42–46] showing that the main advantage of anterior-based approaches has been reduction in the incidence of hip dislocation [47–49]. Charney et al. [50] reported a lower risk of dislocation (hazard ratio [HR] = 0.39) and revision for instability (HR = 0.33) of anterior approaches compared to posterior approach. Higgins et al. [51] likewise reported a significant difference in the number of postoperative dislocations favoring the anterior approach (OR: 0.29, 95% CI 0.09–0.95). Through a posterolateral approach, the joint is violated from posterior, where the capsule is both anatomically weaker and represents the only static stabilizer; only the ischiofemoral ligament reinforces the capsule, but its insertion is not complete over the femoral neck and thus does not extend to the intertrochanteric ridge. The short external rotators (SER) contribute to the dynamic stability of the joint; however, several works have demonstrated that SER and capsule repair at the end of surgery does not modify the risk of dislocation [52, 53]. Moreover, the vast majority of dislocations occur in a posterior direction, even using anterior approaches [54]. All these features demonstrate how the posterior side of the joint is naturally weaker and further account for the increased risk of instability with a posterior approach.

When compared with the DA approach, the ABMS literature does not show different rates of dislocation. Shet et al. [55], in a large total joint replacement registry, found that the ABMS approach (adjusted HR, 0.29) and the DA approach (adjusted HR, 0.44) had a lower risk of dislocation relative to the posterior approach, but nonsignificant differences were found when comparing the direct anterior approach with the ABMS approach. In our personal experience of a prospective cohort study of 343 hips in 321 patients undergoing THA with ABMS approach, we had only 1 dislocation (0.3%).

The reduced dislocation rate with ABMS approach is particularly relevant in case of THA for femoral neck fracture. Recent studies have shown that compared to the posterolateral approach, the ABMS approach strongly reduces this risk. Sköldenberg et al. [56], after changing the approach, reported a reduction in dislocation rate from 8% with posterior approach to 2% with the ABMS approach. Enocson et al. [57], analyzing factors influencing the stability of the total hip replacement and paying special attention to the surgical approach, noted that the ABMS approach was associated with a lower risk of dislocation than the posterior approach with or without posterior repair (2% with ABMS approach, 12% with posterior approach with posterior repair, and 14% with posterior approach without posterior repair ($p < 0.001$)). The posterior approach was the only factor associated with a significantly increased risk of dislocation, with a hazard ratio (HR) of 6 (2–14) for the posterior approach with repair and of 6 (2–16) without repair. This study again underlined how the capsular repair does not significantly protect against hip instability.

Tips and Tricks to Avoid Dislocation

- It is of paramount importance to optimally position patients on the operating room (OR) table to ensure a correct position of the acetabular component. In the lateral position, the pelvic plane may often not be precisely perpendicular to the floor, and its inclination can be potentially altered by gravity. Considering the pelvic plane in the lateral decubitus as a plane parallel to the pubis symphysis, it tends to tilt caudally in patients with a "wide pelvis" and tilt cranially in those with "narrow pelvis." The acetabulum follows the pelvic plane and moves backward or forward accordingly.
- After positioning the patient, we advise taking a preoperative pelvis X-ray to evaluate the amount of lateral opening/closing pelvic tilt in order to correct the inclination of the cup intraoperatively.
- During impaction of the cup, it may be helpful to measure its inclination by using a sterile bubble level. This allows the surgeon to position the cup with the desired inclination and to correct the lateral pelvic tilt intrinsically caused by gravity.
- If the surgery is performed in the supine position, the pelvic plane is in the same reference plane as the floor (angled backward in the pelvis with posterior tilt and forward in the pelvis with anterior tilt), and this may help surgeons in spatial orientation while positioning the cup (referring to a plane parallel to their sight and the floor). However, we prefer to sterilely drape both legs in the surgical field. This allows for an easy check of the leg length discrepancy.
- In the supine position, an intraoperative X-ray or fluoroscopy enables an accurate evaluation of cup and stem position, offset, and leg length.
- In cases of spino-pelvic imbalance, a lumbar lateral standing and upright-seated projection should also be performed, in addition to classic hip anteroposterior (AP) and direct lateral views. The spino-pelvic parameters must be evaluated, and a correction of cup inclination/version should be considered.

Intraoperative Periprosthetic Fractures

Intraoperative periprosthetic fractures (IPPF) are well-described complications of THA. The incidence of intraoperative periprosthetic fractures in primary THA ranges from 0.3% up to 27.8% depending on the stem used, whether the stem was cemented or press fit, on the instrumentation design adopted and many other variables [58–64]. IPPF can eventually happen independent of the surgical approach used. Nevertheless, many orthopedic surgeons believe that some surgical approaches, in particular those that are anterior-based and/or less invasive, may introduce additional risks of complications such as IPPF due to the limited surgical exposure and visibility of anatomical landmarks [65–68]. This notion, however, is not conclusively supported in the orthopedic literature. At the time of this writing, there is only one paper in literature describing different incidences of IPPF comparing different mini-invasive surgical approaches in a homogenous population of patients [69]. The authors reported a percentage of 0.85% of intraoperative fractures in the posterior group, 0.75% in the anterior group, 2.42% in the "superpath" group, and 0.51% in the direct lateral group. No fracture was described when performing the ABMS approach. Nevertheless, the latter report should be considered with caution since only 30 patients were in the ABMS approach cohort out of 3728 consecutive patients undergoing primary elective unilateral THA. Therefore, despite the risk factors for IPPF which have been well described for the DA approach [59, 70–78], this topic has not been equally explored for the ABMS approach.

Reports about IPPF using this anterolateral muscle-sparing approach mostly result from small retrospective case series with a high difference in fractures' percentages which vary from report to report. Klasan et al. reported a low incidence describing only 2 IPPF (0.5%) among a group of 396 primary THAs: one was a minimally dislocated acetabular fracture that needed no revision, and the other was a Vancouver B fracture that was treated with immediate wiring [72]. In a study by Nakai et al., an intraoperative fracture was observed in six hips (5.8%), of which three were greater trochanter fractures and three medial calcar fractures [79]. About the same incidence was described by Herdon and Geller et al. reporting 28 fractures (4.1%) in 648 primary THAs. All intraoperative fractures involved the femoral side and were fixed at the time of surgery (26 with one or more cerclage cables, 1 with suture fixation, and 1 with a greater trochanter locking plate and screws) and healed without adverse events. An incidence of intraoperative fracture of 5% was also reported by Zao et al. In contrast to all of the other studies, the latter author postulated that the ABMS approach may have been a significant risk factor for intraoperative fracture considering univariate analysis ($p = 0.003$) [80]. Conversely, Tsai et al. described only 7 IPPF in 1077 hips using this ABMS approach with an overall fracture's incidence of 0.65%, highlighting that the ABMS approach is a safe method with a very low complication rate [81]. Similarly, a fracture incidence of 1.14% was shown by Pflüger et al. [82], who reported a total of four femoral shaft fractures. All fractures occurred during the early development of this technique in their facility.

Therefore, extracting data from those few clinical series, there appears to be very little difference in the incidence of acetabular and femoral fractures in both the ABMS and DA approaches.

The greater trochanter still remains the most common site of IPPF. The causes of greater trochanter fractures are variable. In obese patients [83], the ABMS approach leads to difficulty in extending the hip joint to the femoral side and is likely to be complicated by fractures especially when there is suboptimal release of the joint capsule and external rotators combined with the use of a two-tined retractor for elevation of the femur [68]. In our experience, insufficient soft tissue release can lead to undue tension around the trochanteric area putting this structure at high risk of avulsion fractures. Another possible cause may be when using a straight broach during the femur preparation, in particular for a conventional straight double- or triple-tapered meta-diaphyseal engaging stem that requires a meticulous preparation of the greater trochanter area. Most commonly, fractures at the medial calcar are more prone to occur during the insertion of the final stem depending mainly on the design of the stem itself. In some instances, diaphyseal fracture can occur in a similar manner or during femoral broaching especially when torsional forces (combined adduction and external rotation) are applied by an assistant to help proximal femur exposure while performing ABMS approach in a supine position.

During the past decade, the adoption of this and other less invasive approaches has evolved along with the increasingly common use of short metaphyseal cementless stems. Press-fit stems have already been associated in literature with a higher incidence of periprosthetic fracture because the operative technique requires more aggressive broaching of the medullary canal with tighter fixation of the stem to avoid micromotion between the femoral component and cortical bone [60, 61, 63]. Given that, we should question whether the approach itself or the use of a cementless stem puts the femur at a higher risk of fracture than using a cemented stem with conventional approaches.

Risk factors for IPPF can therefore be divided into general- and approach-related factors. The more common general risk factors to consider are osteoporosis, increasing age, female sex [84], medical comorbidities such as rheumatoid arthritis (even though those latter three could also be confounded by osteoporosis or osteopenia) [85, 86], altered bone morphology or deformity, as seen in Paget's disease or developmental dysplasia of the hip [87], and obesity [83]. Approach-related factors may include not only surgeon-related factors such as the use of minimally invasive approaches and familiarity with individual prostheses but also implant design factors such as uncemented components and implant geometry [59, 68, 88, 89]. Interestingly, Greenhill et al. have shown that not only implant choice but also broach design could affect IPPF [90]. Given all of these factors, the reported epidemiology, the studies comparing different approaches, and the general- and approach-/implant-related risk factors for IPPF, we strongly believe that this ABMS approach should be considered safe with respect to incidence of intraoperative periprosthetic fractures once the following tips and tricks are observed.

Tips and Tricks to Avoid Intraoperative Femoral Fracture

- A stepwise and accurate soft tissue release is crucial to improve visualization, thus helping to avoid IPPF with the ABMS approach. First, a complete anterior capsulectomy or thorough capsular release is suggested. After that, while pulling the femur up with either a bone hook or a two-tined Hohmann retractor placed at the level of the bald spot in the greater trochanter, a deep vertical capsular release should be performed at the level of the greater trochanter apex. Then, always staying attached to the bone, the release should move medially toward the external rotators. Here, the release should be as relevant as necessary in order to get the proper femoral external rotation.
- Consider using curved (offset) broaches when preparing the femur. Especially in muscular patients with a tight/developed GMed muscle, we strongly recommend the use of curved (offset) broaches avoiding tension on the GMed that can detach/break the greater trochanter at the level of its insertion.
- In the presence of an osteoporotic female patient older than 70 years old, with a critical Metaphyseal-Diaphyseal Index [91] (a Dorr-type C proximal femur [92]), the use of a cemented metadiaphyseal stems should be considered. The ABMS approach helps improve femoral exposure compared to the DA approach by allowing the use of conventional cemented stems without increasing the risk of IPPF.
- Accurate preoperative planning, once a cementless stem is chosen, should be selected and templated based on patient anatomy. Once templating is performed accurately, the surgeon should pay close attention to the preoperative plan to help avoid medial calcar fracture potentially caused by an oversized press-fit stem.

- The assistant is as important as the surgeon to obtain adequate exposure. It is mandatory that the assistant firmly hold the position of the leg during broaching to avoid rotational forces that can lead to a diaphyseal spiral fracture of the femur.

Conclusion

THA performed with an ABMS approach may result in significant complications similar to that of other approaches. Based on the relevant anatomical influence of this anterior-based approach, three complications appear to be more procedure-specific: nerve injuries, intraoperative periprosthetic fractures, and postoperative dislocations. Nerve injury is a relatively rare, yet potentially devastating, complication: lateral femoral cutaneous nerve (LFCN) and femoral nerve (FN) injuries are potentially more prevalent with the ABMS approach than other more lateral or posterior-based approaches. Placing the skin incision at about the anterior edge of the greater trochanter, and firmly positioning the Hohmann retractor at 12 o'clock without applying too much tension on the underling soft tissue/muscle structures, helps surgeons avoid such nerve injuries. Several studies in literature reported that the main advantage of anterior-based approaches has been reduction in the incidence of hip dislocation. A careful examination of patients' spino-pelvic motility, an accurate calculation of pelvic tilt, and a spino-pelvic imbalance, as well as a meticulous patient positioning during surgery, drastically reduce the risk of dislocation with this ABMS approach. Intraoperative periprosthetic fractures are thought to be more common with the ABMS approach compared with posterior approaches. As for anterior-based approaches, fractures are less commonly reported with the ABMS approach compared with the DA approach. The greater trochanter is the site most prone to fracture with the use of ABMS approach: accurate planning of the appropriate prosthesis design and size in conjunction with proper peri-trochanteric soft tissue releases and patient positioning diminishes this risk.

References

1. Taylor-Williams O, Nossent J, Inderjeeth CA. Incidence and complication rates for total hip arthroplasty in rheumatoid arthritis: a systematic review and meta-analysis across four decades. Rheumatol Ther. 2020;7:685–702. https://doi.org/10.1007/s40744-020-00238-z.
2. Upadhyay A, York S, Macaulay W, et al. Medical malpractice in hip and knee arthroplasty. J Arthroplast. 2007;22:2–7. https://doi.org/10.1016/j.arth.2007.05.003.
3. Healy WL, Iorio R, Clair AJ, et al. Complications of total hip arthroplasty: standardized list, definitions, and stratification developed by the hip society. Clin Orthop Relat Res. 2016;474:357–64. https://doi.org/10.1007/s11999-015-4341-7.
4. DeHart MM, Riley LHJ. Nerve injuries in total hip arthroplasty. J Am Acad Orthop Surg. 1999;7:101–11. https://doi.org/10.5435/00124635-199903000-00003.
5. Fleischman AN, Rothman RH, Parvizi J. Femoral nerve palsy following total hip arthroplasty: incidence and course of recovery. J Arthroplast. 2018;33:1194–9. https://doi.org/10.1016/j.arth.2017.10.050.
6. Su EP. Post-operative neuropathy after total hip arthroplasty. Bone Joint J. 2017;99-B:46–9. https://doi.org/10.1302/0301-620X.99B1.BJJ-2016-0430.R1.
7. Macheras GA, Christofilopoulos P, Lepetsos P, et al. Nerve injuries in total hip arthroplasty with a mini invasive anterior approach. Hip Int. 2016;26:338–43. https://doi.org/10.5301/hipint.5000352.
8. Civinini R, Cozzi Lepri A, Carulli C, et al. The anterior-based muscle-sparing approach to the hip: the "other" anterior approach to the hip. Int Orthop. 2019;43:47–53. https://doi.org/10.1007/s00264-018-4190-6.
9. McConaghie FA, Payne AP, Kinninmonth AWG. The role of retraction in direct nerve injury in total hip replacement: an anatomical study. Bone Joint Res. 2014;3:212–6. https://doi.org/10.1302/2046-3758.36.2000255.
10. Sullivan CW, Banerjee S, Desai K, et al. Safe zones for anterior acetabular retractor placement in direct anterior total hip arthroplasty: a cadaveric study. J Am Acad Orthop Surg. 2019;27:e969–76. https://doi.org/10.5435/JAAOS-D-18-00712.
11. Shubert D, Madoff S, Milillo R, Nandi S. Neurovascular structure proximity to acetabular retractors in total hip arthroplasty. J Arthroplast. 2015;30:145–8. https://doi.org/10.1016/j.arth.2014.08.024.

12. Vajapey SP, Morris J, Lynch D, et al. Nerve injuries with the direct anterior approach to total hip arthroplasty. JBJS Rev. 2020;8:e0109. https://doi.org/10.2106/JBJS.RVW.19.00109.
13. Goulding K, Beaulé PE, Kim PR, Fazekas A. Incidence of lateral femoral cutaneous nerve neuropraxia after anterior approach hip arthroplasty. Clin Orthop Relat Res. 2010;468:2397–404. https://doi.org/10.1007/s11999-010-1406-5.
14. Dahm F, Aichmair A, Dominkus M, Hofstaetter JG. Incidence of lateral femoral cutaneous nerve lesions after direct anterior approach primary total hip arthroplasty - a literature review. Orthop Traumatol Surg Res. 2021;102956. https://doi.org/10.1016/j.otsr.2021.102956.
15. Homma Y, Baba T, Sano K, et al. Lateral femoral cutaneous nerve injury with the direct anterior approach for total hip arthroplasty. Int Orthop. 2016;40:1587–93. https://doi.org/10.1007/s00264-015-2942-0.
16. Rudin D, Manestar M, Ullrich O, et al. The anatomical course of the lateral femoral cutaneous nerve with special attention to the anterior approach to the hip joint. J Bone Joint Surg Am. 2016;98:561–7. https://doi.org/10.2106/JBJS.15.01022.
17. Thaler M, Dammerer D, Hechenberger F, et al. The anatomical course of the lateral femoral cutaneous nerve in relation to various skin incisions used for primary and revision total hip arthroplasty with the direct anterior approach. J Arthroplast. 2021;36:368–73. https://doi.org/10.1016/j.arth.2020.07.052.
18. Ince A, Kemper M, Waschke J, Hendrich C. Minimally invasive anterolateral approach to the hip: risk to the superior gluteal nerve. Acta Orthop. 2007;78:86–9. https://doi.org/10.1080/17453670610013466.
19. Unis DB, Hawkins EJ, Alapatt MF, Benitez CL. Postoperative changes in the tensor fascia lata muscle after using the modified anterolateral approach for total hip arthroplasty. J Arthroplast. 2013;28:663–5. https://doi.org/10.1016/j.arth.2012.06.032.
20. Takada R, Jinno T, Miyatake K, et al. Direct anterior versus anterolateral approach in one-stage supine total hip arthroplasty. Focused on nerve injury: a prospective, randomized, controlled trial. J Orthop Sci. 2018;23:783–7. https://doi.org/10.1016/j.jos.2018.05.005.
21. Takada R, Jinno T, Miyatake K, et al. Incidence of tensor fascia lata muscle atrophy after using the modified Watson-Jones anterolateral approach in total hip arthroplasty. Eur J Orthop Surg Traumatol. 2021;31:533–40. https://doi.org/10.1007/s00590-020-02806-z.
22. Grob K, Manestar M, Ackland T, et al. Potential risk to the superior gluteal nerve during the anterior approach to the hip joint: an anatomical study. J Bone Joint Surg Am. 2015;97:1426–31. https://doi.org/10.2106/JBJS.O.00146.
23. Putzer D, Haselbacher M, Hörmann R, et al. The distance of the gluteal nerve in relation to anatomical landmarks: an anatomic study. Arch Orthop Trauma Surg. 2018;138:419–25. https://doi.org/10.1007/s00402-017-2847-z.
24. Apaydin N, Kendir S, Loukas M, et al. Surgical anatomy of the superior gluteal nerve and landmarks for its localization during minimally invasive approaches to the hip. Clin Anat. 2013;26:614–20. https://doi.org/10.1002/ca.22057.
25. Starke V, Stofferin H, Mannschatz S, et al. The anatomical course of the superior gluteal nerve with regard to the direct anterior approach for primary and revision total hip arthroplasty. J Arthroplast. 2021;36:1138–42. https://doi.org/10.1016/j.arth.2020.09.045.
26. Müller M, Tohtz S, Dewey M, et al. Evidence of reduced muscle trauma through a minimally invasive anterolateral approach by means of MRI. Clin Orthop Relat Res. 2010;468:3192–200. https://doi.org/10.1007/s11999-010-1378-5.
27. D'Lima DD, Urquhart AG, Buehler KO, et al. The effect of the orientation of the acetabular and femoral components on the range of motion of the hip at different head-neck ratios. J Bone Joint Surg Am. 2000;82:315–21. https://doi.org/10.2106/00004623-200003000-00003.
28. Miyoshi H, Mikami H, Oba K, Amari R. Anteversion of the acetabular component aligned with the transverse acetabular ligament in total hip arthroplasty. J Arthroplast. 2012;27:916–22. https://doi.org/10.1016/j.arth.2011.10.017.
29. Sariali E, Klouche S, Mamoudy P. Investigation into three dimensional hip anatomy in anterior dislocation after THA. Influence of the position of the hip rotation Centre. Clin Biomech (Bristol, Avon). 2012;27:562–7. https://doi.org/10.1016/j.clinbiomech.2011.12.014.
30. Widmer K-H, Majewski M. The impact of the CCD-angle on range of motion and cup positioning in total hip arthroplasty. Clin Biomech (Bristol, Avon). 2005;20:723–8. https://doi.org/10.1016/j.clinbiomech.2005.04.003.
31. Ong KL, Mowat FS, Chan N, et al. Economic burden of revision hip and knee arthroplasty in Medicare enrollees. Clin Orthop Relat Res. 2006;446:22–8. https://doi.org/10.1097/01.blo.0000214439.95268.59.
32. Saiz AM, Lum ZC, Pereira GC. Etiology, evaluation, and management of dislocation after primary total hip arthroplasty. JBJS Rev. 2019;7:e7. https://doi.org/10.2106/JBJS.RVW.18.00165.
33. Blom AW, Rogers M, Taylor AH, et al. Dislocation following total hip replacement: the Avon Orthopaedic Centre experience. Ann R Coll Surg Engl. 2008;90:658–62. https://doi.org/10.1308/003588408X318156.
34. Li E, Meding JB, Ritter MA, et al. The natural history of a posteriorly dislocated total hip replacement. J Arthroplast. 1999;14:964–8. https://doi.org/10.1016/s0883-5403(99)90011-6.
35. Williams JF, Gottesman MJ, Mallory TH. Dislocation after total hip arthroplasty. Treatment with an above-knee hip spica cast. Clin Orthop Relat Res. 1982:53–8.

36. Kristiansen B, Jørgensen L, Hölmich P. Dislocation following total hip arthroplasty. Arch Orthop Trauma Surg Arch fur orthopadische und Unfall-Chirurgie. 1985;103:375–7. https://doi.org/10.1007/BF00435444.
37. Jolles BM, Zangger P, Leyvraz P-F. Factors predisposing to dislocation after primary total hip arthroplasty: a multivariate analysis. J Arthroplast. 2002;17:282–8. https://doi.org/10.1054/arth.2002.30286.
38. Bertin KC, Röttinger H. Anterolateral mini-incision hip replacement surgery: a modified Watson-Jones approach. Clin Orthop Relat Res. 2004:248–55.
39. Jerosch J, Theising C, Fadel ME. Antero-lateral minimal invasive (ALMI) approach for total hip arthroplasty technique and early results. Arch Orthop Trauma Surg. 2006. https://doi.org/10.1007/s00402-006-0113-x.
40. Kennon R, Keggi J, Zatorski LE, Keggi KJ. Anterior approach for total hip arthroplasty: beyond the minimally invasive technique. J Bone Joint Surg Am. 2004;86-A Suppl:91–7. https://doi.org/10.2106/00004623-200412002-00013.
41. Matta JM, Ferguson TA. The anterior approach for hip replacement. Orthopedics. 2005;28:927–8. https://doi.org/10.3928/0147-7447-20050901-11.
42. Alecci V, Valente M, Crucil M, et al. Comparison of primary total hip replacements performed with a direct anterior approach versus the standard lateral approach: perioperative findings. J Orthop Traumatol. 2011;12:123–9. https://doi.org/10.1007/s10195-011-0144-0.
43. de Verteuil R, Imamura M, Zhu S, et al. A systematic review of the clinical effectiveness and cost-effectiveness and economic modelling of minimal incision total hip replacement approaches in the management of arthritic disease of the hip. Health Technol Assess. 2008;12:iii–iv, ix–223. https://doi.org/10.3310/hta12260.
44. Edmunds CT, Boscainos PJ. Effect of surgical approach for total hip replacement on hip function using Harris hip scores and Trendelenburg's test. A retrospective analysis. Surgeon. 2011;9:124–9. https://doi.org/10.1016/j.surge.2010.08.014.
45. Goosen JH, Kollen BJ, Castelein RM, Kuipers BM, Verheyen CC. Minimally invasive versus classic procedures in total hip arthroplasty: a double-blind randomized controlled trial. Clin Orthop Relat Res. 2011;469(1):200–8. https://doi.org/10.1007/s11999-010-1331-7.
46. Yang B, Li H, He X, et al. Minimally invasive surgical approaches and traditional total hip arthroplasty: a meta-analysis of radiological and complications outcomes. PLoS One. 2012;7:e37947. https://doi.org/10.1371/journal.pone.0037947.
47. Restrepo C, Mortazavi SMJ, Brothers J, et al. Hip dislocation: are hip precautions necessary in anterior approaches? Clin Orthop Relat Res. 2011;469:417–22. https://doi.org/10.1007/s11999-010-1668-y.
48. Sköldenberg OG, Salemyr MO, Bodén HS, et al. The effect of weekly risedronate on periprosthetic bone resorption following total hip arthroplasty: a randomized, double-blind, placebo-controlled trial. J Bone Joint Surg Am. 2011;93:1857–64. https://doi.org/10.2106/JBJS.J.01646.
49. Zimmerma S, Hawkes WG, Hudson JI, et al. Outcomes of surgical management of total HIP replacement in patients aged 65 years and older: cemented versus cementless femoral components and lateral or anterolateral versus posterior anatomical approach. J Orthop Res. 2002;20:182–91. https://doi.org/10.1016/S0736-0266(01)00090-0.
50. Charney M, Paxton EW, Stradiotto R, et al. A comparison of risk of dislocation and cause-specific revision between direct anterior and posterior approach following elective cementless total hip arthroplasty. J Arthroplast. 2020;35:1651–7. https://doi.org/10.1016/j.arth.2020.01.033.
51. Higgins BT, Barlow DR, Heagerty NE, Lin TJ. Anterior vs. posterior approach for total hip arthroplasty, a systematic review and meta-analysis. J Arthroplast. 2015;30:419–34. https://doi.org/10.1016/j.arth.2014.10.020.
52. Zhou Y, Cao S, Li L, et al. Is soft tissue repair a right choice to avoid early dislocation after THA in posterior approach? BMC Surg. 2017;17:60. https://doi.org/10.1186/s12893-017-0212-3.
53. Stangl-Correa P, Stangl-Herrera W, Correa-Valderrama A, et al. Postoperative failure frequency of short external rotator and posterior capsule with successful reinsertion after primary total hip arthroplasty: an ultrasound assessment. J Arthroplast. 2020;35:3607–12. https://doi.org/10.1016/j.arth.2020.06.065.
54. Woo RY, Morrey BF. Dislocations after total hip arthroplasty. J Bone Joint Surg Am. 1982;64:1295–306.
55. Sheth D, Cafri G, Inacio MCS, et al. Anterior and anterolateral approaches for THA are associated with lower dislocation risk without higher revision risk. Clin Orthop Relat Res. 2015;473:3401–8. https://doi.org/10.1007/s11999-015-4230-0.
56. Sköldenberg O, Ekman A, Salemyr M, Bodén H. Reduced dislocation rate after hip arthroplasty for femoral neck fractures when changing from posterolateral to anterolateral approach. Acta Orthop. 2010;81:583–7. https://doi.org/10.3109/17453674.2010.519170.
57. Enocson A, Hedbeck C-J, Tidermark J, et al. Dislocation of total hip replacement in patients with fractures of the femoral neck. Acta Orthop. 2009;80:184–9. https://doi.org/10.3109/17453670902930024.
58. Sidler-Maier CC, Waddell JP. Incidence and predisposing factors of periprosthetic proximal femoral fractures: a literature review. Int Orthop. 2015;39(9):1673–82.
59. Berend KR, Lombardi AV Jr. Intraoperative femur fracture is associated with stem and instrument design in primary total hip arthroplasty. Clin Orthop Relat Res. 2010;468(9):2377–81. https://doi.org/10.1007/s11999-010-1314-8.
60. Taylor MM, Meyers MH, Harvey JP. Intraoperative femur fractures during total hip replace-

ment. Clin Orthop Relat Res. 1978. https://doi.org/10.1097/00003086-197811000-00013.
61. Berry DJ. Epidemiology: hip and knee. Orthop Clin North Am. 1999. https://doi.org/10.1016/S0030-5898(05)70073-0.
62. Abdel MP, Watts CD, Houdek MT, et al. Epidemiology of periprosthetic fracture of the femur in 32 644 primary total hip arthroplasties: a 40-year experience. Bone Jt J. 2016. https://doi.org/10.1302/0301-620X.98B4.37201.
63. Schwartz JT, Mayer JG, Engh CA. Femoral fracture during non-cemented total hip arthroplasty. J Bone Joint Surg Am. 1989. https://doi.org/10.2106/00004623-198971080-00003.
64. Stuchin SA. Femoral shaft fracture in porous and press-fit total hip arthroplasty. Orthop Rev. 1990;19(2):153–9.
65. Nakamura S, Matsuda K, Arai N, et al. Mini-incision posterior approach for total hip arthroplasty. Int Orthop. 2004. https://doi.org/10.1007/s00264-004-0570-1.
66. Restrepo C, Parvizi J, Pour AE, Hozack WJ. Prospective randomized study of two surgical approaches for total hip arthroplasty. J Arthroplast. 2010. https://doi.org/10.1016/j.arth.2010.02.002.
67. Woolson ST, Mow CS, Syquia JF, et al. Comparison of primary total hip replacements performed with a standard incision or a mini-incision. J Bone Joint Surg Am. 2004. https://doi.org/10.2106/00004623-200407000-00001.
68. Jewett BA, Collis DK. High complication rate with anterior total hip arthroplasties on a fracture table. Clin Orthop Relat Res. 2011;469(2):503–7. https://doi.org/10.1007/s11999-010-1568-1.
69. Aggarwal VK, Elbuluk A, Dundon J, et al. Surgical approach significantly affects the complication rates associated with total hip arthroplasty. Bone Joint J. 2019. https://doi.org/10.1302/0301-620X.101B6.BJJ-2018-1474.R1.
70. Hartford JM, Knowles SB. Risk factors for perioperative femoral fractures: cementless femoral implants and the direct anterior approach using a fracture table. J Arthroplast. 2016. https://doi.org/10.1016/j.arth.2016.02.045.
71. Matta JM, Shahrdar C, Ferguson T. Single-incision anterior approach for total hip arthroplasty on an orthopaedic table. Clin Orthop Relat Res. 2005;441:115–24. https://doi.org/10.1097/01.blo.0000194309.70518.cb.
72. Klasan A, Neri T, Oberkircher L, et al. Complications after direct anterior versus Watson-Jones approach in total hip arthroplasty: results from a matched pair analysis on 1408 patients. BMC Musculoskelet Disord. 2019. https://doi.org/10.1186/s12891-019-2463-x.
73. Barnett SL, Peters DJ, Hamilton WG, et al. Is the anterior approach safe? Early complication rate associated with 5090 consecutive primary total hip arthroplasty procedures performed using the anterior approach. J Arthroplast. 2016. https://doi.org/10.1016/j.arth.2015.07.008.
74. Kennon RE, Keggi JM, Wetmore RS, Zatorski LE, Huo MH, Keggi KJ. Total hip arthroplasty through a minimally invasive anterior surgical approach. J Bone Joint Surg Am. 2003;85-A Suppl 4:39–48. https://doi.org/10.2106/00004623-200300004-00005.
75. Cohen EM, Vaughn JJ, Ritterman SA, et al. Intraoperative femur fracture risk during primary direct anterior approach cementless total hip arthroplasty with and without a fracture table. J Arthroplast. 2017. https://doi.org/10.1016/j.arth.2017.04.020.
76. Dietrich M, Kabelitz M, Dora C, Zingg PO. Perioperative fractures in cementless total hip arthroplasty using the direct anterior minimally invasive approach: reduced risk with short stems. J Arthroplast. 2018. https://doi.org/10.1016/j.arth.2017.09.015.
77. Lee GC, Marconi D. Complications following direct anterior hip procedures: costs to both patients and surgeons. J Arthroplast. 2015. https://doi.org/10.1016/j.arth.2015.03.043.
78. Tamaki T, Jonishi K, Miura Y, et al. Cementless tapered-wedge stem length affects the risk of periprosthetic femoral fractures in direct anterior total hip arthroplasty. J Arthroplast. 2018. https://doi.org/10.1016/j.arth.2017.09.065.
79. Nakai T, Liu N, Fudo K, et al. Early complications of primary total hip arthroplasty in the supine position with a modified Watson-Jones anterolateral approach. J Orthop. 2014. https://doi.org/10.1016/j.jor.2014.08.005.
80. Zhao R, Cai H, Liu Y, et al.Risk factors for intraoperative proximal femoral fracture during primary cementless tha. Orthopedics. 2017. https://doi.org/10.3928/01477447-20161116-06.
81. Tsai SW, Chen CF, Wu PK, et al. Modified anterolateral approach in minimally invasive total hip arthroplasty. Hip Int. 2015. https://doi.org/10.5301/hipint.5000218.
82. Pflüger G, Junk-Jantsch S, Schöll V. Minimally invasive total hip replacement via the anterolateral approach in the supine position. Int Orthop. 2007. https://doi.org/10.1007/s00264-007-0434-6.
83. Iwata H, Sakata K, Sogo E, et al. Total hip arthroplasty via an anterolateral supine approach for obese patients increases the risk of greater trochanteric fracture. J Orthop. 2018. https://doi.org/10.1016/j.jor.2018.03.005.
84. Franklin J, Malchau H. Risk factors for periprosthetic femoral fracture. Injury. 2007. https://doi.org/10.1016/j.injury.2007.02.049.
85. Lindahl H. Epidemiology of periprosthetic femur fracture around a total hip arthroplasty. Injury. 2007. https://doi.org/10.1016/j.injury.2007.02.048.
86. Lindahl H, Garellick G, Regnér H, et al. Three hundred and twenty-one periprosthetic femoral fractures. J Bone Joint Surg Am. 2006. https://doi.org/10.2106/JBJS.E.00457.

87. Mitchell PA, Greidanus NV, Masri BA, et al. The prevention of periprosthetic fractures of the femur during and after total hip arthroplasty. Instr Course Lect. 2003;52:301–8.
88. Sheth NP, Brown NM, Moric M, et al. Operative treatment of early peri-prosthetic femur fractures following primary total hip arthroplasty. J Arthroplast. 2013. https://doi.org/10.1016/j.arth.2012.06.003.
89. Herndon CL, Nowell JA, Sarpong NO, et al. Risk factors for periprosthetic femur fracture and influence of femoral fixation using the mini-anterolateral approach in primary total hip arthroplasty. J Arthroplast. 2020. https://doi.org/10.1016/j.arth.2019.10.011.
90. Greenhill DA, Abbasi P, Darvish K, Star AM. Broach handle design changes force distribution in the femur during total hip arthroplasty. J Arthroplast. 2017. https://doi.org/10.1016/j.arth.2016.12.031.
91. Chana R, Mansouri R, Jack C, et al. The suitability of an uncemented hydroxyapatite coated (HAC) hip hemiarthroplasty stem for intra-capsular femoral neck fractures in osteoporotic elderly patients: the Metaphyseal-Diaphyseal index, a solution to preventing intraoperative periprosthetic fr. J Orthop Surg Res. 2011. https://doi.org/10.1186/1749-799X-6-59.
92. Dorr LD, Faugere MC, Mackel AM, et al. Structural and cellular assessment of bone quality of proximal femur. Bone. 1993. https://doi.org/10.1016/8756-3282(93)90146-2.

Revision of the Acetabulum in Total Hip Arthroplasty

15

Matthew M. Levitsky, Michael B. Held, and Roshan P. Shah

Learning Points

- Acetabular revision surgery can be safely performed for most indications using the anterior-based muscle-sparing (ABMS) approach.
- Standard acetabular revision principles are followed, including thorough preoperative workup for infection, bone loss, and mechanical factors while knowing the limitations of the ABMS approach.
- Proper positioning and soft tissue releases of the femur and circumferential acetabular exposure are critical for adequate visualization of the acetabulum to help locate ideal component positioning.
- Most anterior column defects can be safely and effectively treated through the ABMS approach, while large posterior column defects and discontinuities are more challenging due to restricted access of the posterior osseous anatomy.

Introduction

The number of total hip arthroplasties (THAs) performed each year is expected to increase by 71% between 2014 and 2030 [1]. Given the absolute increase in primary THA, there will be an inevitable increase in the absolute number of revision THA. Despite advances in prosthetic design and implantation techniques and decreasing revision rates for contemporary surgery, it is expected that the total number of revision total hip arthroplasties will more than double by 2030 [2]. The most common causes of revision THA include instability/dislocation, aseptic loosening, and infection [3]. Moreover, isolated acetabular component revision accounts for approximately 13% of all revision hip procedures, with the majority of these revisions being performed to address persistent postoperative instability. The primary purpose of this chapter is to summarize the benefits and limitations of utilizing the ABMS approach in the setting of isolated acetabular revision. We also aim to provide technical pearls and considerations to safely and effectively perform properly indicated acetabular revisions through the ABMS approach.

M. M. Levitsky (✉) · R. P. Shah
Columbia University Medical Center, Department of Orthopaedic Surgery, New York, NY, USA
e-mail: mml2221@cumc.columbia.edu; rs3464@cumc.columbia.edu

M. B. Held
New York Presbyterian- Columbia University Irving Medical Center, New York, NY, USA
e-mail: mh3821@cumc.columbia.edu

Indicating a Patient for Acetabular Revision Through the ABMS Approach

Preoperative Patient Evaluation

Pain, instability, infection, iliopsoas impingement, and leg length inequality are frequent reasons for failure of total hip replacements [4]. A

J. A. Geller, B. J. McGrory (eds.), *The Anterior-Based Muscle-Sparing Approach to Total Hip Arthroplasty*, https://doi.org/10.1007/978-3-031-02059-9_15

thorough history and physical exam are critical to identifying the patients' etiology of pain and THA dysfunction. The location and temporal nature of pain can help distinguish acetabular from femoral problems. Patients with femoral component loosening often localize symptoms to the proximal thigh and describe start-up pain, which resolves after a period of time walking. Acetabular loosening, on the other hand, can generally be associated with groin-based start-up pain. Infection can be obvious in some cases, with high fevers, micromotion pain, inability to walk, and even sepsis. More often, the symptoms may be subtle and require a thorough workup including serum erythrocyte sedimentation rate (ESR), c-reactive protein (CRP), and d-dimer; synovial fluid analysis including cell count, differential, alpha-defensin, and culture; and occasionally three-dimensional imaging [5]. Other causes of acetabular component failure may include iliopsoas impingement, which is felt with groin pain with hip flexion activities. In the seated position, resisted hip flexion with the provider applying an internal rotation moment on the hip will cause more agitation of the iliopsoas; and the symptoms improve with an external rotation moment. Direct lateral radiographs may be helpful to assess acetabular overhang [6]. These cases are particularly good for ABMS revision as the anterior rim and iliopsoas can be clearly inspected from this approach. Leg length discrepancy can be assessed at the ankles in the supine position and will occasionally require length radiographs or computed tomography (CT) scanogram to understand developmental issues related to differential bone lengths. Surgeons should carefully assess for hip flexion contractures and knee contractures when assessing leg lengths.

Prior surgical notes are helpful to understand if size or prosthetic design is contributing to the malfunction of the existing THA. The selection of acetabular explantation osteotomes will depend on the cup size and geometry. Hemispherical cups can use the same size for the concentric osteotomes, whereas elliptical cups require 1–2 mm larger blades to account for the peripheral buildup. On occasion, a prior anterior surgical incision may reflect either ABMS or direct anterior (DA) approach, and awareness of the prior surgeon's selection can help anticipate the location of scar tissues. The authors frequently revise prior direct anterior hips through the ABMS approach and prefer the relatively untouched superficial interval.

Radiographic Workup

Standard radiographic workup includes an anteroposterior (AP) pelvis radiograph, a lateral pelvis, and an AP and cross-table lateral of the hips and femurs. The AP pelvis should have the pubic symphysis aligned with the coccyx with the symmetric obturator foramen. Lateral pelvic views show the spino-pelvic relationship, notably anterior and posterior tilt, which can help plan ideal cup positioning. Advanced imaging modalities such as a CT scan or magnetic resonance imaging (MRI) are used to evaluate implant rotation, as well as the extent of any bone loss. When the acetabular component has protruded past Kohler's line, or if there are medially proud screws, a CT angiogram can help assess the risk to intrapelvic vasculature [7]. In the setting of adverse local tissue reaction (ALTR) due to metal-ion release, a metal artifact reduction sequencing magnetic resonance imaging (MARS MRI) will assess the extent of pseudotumor and any damage to the soft tissues. Bone scintigraphy is less commonly used but may still have a role in revealing component loosening in some more difficult to diagnose scenarios.

Laboratory Workup

Serum inflammatory markers are a standard component of the initial workup, such as ESR, CRP, and d-dimer. When these are elevated, hip aspiration is used to assess synovial fluid cell count, WBC (white blood cell) differential, alpha-defensin, and cultures. The diagnosis of infection has been well described and is aided with positive cultures, synovial fluid white blood cell count greater than 3000, and segmented neutrophil differential greater than 80% [5]. In addition to inflammatory markers, serum metal ion levels should be checked to investigate ALTR.

Indications and Exclusions of the ABMS Approach for Revision THA

Each surgeon will have relative indications and contraindications to using the ABMS approach for revision acetabular surgery. The authors' only relative contraindication for this approach is when extensive posterior column augmentation is required. While posterior superior augments can be placed with some targeted maneuvers, augmentation posterior to the acetabular cup often requires screw trajectories that are difficult to achieve from the frontal view to the pelvis.

Prior surgery through a posterior approach is not a contraindication to revision surgery through the ABMS approach, unless the revision occurs in the acute postoperative period when the posterior tissues are unhealed. The authors prefer ABMS revision for prior posterior cases, especially to minimize instability complications and to easily utilize fluoroscopy during the surgery [8–10]. Additionally, prior Hardinge and direct anterior approaches can be well treated with the ABMS exposure for revision cases.

Body mass index (BMI) and the waist circumference of a patient may influence the indications for ABMS approach, but more so for a femoral revision than an acetabular revision, which does not require delivery of the femur past the distance of the thigh soft tissue. Incision location should include some consideration of the panniculus and can often be placed distal and lateral to this line. A large panniculus can be taped away from the surgical field to help retract the uncovered skin over the surgical interval. Nonetheless, increased rates of postoperative wound infection in obese patients with large overhanging abdominal fat remain a concern and have been reported in direct anterior approach cases [11–13].

Classification of Acetabular Bone Deficiency

Though various classification systems have been used to describe acetabular bone loss, the most used system is the one proposed by Paprosky in the early 1990s [14]. The Paprosky classification system reflects the integrity of the posteroinferior and anterosuperior acetabulum, and it also offers guidance for how to treat these defects. The first part of the classification system indicates the amount of bone loss. Type 1 defects have minimal bone loss, type 2 defects maintain supportive columns with a distorted acetabulum, and type 3 defects have significant bone loss with inadequate column support.

Type 2 and type 3 defects are further broken down into subtypes based on the area of the acetabulum affected. Type 2 defects can be either type A, B, or C. Type 2A defects indicate direct superior migration of the acetabular component less than 3 cm, caused by loss of the superomedial pelvic bone. With type 2B defects, the acetabular component migrates superolaterally. Type 2C defects indicate that the acetabular component has migrated medially, violating Kohler's line.

Type 3 defects indicate insufficient anterosuperior and posteroinferior column support, and migration of the femoral head is greater than 3 cm. In type 3A defects, the acetabular defect is found superiorly and laterally ("up and out"). In type 3B defects, the acetabular defect occurs superiorly and medially ("up and in"). Pelvic discontinuity can occur in any of these types but most commonly is found in type 3B defects.

Understanding acetabular bone defects guides decision-making when selecting the ABMS approach. As discussed above, a patient with a pelvic discontinuity and/or significant posterior column osteolysis is often not a candidate for ABMS revision surgery due to the limitations in exposing, fixing, and augmenting the posterior osseous structures.

Technical Considerations of Acetabular Revision Through the ABMS Approach

Patient Positioning and Surgical Approach

A patient may be positioned in the supine or lateral position when performing an ABMS approach, on or off a specialized table. The authors prefer to perform this supine on a regular radiolucent table to simplify setup and allow for easy use of intraoperative fluoroscopy. The incision is generally 4 inches in length and typically avoids the groin crease and overlying panniculus. The lateral femoral cutaneous nerve is infrequently encountered in the more laterally based AMBS approach. Care is taken to minimize dead space above the fascial layer in order to prevent postoperative seroma formation. Although extensive scarring may be encountered in the revision setting, the familiar border between the fascia overlying the gluteus medius (GMed) and the thinner fascia over the tensor fascia latae (TFL) muscle is usually identifiable. The border between the GMed and gluteus minimus (GMin) laterally will be adherent to the deep side of the tensor medially. This plane should be carefully developed staying distal to the most proximal neurovascular bundles of the TFL. Full exposure of the anterior iliofemoral ligaments (joint capsule) allows adequate tissue mobility for revision surgery. The authors prefer using a Cobb elevator to separate the capsule from the overlying adhesions to the rectus femoris, GMin, iliocapsularis, and iliopsoas prior to performing an inverted T-shaped capsulotomy.

Acetabular Exposure

After performing the inverted T-shaped capsulotomy, each limb of the capsule should be tagged with a suture. This suture should then be used to help aid in further retraction and capsular release. It is imperative to perform a wide medial capsular release to allow for adequate visualization of the entire bone implant surface of the acetabulum. The authors prefer an in situ disimpaction of the femoral head component while holding the leg in traction. Care is taken not to damage the trunnion. After the head is removed, the femur should be sequentially released to allow for adequate mobilization and exposure of the cup. Next, the entire acetabular rim and component need to be delineated, with the intervening soft tissue and bone removed. This is necessary for adequate rotation of concentric acetabular osteotomes. A posterior retractor is used to retract the trunnion with the femur and abductor muscles (Fig. 15.1). During revisions where the femoral component will not be explanted, surgeons should be mindful of the trunnion to avoid iatrogenic damage.

Modifying the flexion and rotation angle of the femur and leg will aid in finding the best and safest position for retraction. The leg should also be axially loaded to shorten the surrounding soft tissues. An anterior distal retractor is placed deep to the iliopsoas, and an optional third retractor can be placed anterior and proximal (Fig. 15.2). If exposure remains inadequate, return to the proximal interval between TFL and both abductors to ensure they have been separated up to the neurovascular bundle. Inferior capsule can be released, as well as adhesions from the posterior femoral neck to the posterior acetabulum. Skin incision can also be extended in obese patients to minimize tension and expand the view. However, distal neurovascular bundles at the proximal aspect of the vastus lateralis should not be violated unnecessarily (Figs. 15.3 and 15.4).

Fig. 15.1 Retractor placement with demonstration of trunnion retraction prior to internal rotation, flexion, and retraction

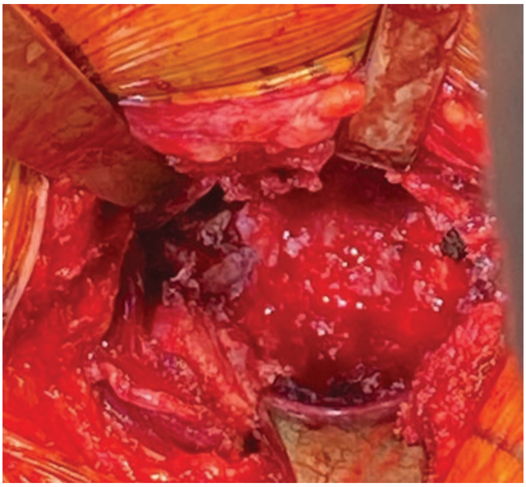


Fig. 15.2 Full acetabular exposure

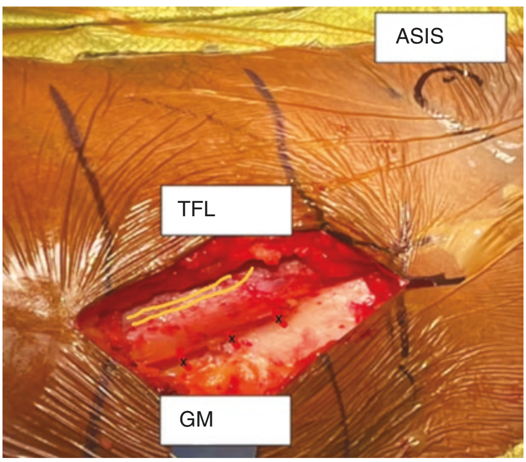


Fig. 15.3 Neurovascular considerations during the ABMS approach. The yellow lines indicate the lateral femoral cutaneous nerve (LFCN) which can be visualized on the anterior and medial TFL. The interval between the TFL and gluteus medius can be confirmed by crossing vessels at the interval, marked here in red with an overlying "x"

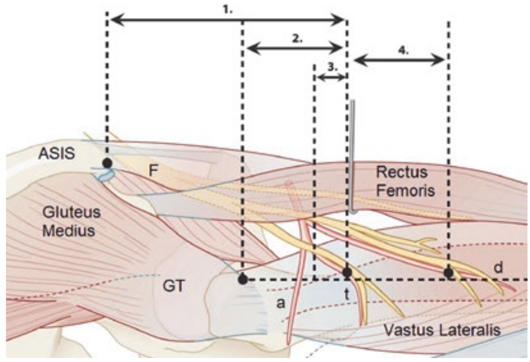


Fig. 15.4 Diagram of a lateral right hip. Distance 1, ASIS to proximal neurovascular bundle; 2, insertion of the anterior fibers of the gluteus minimus on the vastus ridge to the proximal neurovascular bundle; 3, upper margin of the lesser trochanter to the proximal neurovascular bundle; and 4, proximal neurovascular bundle to distal neurovascular bundle: *a* ascending branch of the lateral femoral circumflex artery, *b* descending branch of the LFCA,*F* femoral nerve, *t* transverse branch of the LFCA, *GT* greater trochanter, and *ASIS* anterior superior iliac spine. (Diagram appeared previously in Ghijselings et al. (JOA, 2017))

Acetabular Component Extraction

Safe implant extraction cannot be performed without a circumferential exposure of the implant-bone interface. Before extraction, a bone tamp or Cobb elevator can be used to probe the implant and assess stability. Knowledge of the current acetabular implant is important because certain implants have dedicated removal instruments such as impaction/extraction handles, trial liners, and screwdrivers to dislodge the implant. Explantation osteotome blades are frequently used to circumferentially cut a component from its bony interface. When screws are present, the liner must be removed to access the screws. Narrow osteotomes alone are generally effective in dislodging polyethylene liners, but care should be taken when levering off the rim of the cup. If excessive force is required, pelvic fracture is a risk, especially with loose acetabular components. When osteotomes are not effective in removing the liner, the "screw-in" method can be utilized. This works by piercing the polyethylene liner with a special device or drill and then using a blunt tipped screw against the metal acetabular cup as a backstop to disengage the insert.

Revision Acetabular Preparation

Reamer entry and exit can be difficult in some revision cases. Excessive retraction can errantly break through the weak stress-shielded bone in the acetabular rim, walls, or columns. Therefore,

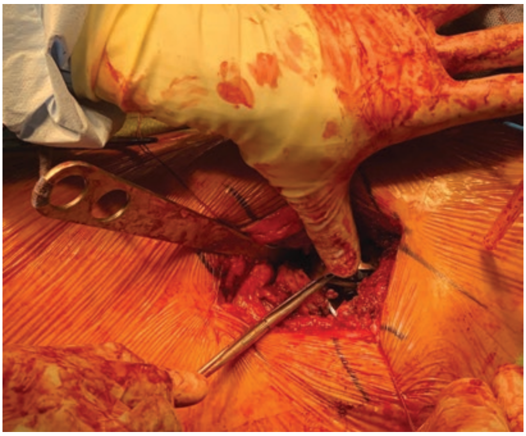


Fig. 15.5 Separate manual entry of the reamer basket

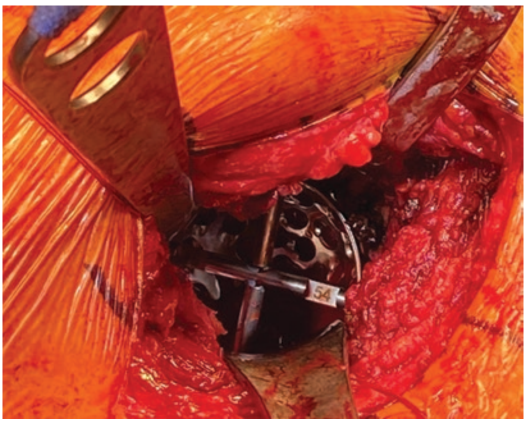


Fig. 15.6 Reamer basket positioned for assembly to the power source

the authors prefer manual insertion of the reamer baskets, allowing entry in the lowest profile position. The reamer is then assembled in situ to the handheld power for preparation. It can be similarly disassembled prior to manual removal (Figs. 15.5, 15.6, and 15.7). Additionally, reaming should be guided by fluoroscopy for best hip center reconstruction. It is important not to errantly ream the posterior wall due to "reaming in the position of the cup." Additionally, in the setting of major osteolysis and poor bone quality, care must be taken to not over-ream and violate the medial wall of the acetabulum.

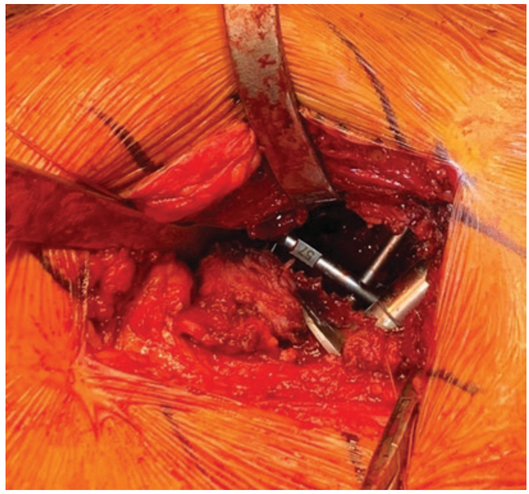


Fig. 15.7 This figure demonstrates the entry of the reamer basket around a trunnion

Revision Acetabular Reconstructive Modalities

When treating acetabular component failure, it is important to identify the location and extent of bone loss, the presence of a pelvic discontinuity, and the ability of the pelvic columns to support the proposed fixation. The spectrum of treatment options for acetabular revision surgery ranges from polyethylene liner exchanges to customized triflange implants.

Polyethylene Liner Exchanges

Polyethylene liner exchanges are performed when the source of pathology is osteolysis caused by polyethylene wear [15]. However, it is important to ensure that the shell of the acetabular component is well fixed and in an appropriate orientation [16]. These are excellent indications for ABMS revision, especially in light of the known dislocation risks with posterior liner exchange surgeries. The liner should be replaced with highly cross-linked polyethylene to decrease wear rates. In rare scenarios where the liner is no longer manufactured and when the risk of cup revision exceeds the benefits (e.g., due to large retroacetabular lytic lesions), a new liner can be cemented into an existing cup.

While an isolated liner exchange provides a low risk of morbidity to the patient, it is limited with regard to its ability to correct version and inclination. Postoperative dislocation following these procedures is speculated to be largely due to insufficient soft tissue restraint following these revision procedures. No current studies compare dislocation rates with an anterior-based muscle-sparing approach to other approaches for an isolated liner exchange. One theoretical benefit of an ABMS approach for this procedure is a lower dislocation rate. Another major benefit is the ease with which fluoroscopy can be used in the supine position.

Hemisphere Porous Acetabular Components

Hemispherical titanium implants are the most commonly used implants for acetabular reconstruction. These were developed for a biologically fixed interface with the bone, allowing long-term durability. Revision with standard or multi-hole acetabular components is recommended for Paprosky type 1 and 2 defects [16, 17]. Column support is required to adequately hold this implant. Primary stability prior to biological ingrowth or on-growth of the bone is afforded by supplemental screw fixation. These implants have excellent survivorship, with 96% cup survivorship at 15 years [18]. In addition, hemispherical shells with locking screw technology are now available to maximize fixation.

Large "Jumbo" Cups

There is no specific size in which a cup becomes classified as a jumbo cup—instead, it is considered one based on its relative size compared to the original acetabular implant. Jumbo cups can be the best choice in certain bone loss scenarios without an intact rim or supportive column fixation at smaller sizes [19]. One advantage of the jumbo cup is its large surface area, therefore increasing the contact area between the cup and host bone. A larger cup can also allow a larger femoral head to be used, thus lowering dislocation risk. Using a jumbo cup can additionally move the hip center to a more inferior and lateral position. At 14 years, patients with jumbo cups generally fare well, with survival rates as high as 92% [20].

Trabecular Metal Cups and Augments

Tantalum acetabular implants can be placed through the ABMS approach and are popular because of their design which provides increased porosity, therefore leading to robust bone ingrowth and good initial stability. With regard to polyethylene liners, tantalum cups can either have a locking mechanism or allow the cup to be cemented in. The latter option allows the surgeon to place the cup in its desired position to address a defect, whereas the liner can be cemented in an orientation that would allow for adequate hip stability and femoral head coverage. Tantalum cups are useful in cases where there is severe bone loss (such as Paprosky types 2C and 3). In these severe cases, titanium cups are twice as likely to show loosening and failure compared to tantalum implants [21]. Metal augments in modular revision systems have also been developed using highly porous metal. Whether used as primary fixation for column support or as secondary fixation for supplemental screws, augments are the authors' preferred workhorse for more complex bone loss cases.

Cup-Cage and Triflange Reconstruction

Cup-cage and custom triflange implants are occasionally used for cases with severe bone loss and pelvic discontinuities. Due to screw position and trajectory, these constructs are likely best employed from the posterior approach.

Unique Considerations of Acetabular Revision Through the ABMS Approach

Component Positioning via Intraoperative Fluoroscopy

The ease of use of intraoperative fluoroscopy is a significant benefit of performing surgery through an anterior approach on a supine patient. A study by Jennings and colleagues determined that the use of intraoperative fluoroscopy leads to an 80% chance of acetabular components being within the combined safe zone compared to a 60% chance without the use of fluoroscopy when utilizing an anterior approach for a primary procedure [22]. The benefits of intraoperative fluoroscopy persist in revision surgery as well, with one study indicating acetabular components outside of the combined safe zone in 48% of posterior approach cases compared to 12% of cases performed anterior with the use of intraoperative fluoroscopy [23]. Supine patient positioning is easily reproducible and allows surgical teams the benefit of avoiding variability in pelvic tilt and obliquity with lateral decubitus positioning, thus facilitating intraoperative radiographs that more closely resemble preoperative ones [24].

Benefits of the ABMS Relative to the Posterior Approach

The literature on ABMS results is still growing, but some of the data on other anterior approaches is helpful for consideration. The rate of dislocation following a DA approach for acetabular revision is approximately 6.6% which puts it in the same range as the dislocation rates observed with other approaches [25]. Though Baba and colleagues noted a lower dislocation rate with a DA approach (4.5%) compared to a posterior approach (14.7%), this was not statistically significant given the relatively small number of patients in the study [26]. However, the use of an anterior approach was also associated with a lower overall complication rate and lower intraoperative blood loss. Isolated acetabular revision surgery through a direct anterior approach does not lead to a higher risk of infection compared to other approaches [27].

Patients who undergo acetabular revision using an anterior approach are able to ambulate independently earlier than are patients who undergo revision through a posterior approach [26]. Patients revised through an anterior approach are mostly walking independently within 1 week after the procedure, compared to 3 weeks after a posterior approach. However, mean Harris hip scores did not differ based on approach at 3 months postoperatively and subsequent visits. Additionally, the surgeons do not generally restrict range of motion after the ABMS, which is different from posterior approach protocols after revision THA.

At the moment, there is limited information regarding isolated acetabular revision which compares ABMS and posterior approaches. As revisions through ABMS approaches become increasingly common, new information will emerge regarding the benefits and viability of the ABMS approach for acetabular pathology.

Conclusion

Revision acetabular surgery can be technically demanding and requires thorough planning. Revision acetabular surgery has been safely performed through the ABMS approach at our institution for a number of diagnoses. A major theoretical advantage is that of increased postoperative stability, although research into this outcome needs to be presented. As individual surgeons gain more experience using this approach for revision cases, the types of revisions tackled will likely increase in complexity.

References

1. Sloan M, Premkumar A, Sheth NP. Projected volume of primary total joint arthroplasty in the US, 2014 to 2030. J Bone Joint Surg Am. 2018;100(17):1455–60.
2. Ong KL, Mowat FS, Chan N, Lau E, Halpern MT, Kurtz SM. Economic burden of revision hip and knee arthroplasty in Medicare enrollees. Clin Orthop Relat Res. 2006;446:22–8.

3. Bozic KJ, Kurtz SM, Lau E, Ong K, Vail TP, Berry DJ. The epidemiology of revision total hip arthroplasty in the United States. J Bone Joint Surg Am. 2009;91(1):128–33.
4. Aqil A, Shah N. Diagnosis of the failed total hip replacement. J Clin Orthop Trauma. 2020;11(1):2–8.
5. Parvizi J, Tan TL, Goswami K, Higuera C, Della Valle C, Chen AF, Shohat N. The 2018 definition of periprosthetic hip and knee infection: an evidence-based and validated criteria. J Arthroplasty. 2018;33(5):1309–14.
6. Kruithoff M, McGrory BJ. The value of the direct lateral hip radiograph in adult reconstruction practice. Arthroplasty Today. 2021;8(2):29–33.
7. Taylor ED, Browne JA. Reconstruction options for acetabular revision. World J Orthop. 2012;3(7):95–100.
8. Haynes JA, Hopper RH Jr, Ho PH, McDonald JF, Parks NL, Hamilton WG. Direct anterior approach for primary total hip arthroplasty lowers the risk of dislocation compared to the posterior approach: a single institution experience. J Arthroplasty. 2021; S0883–5403(21)00846–9.
9. Horberg J, Coobs B, Jiwanlal A, Betzle C, Capps S, Moskal J. Dislocation rates following total hip arthroplasty via the direct anterior approach in a consecutive, non-selective cohort. Bone Joint J. 2021;103-B. Published online ahead of print.
10. Civinini R, Cozzi Lepri A, Carulli C, Matassi F, Villano M, Innocenti M. The anterior-based muscle-sparing approach to the hip: the “other” anterior approach to the hip. Int Orthop. 2019;43(1):47–53.
11. Post ZD, Orozco F, Diaz-Ledezma C, Hozack WJ, Ong A. Direct anterior approach for total hip arthroplasty: indications, technique, and results. J Am Acad Orthop Surg. 2014;22(9):595–603.
12. Russo MW, Macdonell JR, Paulus MC, Keller JM, Zawadsky MW. Increased complications in obese patients undergoing direct anterior total hip arthroplasty. J Arthroplast. 2015;30(8):1384–7.
13. Antoniadis A, Dimitriou D, Flury A, Wiedmer G, Hasler J, Helmy N. Is direct anterior approach a credible option for severely obese patients undergoing total hip arthroplasty? A matched-control, retrospective, clinical study. J Arthroplast. 2018;33(8):2535–40.
14. Paprosky WG, Perona PG, Lawrence JM. Acetabular defect classification and surgical reconstruction in revision arthroplasty: a 6-year follow-up evaluation. J Arthroplasty. 1994;9(1):33–44.
15. Lombardi AV Jr, Berend KR. Isolated acetabular liner exchange. J Am Acad Orthop Surg. 2008;16(5):243–8.
16. Bozic KJ, Rubash HE. The painful total hip replacement. Clin Orthop Relat Res. 2004;420:18–25.
17. Sporer SM, Paprosky WG, O’Rourke M. Managing bone loss in acetabular revision. J Bone Joint Surg Am. 2005;87(7):1620–30.
18. Della Valle CJ, Berger RA, Rosenberg AG, Galante JO. Cementless acetabular reconstruction in revision total hip arthroplasty. Clin Orthop Relat Res. 2004;420:96–100.
19. Ito H, Matsuno T, Aoki Y, Minami A. Acetabular components without bulk bone graft in revision surgery: a 5- to 13-year follow-up study. J Arthroplasty. 2003;18(2):134–9.
20. Wedemeyer C, Neuerburg C, Heep H, von Knoch F, von Knoch M, Löer F, Saxler G. Jumbo cups for revision of acetabular defects after total hip arthroplasty: a retrospective review of a case series. Arch Orthop Trauma Surg. 2008;128(6):545–50.
21. Jafari SM, Bender B, Coyle C, Parvizi J, Sharkey PF, Hozack WJ. (2010). Do tantalum and titanium cups show similar results in revision hip arthroplasty? Clin Orthop Relat Res. 2008;68(2):459–65.
22. Jennings JD, Iorio J, Kleiner MT, Gaughan JP, Star AM. Intraoperative fluoroscopy improves component position during anterior hip arthroplasty. Orthopedics. 2015;38(11):e970–5.
23. Wilson JM, Schwartz AM, Farley KX, Anastasio AT, Bradbury TL, Guild GN 3rd. Postoperative acetabular component position in revision hip arthroplasty: a comparison of the anterior and posterior approaches [published online ahead of print. Jul 17. Hip Int. 2020;2020:1120700020942451.
24. Otero JE, Fehring KA, Martin JR, Odum SM, Fehring TK. Variability of pelvic orientation in the lateral decubitus position: are external alignment guides trustworthy? J Arthroplast. 2018;33(11):3496–501.
25. Cogan A, Klouche S, Mamoudy P, Sariali E. Total hip arthroplasty dislocation rate following isolated cup revision using Hueter’s direct anterior approach on a fracture table. Orthop Traumatol Surg Res. 2011;97(5):501–5.
26. Baba T, Homma Y, Jinnai Y, et al. Posterior versus direct anterior approach in revision hip arthroplasty using Kerboull-type plate. SICOT J. 2020;6:2.
27. Thaler M, Dammerer D, Leitner H, Lindtner RA, Nogler M. Mid-term follow-up of the direct anterior approach in acetabular revision hip arthroplasty using a reconstruction cage with impaction grafting. J Arthroplast. 2020;35(5):1339–43.

16 Femoral Revision via the ABMS Approach

Adam Brekke, Ian Duensing, and Scott S. Kelley

Chapter Summary

- The anterior-based muscle-sparing approach (ABMS) offers an extensile approach capable of utilization for femoral revision arthroplasty procedures – including revisions of cemented or cementless stems, prosthetic joint infections, revisions of loose or well-fixed stems, and periprosthetic fractures.
- The authors prefer the revision approach with the patient in the lateral rather than supine position, especially because of distal posterior drift of exposure.
- Capsulotomy is KEY. An extensive capsulotomy is required for revisions, and the majority of this should be done prior to dislocation.
- The obturator externus must be released, and additional short external rotators may need to be released in revisions that are not typically released in primary total hip arthroplasty (THA).
- The ABMS osteotomy is superior to an extended trochanteric osteotomy (ETO) because the greater trochanter and external capsule and short external rotators are better preserved.
- Thorough disruption of the proximal bone-implant interface (especially posteriorly) should be completed prior to performing an osteotomy, even if the osteotomy was determined likely in the preoperative plan.

A. Brekke (✉)
Texas Hip and Knee Center, Fort Worth, TX, USA
e-mail: Adamcbrekke@texashealth.org

I. Duensing
Adult Reconstruction Division, Department of Orthopedics, University of Virginia, Charlottesville, VA, USA
e-mail: nuz2rr@hscmail.mcc.virginia.edu

S. S. Kelley
North Carolina Orthopaedic Clinic, Duke University, Durham, NC, USA
e-mail: scott.kelley@duke.edu

Introduction

Femoral component revision after total hip arthroplasty (THA) is often technically demanding and requires careful planning and meticulous preparation. The degree of difficulty is influenced by a number of variables including a wide range of stem design options and patient factors.

While numerous choices in stem design offer solutions previously not available to the primary surgeon, they also add complexity to the revision surgery. Method of fixation begins with cement versus cementless (bone ingrowth). With ingrowth, the variables include modularity, location of fixation (metaphyseal versus diaphyseal engagement), porous surface coverage, and texture. Patient factors include the duration since the index procedure, body habitus, presence of osteolysis or heterotopic ossification, presence of infection, and proximal femoral bone loss. When

J. A. Geller, B. J. McGrory (eds.), *The Anterior-Based Muscle-Sparing Approach to Total Hip Arthroplasty*, https://doi.org/10.1007/978-3-031-02059-9_16

present, the loss of bone stock, joint instability, infection, fracture, trochanteric nonunion, and implants or cement that are difficult to extract make revision of the femoral component more challenging.

Complications associated with revisions, including intraoperative femoral fracture and cortical perforation, occur at a disproportionately high rate compared to primary procedures with fracture rates up to 12% and a perforation rate of 5% [1]. Despite the challenges associated with stem removal and revision THA, midterm survivorship data of patients treated with contemporary modular revision stems is quite good ranging from 85% to 92% [2, 3].

The importance of preoperative planning cannot be overemphasized. Understanding etiology of the primary procedure's failure is essential for guiding clinical decision-making. Thorough patient evaluation and well-executed surgical reconstruction based on comprehensive preoperative planning may determine the postoperative results. Familiarization with the implant type and manufacturer, as well as size options and implant-specific extraction devices, can limit operative time and blood loss and prevent intraoperative complications. Knowledge of various reconstructive options and the indications for each is necessary to achieve a successful outcome [4, 5].

Historically, the approaches that have been the workhorses for revision THA are the posterior or direct lateral approaches. They provide reliable and reproducible exposure and have the added benefit of familiarity among arthroplasty surgeons. Conversely, revision arthroplasty through any of the anterior approach techniques requires considerable experience [6]. That said, the potential for reduced rates of dislocations [7, 8, 9] and earlier recovery [10, 11, 12, 13] benefits seen with these anterior approaches makes it an appealing consideration and an opportunity to explore. The lack of extensibility of the direct anterior approach and inability to perform a femoral osteotomy to facilitate stem removal have likely contributed to the lack of widespread enthusiasm.

The anterior-based muscle-sparing (ABMS) approach is uniquely positioned to bridge the gap between more commonly used "traditional" approaches and the direct anterior approaches. It has the potential to provide the stability and recovery benefits of an anterior-based approach but offers extensibility like the posterior or direct lateral approaches [14]. Surgical exposure must be sufficient to allow removal of the original implant with the least possible disruption of the remaining femoral bone and to allow preparation and insertion of the selected revision implant. The ABMS approach allows for the selection and implantation of any of the many femoral options that are available for revision THA. As well, revising a stem through an ABMS approach allows wide exposure for appropriate femoral mobilization and access to both the calcar and shoulder regions of the implant (Fig. 16.1a, b).

Indications and Contraindications

The most common indications for femoral component revision after THA are infection, hip instability (with femoral component malposition), bearing-associated osteolysis, implant fracture, and issues with femoral component fixation. Significant subsidence, fracture, and failure to achieve adequate ingrowth are all related to the same issue: femoral component fixation. Contraindications to revision THA and implant removal include medical illness or severe comorbidities that preclude major surgery. During an acetabular component revision, if the primary femoral implant is well positioned and well fixed, it is generally preferable to leave the femoral component in place, particularly if system modularity allows appropriate restoration of limb length and soft tissue tension.

Indications for the utilization of a certain approach for the revision procedure are not strictly defined, but the previous approach for the index procedure and surgeon's preference and experience are strong deciding factors. Femoral component revision THA via the ABMS approach should be considered by surgeons experienced with this approach. In contrast to the DA approach, the ABMS approach can be utilized for femoral component revisions and acetabular revi-

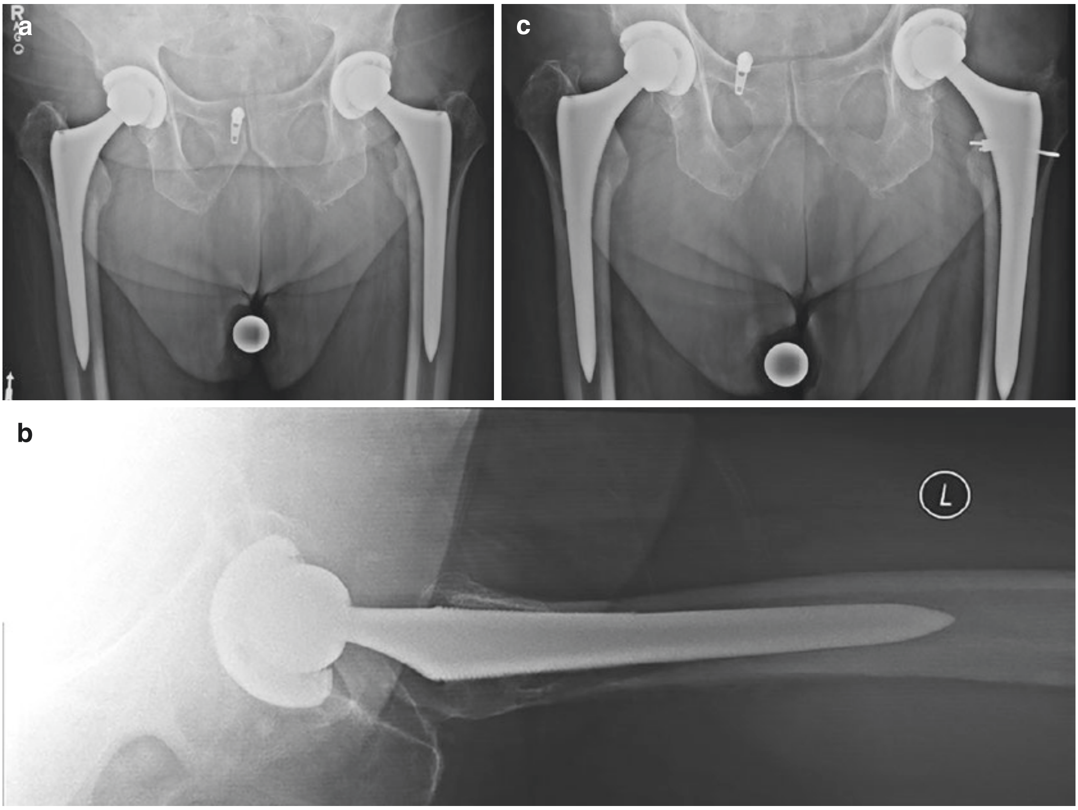


Fig. 16.1 (**a**) Anteroposterior pelvis radiographs of a patient with a painful left hip arthroplasty with subtle radiographic signs of loosening of the femoral stem. (**b**) Cross-table lateral radiograph showing radiolucencies about the femoral stem. (**c**) Postoperative radiograph after revision with a proximally coated, tapered stem and peritrochanteric cable fixation

sions (including cup-cage reconstruction), as well as calcar wiring, greater trochanteric fixation, extended femoral osteotomies, trochanteric slide osteotomies, abductor muscle advancements, and open reduction and internal fixations of periprosthetic fractures.

Preoperative Planning

For optimal results, a meticulous preoperative planning, an ability to conceptualize and attain extensile surgical exposure, and a practical understanding of all available options for reconstruction are required. Critical components of the preoperative plan include developing a strategy for implant removal, defining the subsequent or preexisting bone defects, and determining the best method and implant choices for stable fixation and reconstruction.

Planning Implant Removal

Preoperative imaging should consist of an anteroposterior (AP) radiograph of the pelvis and lateral radiographs of the femur. These help the surgeon identify the manufacturer, brand, and size of the implants as well as the mode of fixation in the primary surgery. Using these radiographs, the surgeon can often determine the stability of the stem.

- For cemented primary stems, loosening may be indicated by subsidence of the femoral implant, fracture of the stem or cement, or the presence of a progressive radiolucent line at the interface between the stem and cement that is not present in the immediate postoperative radiographs.

- For noncemented primary stems, instability is suggested by progressive reactive lines in the area of the porous coating, a distal bony pedestal, implant migration with subsidence, varus or valgus tilting, or late shedding of particles from the porous-coated surface.
- In order to anticipate the site at which the bone-implant surface will have to be disrupted, the surgeon should identify the location of surfaces with bone ingrowth and the extent of ingrowth.
- Other features of the stem, such as an extraction hole or threaded stem insertion hole in the stem shoulder that may allow the use of a stem-specific or universal extraction device, should be identified prior to surgery.
- In patients with cemented stems, the quality of the cement mantle, the length of the distal cement column, or the cement past the isthmus should be evaluated.

Options for Reconstruction

We use the Paprosky classification to assess femoral bone loss [15].

- In a type I defect, both metaphyseal and diaphyseal host bones are preserved, and the femoral bone available for reconstruction is similar to that of primary replacement.
- In a type II defect, the metaphyseal bone is compromised, but the diaphyseal bone is intact.
- In a type III defect, the metaphysis is nonsupportive, and the diaphysis is partially intact. A type IIIA defect has at least 4 cm of intact femoral isthmus, whereas a type IIIB defect has less than 4 cm of intact isthmus.
- A type IV defect has no supportive isthmus and only a cortical tube remaining for reconstruction.
- In revision settings with a type I defect, the noncemented femoral implants used in primary THA can be used, including anatomic stems that match the contour of the proximal femur and straight stems which provide diaphyseal fixation (Fig. 16.1c). Straight implants can be proximally coated or extensively coated. Tapered stems with proximal coating can be used in type I as well.
- Historically, type II defects have been reconstructed with extensively coated stems or modular body stems, but since 2010, tapered, fluted modular stems also have been used with good results. Improved design has markedly reduced the occurrence of proximal body-stem modular junction fractures that were associated with first-generation design.
- Type III defects can also be treated effectively with extensively coated long stems or tapered, fluted modular or monolithic stems. These are often done in conjunction with an osteotomy to aid in removal of the failed stem and/or retained cement and introduction of the revision stem.
- The use of the modular or monolithic fluted stem enables attainment of distal fixation in patients in whom little to no femoral isthmus remains, including most patients with type IV defects.
- High failure rates have been reported with the use of cemented stems in revision arthroplasty, especially in patients who have substantial bone loss. However, the use of a polished cemented stem with impaction bone grafting in the femoral canal has been shown to provide durable results even in patients who have severe femoral bone deficiencies (IV) with long stems recommended in patients with diaphyseal deficiencies [16].
- Cemented modular or nonmodular proximal femoral replacement implants can also be used in elderly patients who have type IV defects with or without discontinuities of the cortical tube and who have low activity demands. In such patients, the bone defect is excised and replaced proximally with metal (i.e., proximal femoral replacement), and the stem is cemented into the remaining intact femur.

Setup and Equipment

The equipment and setup necessary for a femoral revision include those required for a primary procedure as well as an array of hand and power instruments, extraction tools, and instruments for fixation which should be a part of all revision surgeons' arsenals. After the existing implants and fixation method are identified and method of reconstruction is planned, appropriate instrumentation should be ordered. The surgeon should be aware of all available options. In particular, we find the following to be most useful:

- Standard retractors include blunt-tipped curved cobra retractors, a side-specific double curved sharp cobra, a two-pronged femoral elevator, a blunt-tipped narrow straight Hohmann, and a sharp narrow 90-degree bent Hohmann.
- Hand tool sets, flexible osteotomes, and high-speed burrs can be used to disrupt areas of bony ingrowth or bone-cement interface.
- Ultrasonic devices can also be useful for cement removal.
- Implant-specific (usually thread-in) extraction devices or universal extraction devices should be available.
- In case an osteotomy is required to extract the stem, an oscillating saw, drill, high-speed pencil-tipped burr, osteotomes, and several Gigli saws should be available as well as the preferred method of fixation (e.g., cerclage cables, wires, and/or plate).

While femoral revision via ABMS approach can be performed in either the supine or lateral position, we find that the lateral position allows for more extensile options to the entire leg, including a more posterior extensile drift distally. With the lateral approach, the patient is positioned as for a primary approach, with a more extensile leg preparation and draping, at a minimum below the knee. The OR (operating room) table with a split leg extension and a peg board with a cutout for leg support are useful for these procedures when performed in a lateral position.

Technique

Approach and Mobilization

The approach utilized in the primary surgery will affect the superficial approach in a femoral revision. Palpate the ASIS and the trochanteric portion of the proximal femur, which serve as the landmarks for the incision and approach. If the previous approach was an ABMS or another anterolateral-based incision, then the previous incision could be utilized. If a posterior incision was utilized for the primary surgery, then utilize these landmarks to make a standard ABMS incision. In either case, ensure that enough of the thigh is exposed to allow for an extensile incision, if needed. Sufficiently wide exposure is necessary to improve the mobility of the proximal femur and to decrease the risk of an intraoperative greater trochanter fracture. Generally, in the setting of infection or possible infection, it is advisable to excise the entire previous scar or sinus tracts and debride the scarred, infected, necrotic, or otherwise compromised subcutaneous tissues.

As with any revision, it is helpful to excise the previous scar, including the skin and superficial scar tissue, and to carefully define the fascial plane. Often, a Cobb or other elevator can be used to mobilize the subcutaneous fat off the fascia in order to obtain clear visualization of the fascial layer, but excessive devascularization should be avoided. Because some of the previous soft tissue landmarks utilized in the primary ABMS approach may be scarred or otherwise altered, palpate the anterior border of the trochanter in order to plan the longitudinal fascial incision. The incision should be parallel and approximately 1 cm anterior to the proximal femur.

Dissection of the muscular plane between the gluteus medius (posterior) and the tensor fascia latae (anterior) can be more difficult in the revision setting, and meticulous dissection is required. Abducting the leg can relieve tension and allow for an easier definition of the intermuscular plane. The curved cobra retractors are then placed over the superior and inferior femoral neck capsule or scarred pseudocapsule. The rectus femoris is dissected from the capsule with an elevator, and a medial cobra retractor is placed under the rectus femoris to allow visualization of the capsule as far medial as possible.

A capsulotomy is then performed parallel to the superior border of the neck of the femoral stem and is extended distally to the junction of the femoral stem and greater trochanter. A heavy tag stich is placed in the superolateral corner of the capsular flap to facilitate the retraction, exposure, and later repair. The superior and inferior cobra retractors can then be placed intracapsular.

Clear and unobstructed visualization of the proximal femur should be gained prior to any attempts at implant manipulation. This includes thorough debridement of the anterior pseudocapsule and dense scar around the proximal femur. The hip is then dislocated, but importantly, the dislocation should be staged to prevent femoral fracture. Begin by subluxating the hip and identifying the anatomy that is under most tension and is the most limiting. This is accomplished with the hip in neutral abduction and neutral rotation and slight flexion with distal and lateral traction. Often, assistance with a bone hook around the neck of the stem and a towel bump in between the proximal thighs is needed.

The capsulotomy is key. Generally, a much more extensive capsulotomy than with a primary procedure is required prior to dislocation, followed by more femoral releases after dislocation. Often, we release the capsule proximally and posterior to the piriformis fossa and inferiorly around the femoral neck, almost to the lesser trochanter. The inferior exposure can be facilitated by elevating the vastus lateralis prior to its release. It is often necessary to incise the capsule longitudinally in various locations as needed.

Once the head is free from the acetabulum, the capsule needs to be released further almost circumferentially around the proximal femur. The hip is then externally rotated to a figure four position to allow access to the femoral head and neck. The head is disassociated from the taper using a bone tamp and a mallet with a single direct strike to the base of the head. If the stem is to be retained, the head can be covered in a laparotomy pad to protect the trunnion.

Ensuring optimal femoral mobilization is the next step. Femoral mobilization is critical because it provides exposure of both the acetabulum and proximal femur. Methods of dissection and mobilization may be adjusted based on patient characteristics (e.g., BMI, mechanism of failure, degree of femoral neck varus/implant varus, muscle mass).

The release initiated during the dislocation should be extended as much as possible first by ensuring that the standard primary capsular releases off the proximal femur are done, with continued debridement of the capsular tissue and scar with each release. With the leg abducted and externally rotated thereby decreasing the tension of the abductors, remove the superior cobra retractor, and place a curved sharp Hohmann retractor over the trochanter and underneath the abductor tendons. With electrocautery, release any pseudocapsule from the saddle and medial trochanter, and excise any redundant or obstructive fibrous tissue.

Moving the leg into a figure four position, replace the medial cobra with a straight Hohmann retractor along the posteromedial femoral neck, and release any medial and posterior pseudocapsule. In this position, clear the fibrous soft tissue from the medial implant-bone or implant-cement-bone interfaces.

With the leg back in the abducted and externally rotated position, place a two-pronged retractor under the medial calcar, and replace the sharp curved Hohmann retractor with the modified offset Hohmann retractor over the trochanter and under the abductors. When performing the surgery in a lateral position, the posterior leg extension drop-down allows improved placement of affected extremity in extension, adduction, and external rotation for further femoral exposure and preparation. Then, a straight sharp Hohmann retractor over the shoulder of the implant, medial to the trochanter and onto the posterior femoral neck, allows for visualization and release of the obturator externus and full skeletonization of the piriformis fossa. To gain additional mobilization, it may be necessary to release additional short external rotators and occasionally the iliopsoas tendon off of the lesser trochanter.

Stem Removal

After the femur is fully mobilized, the leg is placed with the hip in extension, adduction, and external rotation (ER) to expose the femur. A modified cobra retractor is placed over the greater trochanter to retract the abductor muscles, and a two-pronged retractor is placed under the medial calcar. Accurate retractor replacement is required to retract the abductor musculature safely and appropriately and to avoid significant damage.

Next, sequential visualization of the implant-bone interface is accomplished by removing the remaining soft tissue, cement, or bone in order of preference. The lateral shoulder is visible, and the surgeon may begin removing any overhanging bone on the medial trochanter with a rongeur or high-speed burr. The bone must be removed until there is unobstructed access to the recessed shoulder of the implant. Failure to remove this prior to stem extraction may lead to trochanteric fracture.

The medial calcar is cleared using a high-speed burr. A pencil tip burr works well in this location as it is thin enough to address the narrow interface and avoid significant bone loss at this location. Collared stems can pose a challenge to access the medial curve of the implant, though with a careful, methodical approach, this junction must also be freed without damaging the proximal femur or calcar region. Occasionally, a metal cutting burr may be required to transect the collar to gain access to the medial aspect of the implant. To minimize spread of metal debris, the patient's bone and soft tissues should be isolated with sponges or plastic drapes before the metal cutting burr is used. The technique of using sterile gel is also effective [17].

Removal of a Loose Noncemented Stem

Noncemented stems are either proximally or extensively porous coated. Removal of a loose, proximally coated undersized stem is much easier than removal of a well-fixed, extensively porous-coated canal-filling stem. If the stem is determined to be loose based on preoperative radiographs, the proximal extraction device can be attached at this point.

Many implants have stem-specific extractors which may thread into the implant and provide more direct in-line force for extraction. Otherwise, conventional universal extraction devices, such as the Shukla stem extractor (Shukla Medical, St. Petersburg, FL), can be successful. Three to five firm, controlled disimpaction blows are administered. If blows are not sufficient to disimpact stem, the surgeon must disrupt the bone-prosthesis or fibrous tissue-prosthesis interface.

The bone-prosthesis interface of a proximally coated stem can be disrupted with the use of a pencil-tipped burr to divide the anterior, posterior, medial, and lateral interfaces. The proximal posterior cortex will be the most difficult aspect of the interface to disrupt. When burrs are used, care must always be taken to work along the prosthesis to avoid perforation of the cortices. Flexible osteotomes are useful for breaking up metaphyseal bony contact distal to the reach of the pencil-tipped burr, and a number of shapes, sizes, and curvature radii are available within the osteotomy set. When using osteotomes around the lateral aspect of the implant, care should be taken to remain in line with the distal taper of the stem and avoid following the recessed lateral shoulder. Failing to do so may lead to lateral cortical perforation and greater trochanter fracture. Straight osteotomes are useful for the straight edges of the implant on the anterior and posterior surfaces, while curved or semicircular osteotomes are useful for the medial and lateral curvatures.

A dual-sided reciprocating saw can be useful on both the anterior and posterior surfaces particularly as the bone becomes denser and more sclerotic toward the metaphyseal-diaphyseal junction. Again, care should be taken to remain abutted against the implant and avoid cortical perforation. Similarly, a Kirschner wire driver may be utilized to disrupt the interface distally as well.

Once all accessible areas of bony contact with the implant have been disrupted, stem extraction may again be attempted. In a majority of cases, complete and circumferential bony disruption is not accomplished with osteotomes alone. Sequential strikes with a mallet or slap hammer on the extraction devices are useful for fatiguing any remaining ongrowth and spot welds.

If 3–5 blows are not sufficient, the surgeon should determine whether further disruption of the bone-implant interface would result in unacceptable risk for fracture or perforation. If such disruption would be too risky, the surgeon may select to perform an extended osteotomy and other measures to extract a well-fixed stem.

Removal of a Cemented Stem

Removal of a cemented stem consists of two phases: disimpaction and cement removal.

Disimpaction Ensure that any bone or cement overhanging on the shoulder of the prosthesis or the medial trochanter has been cleared. An obstructed path must be available for disimpaction.

With appropriate exposure, cemented stems, particularly smooth polished stems, can be tapped out of the cement mantle without significant force. If the primary stem has subsided, however, removal can be more difficult. In these instances, a medial collar may have bony overgrowth that must be cleared to allow removal. Also, attachment of stem-specific or universal extraction devices to the trunnion may be compromised or more difficult if the stem has subsided.

With a clear trajectory, the extraction device is applied. Most highly polished or textured stems can be removed with 3–5 firm, controlled disimpaction blows.

If not, the cement-prosthesis interface should be disrupted with a narrow pencil-tipped burr or thin, flexible osteotomes, as described above. After the interface has been disrupted, the extraction device should be reapplied and disimpaction blows attempted.

If the stem is unable to be removed after these steps, consider the steps for removal of a well-fixed implant, including a femoral osteotomy.

Cement Removal In cases with good remaining bone-cement interdigitation and without infection, revision reconstruction with the cement-in-cement technique may be preferable. In these cases, the existing cement mantle is roughened and textured with a burr or ultrasonic tool to create space for the new prosthesis and to enhance cement-to-cement bonding.

In patients with poor cement interdigitation or loose implants, the surgeon may be able to remove the cement mantle and distal cement column en masse by drilling a hole and threading a tap into the cement mantle in a retrograde manner. An ultrasonic device may also be used to gain purchase on the cement mantle and allow removal. However, most typical mantles must be removed in pieces using a combination of hand tools, burrs, drills, or ultrasonic devices.

Metaphyseal cement mantles are often thick and can be debulked with a high-speed burr. Well-fixed and circumferentially intact mantles must be split before they can be separated from surrounding bones. Failure to do so can lead to an iatrogenic fracture. Hand tools such as splitters, T-shaped and V-shaped osteotomes, reverse hooks, and pituitary rongeurs are used methodically and carefully to break and remove metaphyseal and diaphyseal cements.

To remove a well-fixed distal cement plug, a central hole in the plug should be created with a burr, a drill, or an ultrasonic device. Then, the hole can be progressively dilated with sequential drilling, and a reverse hook can be used to drive cement fragment proximally. If the distal cement plug expands past the isthmus of the femur, an extended osteotomy or cortical window may be necessary for safe extraction.

It can be helpful to do any of these steps under fluoroscopy or with confirmation using an intraoperative flat plate radiograph to ensure that all instruments are within the canal.

Removal of a Well-Fixed Stem

Removing a well-fixed stem requires each of the steps listed above including using osteotomes along the posterior implant-bone interface. Then, consider different techniques based on the stem design – modular splined tapered diaphyseal engaging stems pose a different set of challenges than well-fixed extensively or proximally coated stems.

For modular stems, after dislocation and once the head is disassociated from the neck, the modular proximal body must be disassociated from the stem by disengaging the Morse taper or locking mechanism. This should be performed by clearing the overhanging bone and fibrous tissue from the extraction trajectory and disrupting the proximal bone-implant interface using the techniques for a loose stem removal.

Removing the modular proximal body allows access to the canal and the proximal portion of the stem. If available, implant-specific extractors can be threaded into the stem for extraction using disimpaction blows. Often, however, these stems are not successfully removed by fatiguing the bony interface and require additional steps to remove.

Trephines can be used at this stage to remove a well-fixed diaphyseal engaging stem. Knowing the size of the stem is helpful for trephine choice, the goal is to select a trephine just larger than the maximum stem diameter. Multiple trephines are often needed as they can become dull during use. Caution must be exercised because trephine use is not without hazard. The use of trephines does not allow the surgeon to account for the taper of the stem or anterior cortical abutment, and therefore, eccentric reaming and cortical perforation are not easily avoided. Size mismatch can lead to binding of the trephine to the stem, and the torque of the trephine can fracture the femur. It is also important to replace dull trephines as advancement of a dull trephine may lead to elevated temperatures within the femoral canal, and secondary thermal necrosis of the bone, thus impeding future bone ingrowth into the revision cementless stem.

In alternative technique, which may result in less bone loss, a long drill bit or a long Kirschner wire is advanced along the concave channels between the splines to help disrupt the distal bone-prosthesis interface while following the taper of the stem. After being disrupted, a universal extraction device or vise grip is attached to the exposed Morse taper, and the stem is disimpacted with retrograde blows.

ABMS Anterior Osteotomy

Extensively porous-coated noncemented stems, double-tapered proximally coated stems with osseointegration, and certain cemented prostheses with an anteroposterior dimension widest in the midsection of the implant are generally not removed successfully using standard extraction techniques. In these cases, an osteotomy is required for removal. Additionally, osteotomies are indicated for patients with a stem fracture, a cement mantle that extends beyond the anterior bow of the femur, or a long bowed femoral implant. However, it is important to disrupt extensively the proximal bone-implant interface, especially posteriorly, prior to resorting to the osteotomy.

The extended trochanteric osteotomy (ETO) has been popularized and involves removing the anterolateral third of the femoral cortex at or near the level of the implant which allows access to the entire stem. Historically, one of the limitations of an anterior approach has been thought to be the inability to perform or difficulty performing this osteotomy since access to the posterior and lateral surfaces of the femur is limited.

Alternative osteotomies have been described including a femoral longitudinal split or cortical fenestration which may be performed from an anterior or a posterior approach [18]. This is a corticotomy and does not involve removal of the segment femur. It does, however, allow access to the length of the femoral stem through a very narrow window. Others have described distal access through a cortical window which, again, can be performed through any approach [19]. These alternatives obviously have significant limitations since circumferential access to the stem is not feasible.

Through the ABMS approach, there is an opportunity for an anterior cortical osteotomy that not only provides for access to the entirety of the stem and for circumferential disruption of ongrowth but also mitigates the need to remove the trochanter (Fig. 16.2). This osteotomy allows anatomic preservation of the abductor muscle attachments, unobstructed exposure to the stem, in particular the medial curvature, which is oftentimes the most difficult to access, and may be fixed using standard cerclage techniques.

Osteotomy Technique

The hip is reduced or placed in a neutral position to ensure appropriate muscle tension and rotation of the femur. Exposure begins with in-line extension of the standard ABMS skin and fascial incision. Deeper exposure through the fascia reveals the vastus lateralis musculature overlying the appropriate length segment of the femur.

The vastus origin is taken down from its attachment in an "L" shape (Fig. 16.3). The transverse limb of the "L" is carried anteriorly along the tendinous attachment all the way to the capsule preserving a cuff of tendon to reattach, and the vastus is dissected completely off the inferior capsule. The vertical limb of the "L" is continued down the posterior aspect of the vastus fascia just anterior to the intermuscular septum. From here, a standard subvastus approach to the femur is carried out by elevating the musculature while identifying and coagulating perforating vessels throughout the dissection. The anterior attachment of the vastus is left intact. Muscle stripping is minimal and limited to a strip several millimeters wide and for as long as the proposed osteotomy (Fig. 16.4).

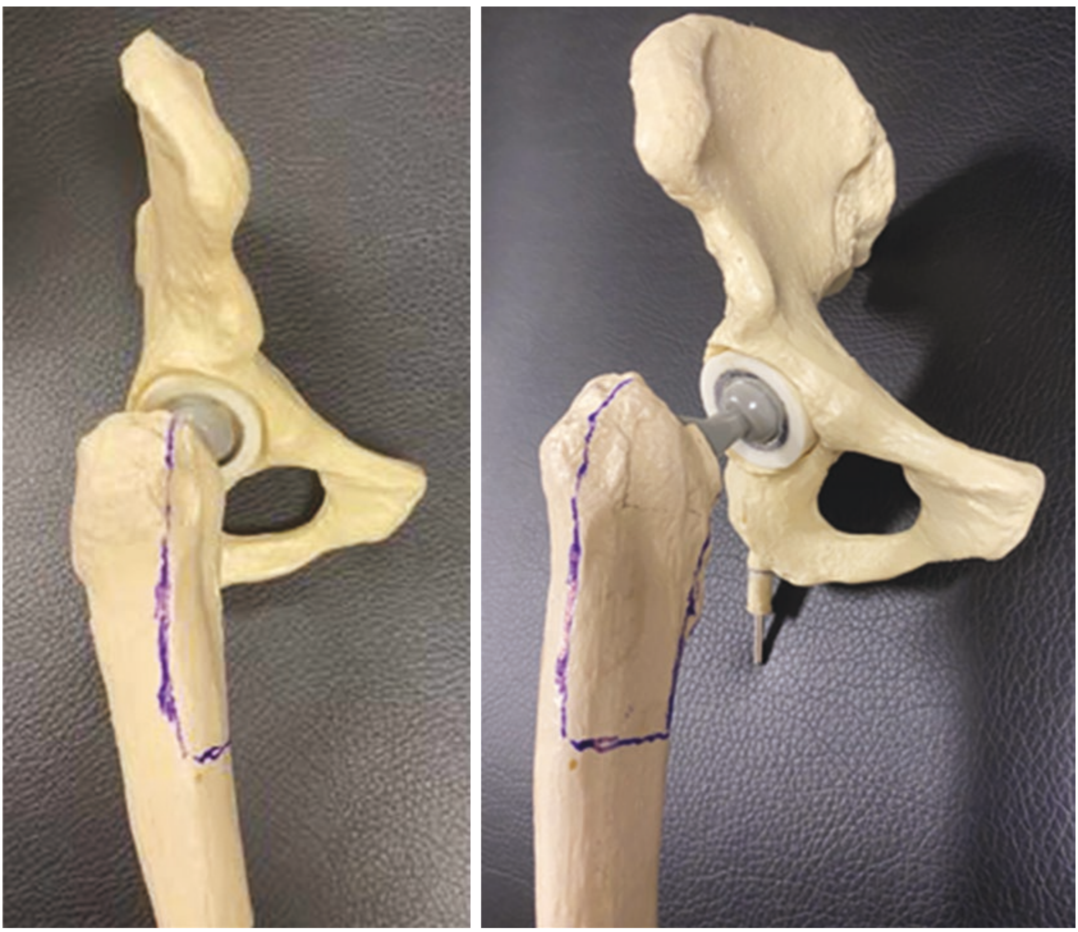


Fig. 16.2 The ABMS anterior femoral osteotomy marked on a Sawbones model from a lateral view (left) and anterior view (right)

Fig. 16.3 The "L"-shaped release of the vastus origin taken down from its origin. The transverse limb of the "L" is carried anteriorly along the tendinous attachment all the way to the capsule preserving a cuff of tendon for reattachment

Fig. 16.4 A subvastus approach to the femur after the "L" vastus release with elevated musculature. Muscle stripping is minimal and limited to a strip several millimeters wide and as long the proposed osteotomy

Several blunt, curved Hohmann, or Bennett retractors are placed over the anterior edge of the femur to retract the dissected muscle bulk and expose the anterolateral surface of the femur. The leg is placed in neutral rotation or slight external rotation, and under direct visualization of the implant position and rotation of the femur, the osteotomy is marked with electrocautery or scored with a thin saw blade in a proximal to distal direction beginning just anterior to the tip of the trochanter.

The planned osteotomy is made in line with the lateral shoulder of the implant and carried distally to the tip of the stem. The tip of the stem can be identified by using a small drill bit to perforate the distal aspect of the femoral segment until the tip of the implant is identified. The transverse limb is planned at or near the tip of the implant based on preoperative templating and planning.

Once marked, the osteotomy is performed using a thin oscillating saw blade or single-sided reciprocating saw (Fig. 16.5). The cortex should be perforated with the hand at a slight angle such that the blade skives off the anterolateral surface of the implant.

The osteotomy is carried distally to the tip of the implant at which point a pencil tip bur or small saw blade is used to create the horizontal limb of the osteotomy. The transverse limb should be approximately one-third of the diameter of the femur (Fig. 16.6). Rounding the edges of the transverse limb or beveling the cut prevents propagation and improves accuracy of reduction.

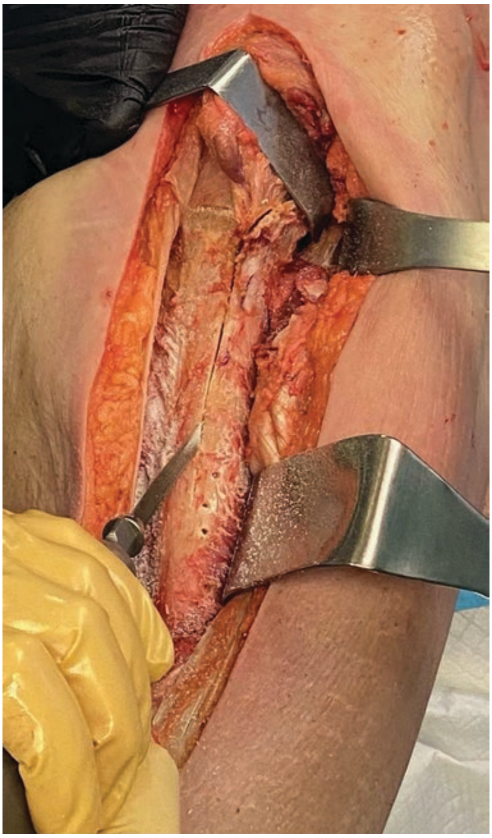


Fig. 16.5 The osteotomy performed with a single-sided reciprocating saw, with the hand at a slight angle such that the blade skives off the anterolateral surface of the implant

Fig. 16.6 The distal transverse limb of the osteotomy shown. It should be approximately one-third of the diameter of the femur

The anteromedial cortex is then addressed by passing a drill bit multiple times through the first cut and across the femur (skiving off the implant), creating a dotted line of holes on opposite side of the femur (Fig. 16.7). At this point, a series of osteotomes may be used (Fig. 16.8) to hinge the osteotomy open from lateral to medial thereby exposing the entire anterior surface of the implant (Fig. 16.9). The shoulder region and the medial curvature/calcar region are both readily accessible giving the surgeon full access to three-fourths of the implant.

Using a combination of flexible osteotomes and pencil-tipped bur, the remaining exposed bony interfaces are disrupted. As mentioned above, a Gigli saw can be passed distal to proximal to break up the difficult to reach posterior implant surface if not already addressed from the proximal efforts. Once all interfaces are freed, standard extraction devices can be used to remove the implant (Fig. 16.10).

The osteotomy site is repaired by reducing the bony flap back down along the cut surface of the femur (Fig. 16.11) and passing two or three cables or Luque wires and tightening sequentially. The vastus lateralis attachment is repaired back to its attachment using heavy suture. This leaves the entirety of the trochanter uninvolved and, importantly, the abductor musculature is not violated and retains its length, tension, and tendinous insertions. Additionally, there is very little dynamic stress to the repaired osteotomy segment, and the muscle attachments are limited. The posterior column of the femur is maintained as is the structural posteromedial calcar minimizing the risk of fracture.

Fig. 16.7 The anteromedial cortex addressed by passing a drill bit multiple times through the first cut across the femur and skiving off the implant, creating a dotted line of holes on opposite side of the femur

Fig. 16.8 Multiple osteotomes from lateral to medial utilized to elevate the osteotomy fragment

The length of the osteotomy and the distal margin are determined based on preoperative templating. It should be sufficiently distal to facilitate stem removal and allow correction of any varus remodeling while maintaining at least 4–6 cm of the isthmic bone for reliable fixation of revision stem. For removal of a fully coated stem that is relatively short, the osteotomy can be made at the level of the stem tip if satisfactory fixation of the revision stem can be achieved below the level of the osteotomy. For removal of longer primary stems, the distal aspect of the osteotomy should be located just distal to the point at which the stem becomes cylindrical. The stem can be divided at this juncture, and the distal portion can be removed with the use of trephines. Copious irrigation is necessary to avoid thermal damage from motorized trephines. If a curved stem is being removed, the osteotomy must be sufficiently distal to allow a straight pathway below the bow of the stem.

Methods for Reconstruction

The ABMS approach provides sufficient exposure allowing for the selection of any available revision stem designs, including modular or non-modular tapered fluted stems, extensively porous-coated stems, modular porous-coated proximal stems, or revision-cemented stems.

Reconstruction with a Cemented Stem

The benefits of cement in femoral revision include the possibility of immediate fixation, enhancement of proximal bone stock, ability to

Fig. 16.9 After elevation of the anterior osteotomy fragment, the anterior, lateral, and medial aspects of the stem are visualized

Fig. 16.10 After implant removal and prior to osteotomy reduction

bypass defects, and elution of antibiotics. The most important factors to consider are the indication for revision surgery, mechanism of failure, bone stock, and femoral anatomy.

The primary indication for cement in revision surgery is in the context of revision of a previously cemented femoral implant in whom the mantle remains intact and fixed to the bone. Cement-in-cement revision may be sufficient. Cemented revisions also play a major role in the management of infected THA because polymethyl methacrylate acts as a carrier for appropriate antibiotics, allowing local elution of antibiotics into the tissues at high concentration.

Cement-in-cement revisions will never require an osteotomy. Debonded rough stems as well as never-bonded polished stems will be easily extracted. Successful cement-in-cement revision requires an integrated, intact cement mantle assessed by preoperative anterolateral and lateral radiographs and intraoperative examination of proximal cement-bone interface. This technique is not unique to ABMS approach and has been well described.

If the patient had a previously malpositioned implant, the remaining cement mantle can be burred from within to allow correct positioning. For cement-in-cement fixation, select a collarless polished revision cemented stem smaller than the original stem. After irrigating and drying the cement mantle, inject the new cement with a narrow nozzle, and pressurize prior to implantation.

Cemented femoral revision is otherwise rarely indicated. It is most suited for a more elderly patient who failed to achieve fixation with an ingrowth component. If selected, the col-

Fig. 16.11 Osteotomy fragment reduced with a bone hook prior to fixation

larless polished revision stem should exceed the length of removed stem by two femoral shaft diameters or the previous cement mantle of at least 2 mm.

Reconstruction with a Noncemented Revision Stem

If removal necessitated an ABMS anterior osteotomy, the authors prefer reduction of the osteotomy fragment prior to preparation for implantation. Occasionally, the cancellous surface of the osteotomized fragment can be prepared with a burr prior to reduction to accommodate the proximal revision implant.

Techniques for preparation and reconstruction with noncemented revision stems, in general, are not unique to the ABMS approach. What is essential to allow for the extensive reaming, though, is adequate femoral mobilization and exposure. We prefer to perform these steps prior to stem removal.

Conical hand or power reamers are used sequentially to prepare the diaphysis. Reaming continues until stability is demonstrable under axial and rotational loads to the hand reamer by tactile feedback. It is essential to achieve excellent initial stability. In general, the shortest stem possible achieving the stable fixation is desirable. If an anterior osteotomy was required, the selected stem for reconstruction should bypass the osteotomy and engage the diaphysis.

In most modular implant systems, the handles of the reamers have markings that correspond to the desired center of rotation, usually referring to the tip of the greater trochanter. Most modular systems offer various stem lengths; therefore, it is recommended to ream to an intermediate length so that options remain available if the final stem sits proud or recessed compared to the desired level. The final distal stem is inserted and firmly seated.

If a modular stem is preferred, then at this point, the proximal femur is prepared for placement of the body segment with the use of handheld or power reamers that are placed over a taper protector or the modular junction. The stable distal stem serves as a reference ensuring appropriate depth and orientation of the proximal reamer.

A provisional body is applied for trial, and the final body size, offset, and neck length can be chosen and implanted based on stability assessment.

In most nonmodular stem systems, the trials have modularity such that a trial stem can be inserted after the reaming is completed and various options for offset and neck length can be assessed. The final implant is selected and implanted based on stability, leg length, soft tissue tension, and optimal stem version.

Revision for Periprosthetic Fractures

Addressing periprosthetic femur fractures around a femoral stem through the ABMS approach follows many of the same principles necessary for revision surgery and closely parallels techniques

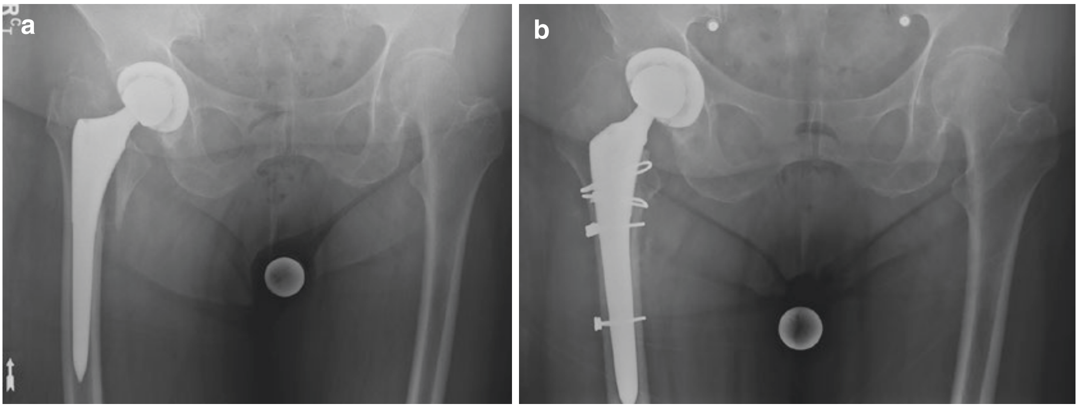


Fig. 16.12 (**a**) Anteroposterior radiograph of a right-sided periprosthetic fracture with peritrochanteric comminution resulting in stem subsidence. (**b**) Postoperative radiograph after stem revision and fracture reduction with cerclage cables and a distal prophylactic cerclage cable showing union and satisfactory union and reconstruction

for the previously described anterior-based osteotomy (Fig. 16.12a, b). Preoperative radiographs, mechanism and energy of injury, fracture pattern, and advanced imaging, when appropriate, can often identify an unstable or loose femoral component. This is an important distinction to make because stable components can be treated with implant retention with open reduction internal fixation of the fractured fragments, whereas loose components require implant extraction with stem revision and possibly supplemental internal fixation.

After standard perioperative planning efforts, medical optimization, and close scrutiny of radiographs, revision surgery may be carried out if indicated. The standard ABMS approach and femoral elevation and mobilization are carried out through previously described techniques.

The entirety of the leg should be prepped into the surgical field to allow extension of the incision as far distally and proximally as necessary. The most distal extent of the fracture should be identified early, and the incision should provide sufficient exposure at this level to allow for anatomic reduction of the fragments or identification of an intact isthmus in the case of severe comminution.

It is not always entirely evident during preoperative evaluation if the femoral component is loose. Thus, the first step after exposure is stem interrogation. Often, by following the steps described above for the extraction of a loose stem preparation, the stem may be removed without much difficulty. However, spot welding or partial fixation to one or more of the fractured fragments may be present which must be disrupted prior to stem removal. In these cases, the surgeon should disrupt the bone-prosthesis interface carefully with osteotomes or a burr prior to further extraction with disimpaction blows.

Once the stem is removed, femoral reconstruction can begin. The authors prefer reconstruction with a diaphyseal fitting tapered, fluted modular or monolithic stem. Prior to stem placement, the femur must be reconstituted. This can be accomplished in several different ways depending on fracture complexity and degree of comminution. Relatively simple patterns involving two or three fragments can be treated similarly to the anterior osteotomy technique described above. The hematoma and interposed periosteum should be removed along the length of the fractured fragment to allow anatomic reduction. Then, provisional fixation should be attained with bone-holding forceps or loosely tensioned cerclage wires or cables. Once reduction is confirmed, definitive fixation can be performed by final tightening the cables or, occasionally, using plate fixation. The surgeon should ensure the fragments are firmly secured and that the femoral canal is reconstituted.

An important consideration at this stage is to avoid over-reducing the fractured fragment in a way that reduces the diameter of the proximal canal relative to the distal diaphysis. This over-reduction can cause premature chatter during reaming and a false sense of appropriate sizing based on the over-reduced fragment which may become mobile during the course of implantation or in the early postoperative period. This may lead to fracture, stem subsidence, or potential instability.

Another technique which mitigates this risk is to disregard the proximal fragment and ream into the distal segment first to establish the size needed for diaphyseal engagement. After distal preparation, the trial or final stem is placed, and the proximal segment is reduced to the implant, usually with cerclage cables or wires. It may be helpful to burr portions of the cancellous surface of the fracture fragment to accommodate the proximal stem or body and improve the reduction. This method occasionally sacrifices anatomic reduction of the fracture but ensures a tight diaphyseal fit of the revision stem.

When treating highly comminuted fractures, a similar methodology is recommended. Ignoring the comminution proximally and focusing on scratch fit at the isthmus allow for a stable construct to which the larger fragments can be reduced. In these cases, provisional reduction, if possible, can still be valuable in determining length and version when the typical landmarks are involved in the fracture.

Wound Closure and Postoperative Protocol

Femoral revision wounds can be closed in a similar fashion to that of primary arthroplasties. The anterior pseudocapsule is repaired with heavy suture if there is enough remaining capsular tissue to reapproximate. The side-to-side fascial repair can be done with interrupted stitches or with a running barbed suture. The superficial wound is closed in layers. Generally, in the context of infection or suspected infection, monofilament suture is advisable.

In absence of hip instability, postoperative use of an abduction orthosis is not necessary. If an ABMS anterior osteotomy was performed, protected weight-bearing may be beneficial. Weight-bearing is at the discretion of the surgeon, and any restrictions are determined according to the surgeon's preference and experience.

Conclusion

The anterior-based muscle-sparing approach is an apt and even preferable approach to manage femoral component revision and reconstruction without limitations based on indication. Appropriate attention should be paid to the capsular and soft tissue releases and to meticulous technique when removing the previous implant, as with any revision. The approach allows for an extensile exposure and for an anterior osteotomy and provides unobstructed exposure of the stem while preserving the abductor tendons' insertion site on the trochanter. Via this approach, surgeons can complete the revision procedure by proceeding with reconstruction with the revision femoral components of their preference.

References

1. Laffosse JM. Removal of well-fixed fixed femoral stems. Orthop Traumatol Surg Res. 2016;102(1 Suppl):S177–87.
2. Rieger B, et al. Mid-term results of revision total hip arthroplasty with an uncemented modular femoral component. Hip Int. 2018;28(1):84–9.
3. Riesgo AM, et al. Survivorship and complications of revision total hip arthroplasty with a mid-modular femoral stem. J Arthroplast. 2015;30(12):2260–3.
4. Brown JM, Mistry JB, Cherian JJ, Elmallah RK, Chughtai M, Harwin SF, Mont MA. Femoral component revision of total hip arthroplasty. Orthopedics. 2016;39(6):e1129–39.
5. Taylor JW, Rorabeck CH. Hip revision arthroplasty: approach to the femoral side. Clin Orthop Related Res. 1999;369:208–22.
6. Kerboull L. Selecting the surgical approach for revision total hip arthroplasty. Orthop Traumatol Surg Res. 2015;101(1):S171–8.
7. Angerame MR, et al. Early failure of primary total hip arthroplasty: is surgical approach a risk factor? J Arthroplast. 2018;33(6):1780–5.

8. Kahn TL, et al. Can dislocation rates be decreased using the anterior approach in patients with lumbar spondylosis or lumbar instrumented fusion? J Arthroplast. 2021;36(1):217–21.
9. Yuasa T, et al. Comparison of direct anterior approach and posterior approach total hip arthroplasty: more than 5-year follow-up. J Orthop. 2021;24:271–3.
10. Parvizi J, Restrepo C, Maltenfort MG. Total hip arthroplasty performed through direct anterior approach provides superior early outcome: results of a randomized, prospective study. Orthop Clin North Am. 2016;47(3):497–504.
11. Rodriguez JA, et al. Does the direct anterior approach in THA offer faster rehabilitation and comparable safety to the posterior approach? Clin Orthop Relat Res. 2014;472(2):455–63.
12. Taunton MJ, et al. John Charnley award: randomized clinical trial of direct anterior and miniposterior approach THA: which provides better functional recovery? Clin Orthop Relat Res. 2018;476(2):216–29.
13. Zawadsky MW, et al. Early outcome comparison between the direct anterior approach and the mini-incision posterior approach for primary total hip arthroplasty: 150 consecutive cases. J Arthroplast. 2014;29(6):1256–60.
14. Leiberman J, Berry D. Advanced reconstruction: hip 2. Lipponcott Williams & Wilkins; 2018.
15. Paprosky WG, Burnett RS. Assessment and classification of bone stock deficiency in revision total hip arthroplasty. Am J Orthop (Belle Mead NJ). 2002;31:459–64.
16. Wilson MJ, et al. Femoral impaction bone grafting in revision hip arthroplasty: 705 cases from the originating centre. Bone Joint J. 2016;98-B(12):1611–9.
17. Mcgrory AC, et al. Ultrasound gel minimizes third body debris with partial hardware removal in joint arthroplasty. Arthroplast Today. 2017;3(1):29–31.
18. Nagoya S, et al. Extraction of well-fixed extended porous-coated cementless stems using a femoral longitudinal split procedure. Eur Orthop Traumatol. 2015;6(4):417–21.
19. Park CH, et al. Anterior cortical window technique instead of extended trochanteric osteotomy in revision total hip arthroplasty: a minimum 10-year follow-up. Clin Orthop Surg. 2019;11(4):396–402.

Total Hip Replacement for Fragility Fractures Using the ABMS Approach in the Older Adult

17

Michael B. Held, Kyle L. McCormick, and Jeffrey A. Geller

Learning Points

- Incidence of femoral neck fractures in the elderly is rising.
- As patients are living longer and better results are being demonstrated, THR (total hip replacement) is proving to be the most effective treatment for the duration of the patients' life span.
- The ABMS (anterior-based muscle-sparing) approach allows for versatile options of arthroplasty including both hemiarthroplasty and THR.
- The ability to safely implant any femoral stem option and low risk of hip instability makes the ABMS approach an excellent option for this patient population.

M. B. Held
New York Presbyterian- Columbia University Irving Medical Center, New York, NY, USA
e-mail: mh3821@cumc.columbia.edu

K. L. McCormick
Columbia University Irving Medical Center, New York Presbyterian Hospital, New York, NY, USA
e-mail: klm2159@cumc.columbia.edu

J. A. Geller (✉)
Department of Orthopedic Surgery, New York Presbyterian-Columbia University Irving Medical Center, New York, NY, USA
e-mail: jgeller@columbia.edu

Epidemiology of Femoral Neck Fractures in the Older Adult

Incidence and Prevalence

The lifetime risk of a hip fracture in a Caucasian female is 16–18%; nearly 50% of women living past 90 years of age will suffer a hip fracture [1]. Femoral neck fracture (FNF) in the elderly is a leading cause of significant morbidity and mortality in this patient population [2, 3]. Worldwide, 18% of all fragility fractures involve the hip joint, with the majority of them involving the femoral neck [4]. Patients with FNFs require hospitalization and operative treatment; thus, this injury carries a significant economic burden to the healthcare system.

From 2003 to 2013, over 800,000 FNFs were identified in patients older than 65 in the United States [3]. It has been estimated that over 250,000 hip fractures occur annually [2]. The US national incidence of femoral neck fracture has decreased due to improvements in osteoporosis screening and treatment; however, the 2013 age-adjusted incidence was still significant at 146 per 100,000 US adults [3]. As life expectancy continues to increase and the population continues to age, it is estimated that the prevalence of hip fracture in the elderly will increase to over 500,000 per year [3].

Risk Factors

The pathogenesis of hip fracture is multifaceted; however, it can be simplified into two major cate-

J. A. Geller, B. J. McGrory (eds.), *The Anterior-Based Muscle-Sparing Approach to Total Hip Arthroplasty*, https://doi.org/10.1007/978-3-031-02059-9_17

Table 17.1 Risk factors for low bone mineral density

	Modifiable	Nonmodifiable
Risk factors	Smoking Alcohol intake Inadequate intake of calcium Inadequate intake of vitamin D Glucocorticoid use Sedentary lifestyle	Older age Female Family history White/Asian race History of previous fracture

gories: (1) decreasing bone mineral density (BMD) [osteoporosis] and (2) increasing rate of falls [5]. There are modifiable and nonmodifiable factors that negatively influence BMD (Table 17.1).

While there are numerous treatments of osteoporosis such as lifestyle modification, bisphosphonates, and immunomodulators, many still suffer the devastating effects of fragility fracture due to falls. Fall prevention is critical to avoiding femoral neck fracture.

Morbidity and Mortality of Femoral Neck Fracture

The 30-day mortality rate following operative treatment of acute FNFs in the elderly is cited to be as high as 9.6%. A one-year mortality following this injury has been reported to be as high as 33% [6]. The strongest predictor of death in the elderly patient with an acute hip fracture is the presence of more than three medical comorbidities [6].

Over 30% of all elderly patients suffer a 30-day postoperative complication following surgery for acute FNFs [7]. Common postoperative complications following FNF include hypoxia, acute renal impairment, the need for blood transfusion, pneumonia, and urinary tract infection [7]. Elderly patients have lower physiologic reserves; thus, things like postoperative chest infection, fluid overload, and urinary tract infection can have devastating effects on one's health compared to the younger, healthier patient.

The goal of operative treatment for femoral neck fracture is to return the patient to his or her baseline ambulatory function, yet the outcomes following treatment for hip fracture are often suboptimal. Patients are frequently unable to return to their previous ambulatory level, require an increased level of care and supervision, and have lower functional patient-reported outcome measures. Following injury and treatment, nearly 33% of patients never independently ambulate again [8]. Moreover, 50% of patients never regain pre-fracture independence in activities of daily living (ADLs), and 20% of patients end up permanently in long-term care facilities within 1 year of injury [9, 10].

Clinical Presentation

Initial History and Physical Exam

Most femoral neck fractures in the elderly occur secondary to a low-energy mechanical fall from standing. The fractured hip generally occurs on the side of the body that directly impacts the ground following the fall. A thorough history should be obtained to ensure that the fall was indeed mechanical and not syncopal. If the history indicates the possibility of syncopal fall, a medical workup for syncopal etiologies should be pursued, as this may indicate an underlying untreated medical condition.

Patients with acute FNF will report groin and proximal thigh pain with the inability to ambulate or stand up following the inciting event. If the patient suffers a displaced FNF, on physical exam, the injured extremity is usually shortened and externally rotated compared to the uninjured side. However, this difference in leg length and position will not be evident if the fracture is nondisplaced. Pain will be elicited with most movements of the hip including logroll and heel strike of the injured extremity. The Stinchfield test, or ability to straight leg the affected side, will also be evident with either a displaced or nondisplaced FNF. As with any orthopedic injury, a thorough exam of the affected extremity's neurovascular structures should be performed. Given the high rate of additional injuries, both orthopedic and nonorthopedic, a comprehensive primary and secondary trauma assessment should be conducted, and one should have a high suspicion for concomitant head injury.

Radiographic Workup

An anterior-posterior (AP) pelvis X-ray should be obtained for all geriatric patients following a fall. If the patient's presentation is consistent with a possible FNF, a dedicated AP and cross-table lateral of the affected hip and femur should be obtained. A radiopaque marker ball or coin should be placed in between or adjacent to the thigh at the level of the femur for operative templating purposes. It is important to image the entire affected extremity as well as the joint proximal and distal to injury to rule out adjacent extremity injury. Additionally, if there is question to whether the fracture may be either extracapsular or intracapsular, a traction internal rotation X-ray may be obtained to help better identify the fracture characteristics that may change operative treatments.

There is a role of advanced imaging in cases when a false negative is suspected on plain radiographs. If the patient is still unable to ambulate following negative radiographs, a CT scan or MRI may be obtained to rule out a non-displaced femoral neck fracture. The American Academy of Orthopaedic Surgeons (AAOS) advocates for MRI (magnetic resonance imaging) as the advanced imaging modality of choice for diagnosis of occult FNF not apparent on initial radiographs after falls in the elderly [11].

Fracture Classification

Femoral neck fractures can be classified as subcapital, transcervical, or basicervical based upon the level of the fracture. Subcapital fractures occur at the junction of the femoral head and femoral neck. Transcervical fractures occur through the midportion of the femoral neck, where basicervical fractures occur at the base of the femoral neck (Fig. 17.1).

The most commonly used classification system to describe femoral neck fractures is the Garden classification. Garden type 1 fractures are incomplete (Fig. 17.2), valgus-impacted injuries.

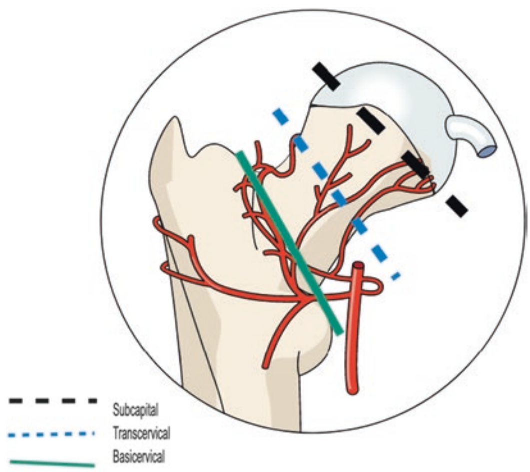


Fig. 17.1 Femoral neck fracture anatomy

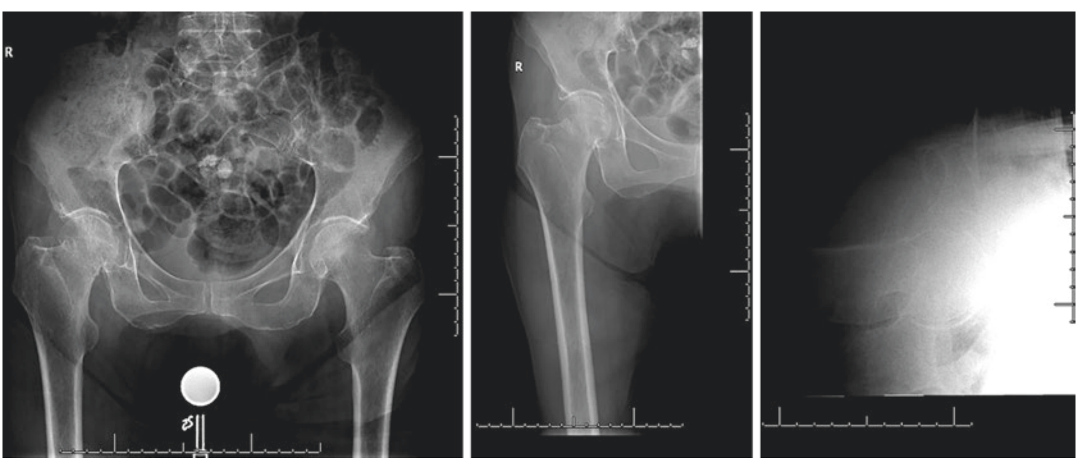


Fig. 17.2 Example of Garden type 1 valgus-impacted right hip femoral neck fracture

Type 2 fractures are complete and nondisplaced. Type 3 fractures are complete and partially displaced. Type 4 fractures are complete and fully displaced and mild fracture angulation. The modified Garden classification categorizes femoral neck fractures simply as nondisplaced or displaced [9, 11].

Surgical Treatment Options for Femoral Neck Fractures

While the scope of this chapter is to discuss total hip replacement (THR) for fragility fractures using the ABMS approach in the elderly patient, it is important to briefly note the alternative treatment options for this patient population. Apart from THR, hemiarthroplasty (HA) and closed reduction percutaneous pinning (CRPP) are two commonly utilized operative techniques in treating fragility fractures of the femoral neck in the elderly patient.

Arthroplasty

Either HA or THR is indicated in the setting of displaced FNF in the elderly patient. Arthroplasty allows for immediate weight-bearing with the resection of the fractured femoral neck and head. Displaced femoral neck fractures have a high rate of avascular necrosis (AVN) even if fixed anatomically in the geriatric patient. Thus, given the risk of AVN and the need for a second surgery, arthroplasty is often considered the most reliable treatment option in this patient population.

Hemiarthroplasty

HA has long been considered the workhorse of displaced femoral neck fractures in the elderly. Also known as partial hip replacement, hemiarthroplasty (HA) involves replacing the femoral head and neck with a metal component; however, it does not address the acetabulum. Historically, this allows for increased hip stability given the larger available femoral head size when the acetabulum is not replaced. Active elderly patients with prior hip pain and preexisting hip arthritis are not ideal candidates for this procedure as this procedure does not address acetabular pathology.

Total Hip Replacement

THR involves replacement of both the femoral head and neck and the acetabulum. Much like HA, THR is a successful reproducible procedure which is indicated for any displaced femoral neck fracture in the elderly. THR is specifically indicated in this patient population in the setting of a younger, more active patient, with or without preexisting hip arthritis.

Closed Reduction Percutaneous Pinning (CRPP)

Nondisplaced and valgus-impacted femoral neck fractures in geriatric patients are instances when CRPP may be indicated. This minimally invasive technique utilizes cannulated screws to repair stable fracture patterns that do not require a formal open reduction. Nondisplaced fracture patterns have a lower rate of AVN, making this the preferred treatment option for these types of fractures. However, it should be noted that there is still a risk of nonunion, AVN, degenerative joint disease and screw penetration into the hip joint with this technique.

Total Hip Replacement Versus Hemiarthroplasty

The decision to perform a THR or a HA for a displaced geriatric femoral neck fracture remains debated in the literature. Older evidence suggested that HA was associated with lower rates of dislocation, less blood loss, shorter operative duration, and overall decreased costs compared to THR [12]. However, when performing a hemiarthroplasty, there is a future risk of conversion to THR due to acetabular erosion or continued pain [13]. Nonetheless, THR has been cited to have superior functional outcomes, especially in the younger, more active, elderly patient [14, 15].

A recent 2020 systematic review and meta-analyses of randomized controlled trials by Ekhtiari et al. found that a 5-year follow-up following either HA or THR for FNF resulted in no significant difference in revision rate, dislocation, periprosthetic fracture, function, mortality, or meaningful difference in functional outcome between the two different arthroplasty procedures [16]. While they did find that THR resulted in slightly increased functional scores, it did not meet meaningful clinical difference. Additionally, HA was on average 22 minutes shorter, which likely is a clinically unimportant reduction in operative time [16]. While they did not specifically evaluate the effect of approach on outcomes, this study states that both are reasonable treatment options for elderly patients with displaced femoral neck fractures.

Thus, the decision to perform either a THR or HA for a displaced femoral neck fracture in the geriatric patient still remains the attending surgeon's discretion, which is generally based on individual patient characteristics and the surgeon's own training in arthroplasty practices. Yet, the evidence is still not clear if differences exist when evaluating postoperative outcomes for HA versus THR through the ABMS approach.

ABMS Approach Technique for Total Hip Replacement

The ABMS approach utilizes the intramuscular plane between the tensor fasciae latae (TFL) and the gluteus medius muscles, both of which are innervated by the superior gluteal nerve. Recent advancements in this ABMS technique utilize an abductor-sparing approach with many of the same recovery and pain benefits of the DAA. This ABMS technique may be used in the setting of fracture, primary osteoarthritis, or revision hip replacement.

Patient Positioning and Surgical Exposure

In our center, the patient is positioned supine on a radiolucent table with a bump (folded sheet or bag of IV (intravenous) fluid) under the ipsilateral ischium. This bump allows the femur to drop posteriorly to aid in acetabular exposure and preparation. Skin incision is made 2.5 cm posterior and distal to the ASIS and runs distally over the anterior border of greater trochanter (Fig. 17.3).

The incision is generally 10–14 cm in length and avoids the groin crease unlike some DAAs. Two skin rakes are used to apply tension to the soft tissues, and an electrocautery is utilized to reach the fascia overlying the TFL and gluteus medius muscles. Unlike the DAA, the lateral femoral cutaneous nerve is less frequently encountered and injured given the more laterally based approach. Care is taken not to create dead space above the fascial layer to prevent postoperative seroma formation. Once the fascial layer is reached, it may be gently cleaned with a surgical sponge. The fascial layers have a unique color tone to them that aid in correct identification in the ABMS interval. Medially, the sartorial fascia

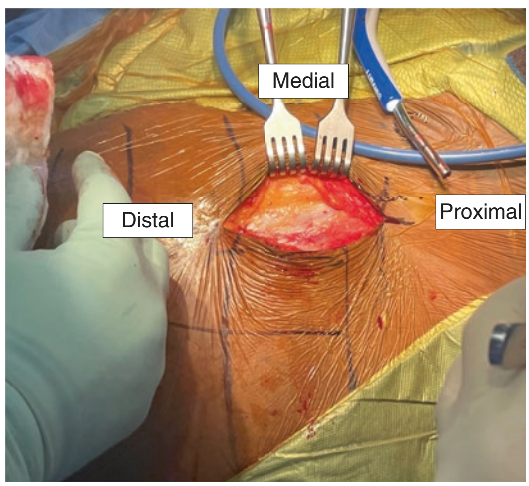


Fig. 17.3 Incision of anterior-based muscle-sparing approach (left hip)

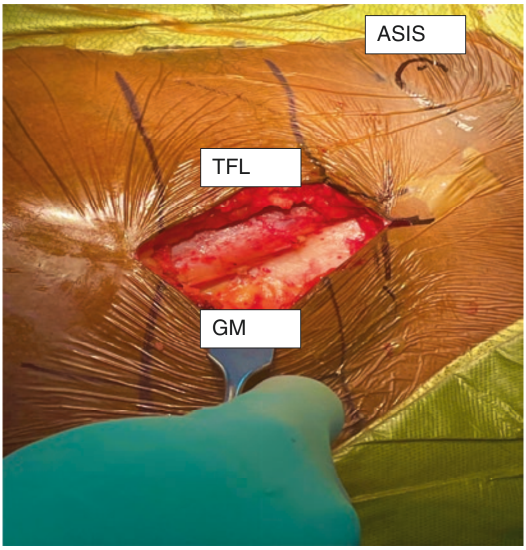


Fig. 17.4 Superficial interval. TFL tensor fascia latae fascia, ASIS anterior superior iliac spine, GM gluteus medius fascia

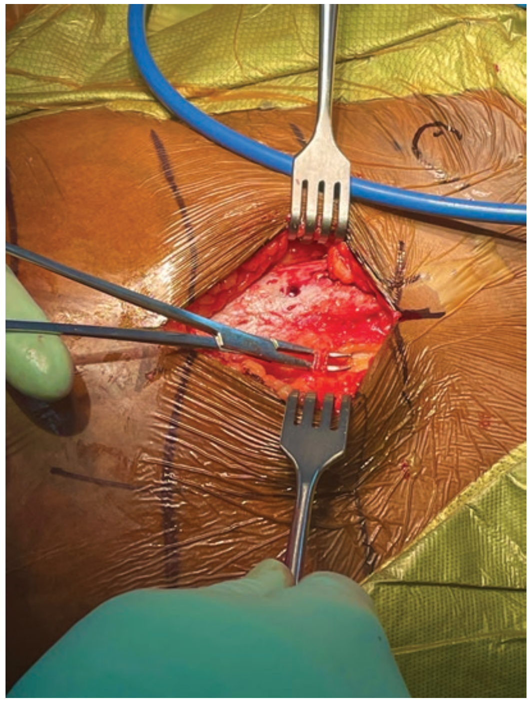


Fig. 17.5 Ascending branches of the lateral femoral circumflex vessel

is white. Just lateral to this, the TFL fascia changes to a bluish color. And again, just lateral to this, the gluteus medius fascia changes back to a whitish color (Fig. 17.4).

Accordingly, medial to lateral, the fascia colors are white-blue-white. Utilizing the electrocautery, the fascia over the gluteus medius muscle, whitish in color, is incised 1 cm lateral to the blue-white transition. This aided in fascial closure, as the fascia over the abductors is more robust than the TFL fascia. The fasciotomy is extended proximally and distally to the edges of the incision.

Using gentle, blunt, finger dissection, the space deep and posterior to the abductors can be freed up from the anterolateral hip capsule. Aufranc cobra retractors can be placed around the inferior and superior neck, outside the hip joint capsule. At this point, branches of the ascending lateral circumflex are coagulated using a tonsil and electrocautery. They are generally found in the distal end of the incision and are encased by a thin layer of yellowish fat (Fig. 17.5).

A curved anterior acetabular retractor is then placed over the anterior acetabular rim. Care must be taken during placement to not drift too far medially to avoid injury to the femoral vein, artery, and nerve.

In the setting of fracture, the tissue planes will be less obvious given the surrounding hemorrhagic tissues and edema. The pre-capsular fat should be carefully removed from the underlying hip capsule to help identify the capsular orientation. Deep to the hip capsule, the femoral neck should be palpated to ensure correct exposure. Next, a sequential anterior capsulotomy or capsulectomy is performed using an electrocautery. In our center, both techniques are used; however, the senior author prefers capsulectomy. Wide capsulectomy, avoiding injury to the indirect head of the rectus superomedially, abductor tendons superolaterally, and the vastus inferolaterally are essential for easy removal of the femoral head after osteotomy. Upon entering the hip joint, hemorrhagic fluid may be observed when performing THR in the setting of fracture (Fig. 17.6). Hematoma and clot are then removed through the capsular window to aid in visualization of the fractured femoral neck.

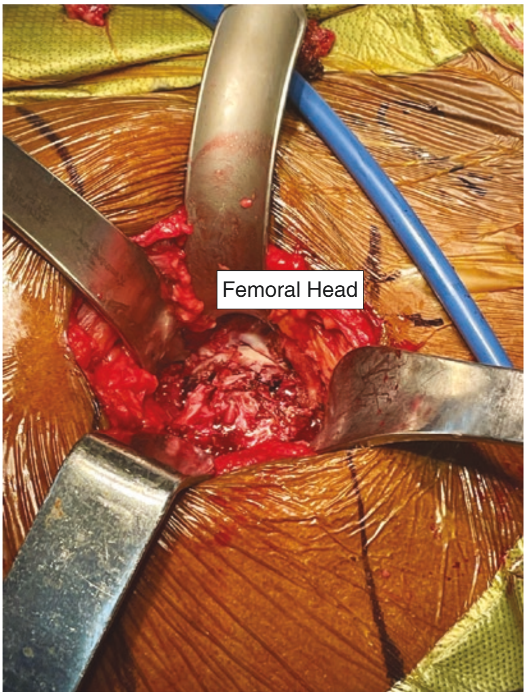


Fig. 17.6 Fractured femoral neck

At this point, the capsulectomy is extended proximally through the labrum, which will allow for easier delivery of the femoral head. All visible capsular tissues are removed from the superior neck extending into the piriformis fossa and inferiorly toward the lesser trochanter. After adequate capsular resection, both Aufranc cobra retractors are placed deep to capsule around the superior and inferior femoral neck. Using a wide flat saw blade, a "cleanup" femoral neck osteotomy is completed as per the preoperative surgical template plan based off of the distance from the lesser trochanter. Care must be taken during osteotomy to avoid damaging the greater trochanter. The cut neck is removed, and the fractured femoral head is captured using a corkscrew drill which is placed into the center-center position. The femoral head is then delivered out of the acetabulum and removed from the wound without damaging the surrounding structures (Fig. 17.7). There may be some additional bony debris from the residual fracture fragments.

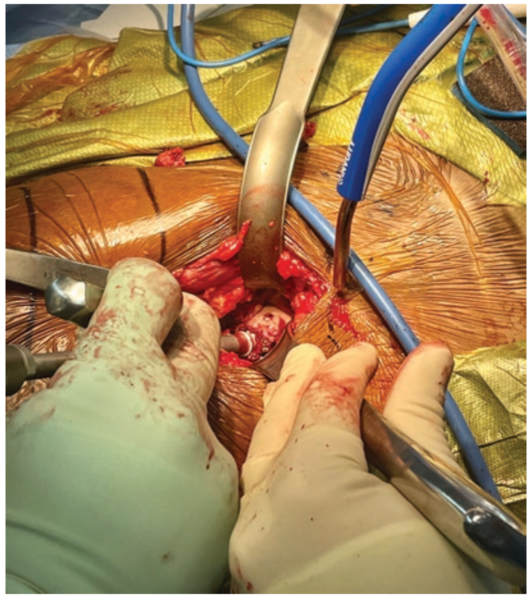


Fig. 17.7 Femoral head delivery

Acetabular Preparation

Once the fractured femoral head is completely removed from the wound, acetabular preparation is begun. Exposure of the acetabulum is aided by placing a posterior pointed retractor over the posterior wall and by placing a traditional "C" retractor over the anterior wall. Care must be taken when handling these retractors to avoid fracturing the anterior and posterior walls of the acetabulum. Next, the pulvinar tissue is removed from the deep acetabulum, and the labrum is sharply excised and removed. The appropriate starting reamer, based off preoperative templating, is then placed into the socket. As these elderly fracture patients have decreased BMD, significant care must be taken to not over medialize and break through the medial wall. Using fluoroscopy, the reamer is medialized down to the cotyloid fossa. Once sufficiently medialized with the appropriate starting reamer, the acetabulum is sequentially, concentrically reamed.

Reaming is considered complete once the reamers have sufficiently engaged the native acetabulum and the bleeding cancellous bone is observed 360 degrees around the acetabulum. Fluoroscopy may be utilized while inserting the final acetabular component to ensure proper acetabular component positioning. Intraoperative goals of component position are 45 degrees of abduction and 10–15 degrees of anteversion (Fig. 17.8).

After the component is inserted into place, the senior author typically augments acetabular fixation with one fully threaded cancellous screw in the posterior superior "safe zone" to aid in fixation. The final polyethylene liner is impacted into place, and a final check is taken to ensure that the liner is seated appropriately in the acetabulum.

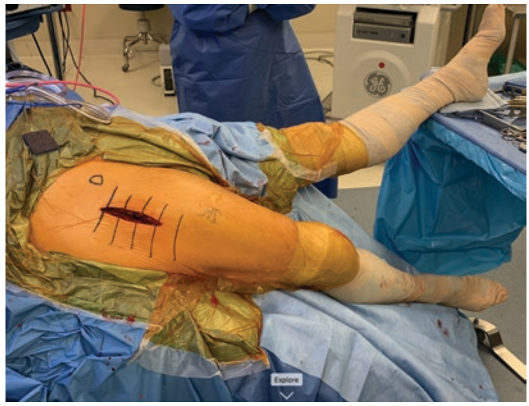


Fig. 17.9 Figure of four position of the legs for preparation of the femoral component

Femoral Preparation

Patient positioning is critical in aiding in successful femoral exposure and elevation. The foot of the table is lowered in order to aid in ipsilateral hip extension and deliver the metaphyseal portion of the femur into view. The contralateral leg is placed on a mayo stand with a pad for the heel in order to create space for the ipsilateral leg to be adducted underneath. The operative extremity is extended, adducted, and externally rotated maximally in order to gain exposure to the femur in a "figure of four" position (Fig. 17.9). A femoral neck elevating retractor is placed medially around the femoral neck calcar. A large pointed Hohmann retractor is placed around the greater trochanter without injuring the abductor tendons.

Posterior capsular release is imperative to aid in proper elevation of the femur to gain access for femoral preparation. While extending, adducting, and externally rotating the hip, the superior capsule is released. The capsular tissue inside the saddle is carefully released from inside out while avoiding the abductor tendons. If necessary for appropriate elevation, the more proximal short external rotators of the hip can be released. The obturator internus, piriformis, and obturator externus are sequentially released in that order, if necessary, though the main benefit to the ABMS approach is the minimal release of these tendons compared to the DA approach.

Once adequate elevation is achieved, sequential broaching is then performed. In the setting of fracture in a geriatric patient, a cemented femoral component is most often utilized. This helps prevent intraoperative fracture in this patient population with poor bone quality. If a calcar fracture was present from injury or occurred intraopera-

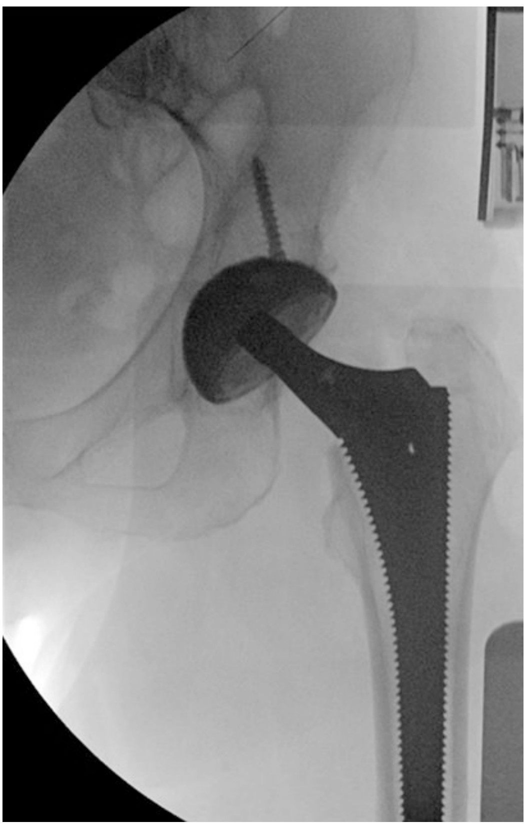


Fig. 17.8 Intraoperative imaging of proper acetabular cup positioning

tively, a cerclage cable can be placed around the femur just superior to the lesser trochanter. A cable may also be placed prophylactically if the surgeon is worried about poor bone quality, especially if a cementless technique is utilized.

Once the femur is adequately prepared, components are trialed. The hip is reduced with a head pusher while an assistant pulls traction and internal rotation on the leg. Stability of the implant is checked, and leg lengths are checked using intraoperative fluoroscopy. Our technique is to use the radiopaque cord of the electrocautery device to aid in further confirming leg lengths radiographically, in addition to clinically. The cord is placed tangential to both ischial tuberosities, and the intersection of this line with both lesser trochanters is evaluated (Fig. 17.10).

If leg lengths need adjustment, neck lengths and/or the femoral component can be adjusted.

Once the component sizes have been selected, we typically cement using fourth-generation cementing techniques. At this point, it is critical to communicate with the anesthesiologist that cement will be placed in the event that they need to intervene in the case of hypotension or respiratory compromise. The cup is checked to ensure there is no cement debris. The final femoral head is impacted, and the hip is reduced.

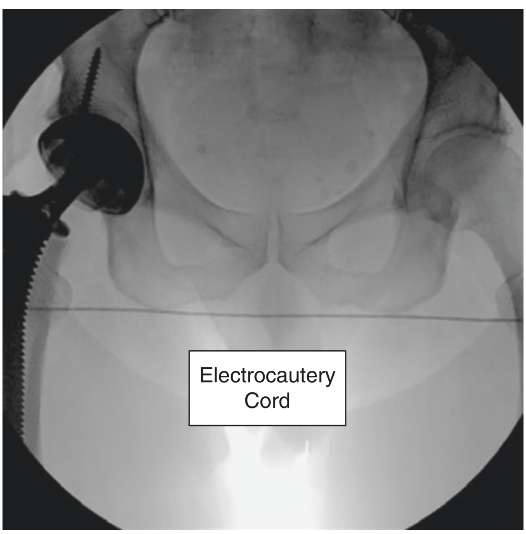


Fig. 17.10 Intraoperative assessment of leg lengths

Postoperative Care

Postoperatively, the patients are made weight-bearing as tolerated with no activity restrictions or precautions. Final flat plate X-rays are obtained in the recovery room, and the patients receive physical therapy on the same day as surgery. Deep vein thrombosis prophylaxis is standardized to begin on postoperative day 1 (POD1) with aspirin 81 mg twice daily for 21 days. However, if a patient is at higher risk for venous thromboembolic complications, newer oral agents such as apixaban or rivaroxaban are begun on POD1 for 21 days.

Implant Considerations Utilizing the ABMS Approach

Femoral Component

Selecting the proper femoral component in a geriatric patient is an important preoperative decision when planning for THR for FNF. Especially in geriatric patients with FNF, the risk of intraoperative periprosthetic fracture (PPF) must be considered when THR is performed through the ABMS approach. As stated in earlier sections, the geriatric fracture patient should be treated differently than a primary hip arthritis patient due to their decreased BMD and overall frailty. We make every effort to optimize these patients and get them to the surgical suite within 12–24 hours to minimize time in bed and get patients moving postoperatively.

The incidence of proximal femur intraoperative PPF through an anterior approach has been associated with increased risk compared to a posterior approach. However, recent evidence has suggested that once surgeons are through their learning curve of the anterior approach, no increased risk is observed [17]. The risk of early PPF has been cited to be 0.9–4.5% [17–20]. Risk factors include osteoporosis, age greater than 80, female sex, a diagnosis other than osteoarthritis, and uncemented femoral prostheses [18, 19, 21, 22].

When selecting a femoral prosthesis, a surgeon can elect to use a cemented or cementless design. However, cementless prostheses have been associated with increased risk of PPF in the geriatric patient [19], and thus cemented technique is strongly recommended. When a cemented femoral component is utilized, the proximal femur does not experience the same magnitude of hoop stresses that a cementless component produces. As cementless components are predicated on achieving a stable press fit, incremental broaching of the femoral canal poses a risk of PPF, especially with poor bone quality. Although cemented femurs still have a risk of PPF, it is significantly less than cementless technique. However, cementing is not benign and poses other risks such as cement embolization, hypotension, and possible respiratory compromise in patients with decreased pulmonary reserve [23].

If an intraoperative PPF within the metaphysis of the proximal femur is recognized, a cerclage cable can be carefully passed around the femur, while avoiding capturing any of the medial neurovascular structures. If a surgeon is concerned about bone quality preoperatively and the pulmonary risks of cementation are considered too high, one can prophylactically cerclage the femur to help mitigate the risk of intraoperative PPF when utilizing a cementless component. If an intraoperative PPF does occur, the surgeon may consider restricting the patient to partial weight-bearing for a short period postoperatively.

Furthermore, femoral components can be either collared or collarless. Femoral collars are seated on the cut surface of the medial femoral neck. Traditionally, collars have been thought to prevent loosening and subsidence of the femoral component by loading the proximal femur and preventing bone absorption. Collars serve as a hard stop in determining the depth of femoral component insertion preventing subsidence and leg length discrepancies [24]. However, overall revision risk does not differ between collared and collarless stems, and thus their proposed advantages remain disputed among surgeons [25].

Lastly, a cementless femoral component can be either metaphyseal or diaphyseal fitting. While there are numerous designs of both such as single-wedge, double-wedge, and modular components, any of these stems pose an increased fracture risk for the geriatric patient due to the risk of periprosthetic fracture; therefore, we generally endorse a cemented femoral component as the gold standard for patients with femoral neck fractures requiring arthroplasty as definitive treatment.

Acetabular Component

Acetabular components for THR can also be cemented or cementless. Cemented acetabular components have fallen out of favor for primary THR, and their current use is mostly in the infection setting for delivery of high-dose antibiotics in the form of an articulating spacer. Cemented acetabular components have an increased risk of aseptic loosening produced by a macrophage inflammatory response compared to their cementless counterpart [26]. The acetabular revision risk with a cemented cup has been reported to be as high as 10–15% compared to 1% for cementless component [27–29].

Fully threaded cancellous screws are often used for additional fixation when implanting a cementless acetabular component in the elderly. Screws allow for additional fixation preventing micromotion and gapping between the component and bone, thus preventing a loss of compressive stresses at the implant-bone interface [30].

Femoral Head and Liner

There are a variety of different implant materials for the femoral head and liner. The most commonly used are ceramic (CoP) or chrome-cobalt alloy (MoP) heads on polyethylene liner. Cobalt alloy femoral heads are an attractive option for the geriatric patient due to the patient's likely limited life span in conjunction with a lower cost. However, if the patient is on the younger spectrum of age for a FNF, consideration may be given to the increased risk of mechanically assisted crevice corrosion making CoP a more attractive implant in a population where revision surgery carries a large risk of morbidity and mortality.

Dual mobility (DM) liners have gained popularity due to their biomechanical advantage in preventing dislocation by increasing the effective head diameter and jump distance [31]. Darrith et al. found the rate of dislocation following DM for fracture to be 0.18% [31]. The ABMS approach largely decreases the risk of instability, and the role of DM liners remains debated as it adds costs with a controversial benefit. However, with a posterior approach, one can argue for added stability with DM due to the violation of the posterior capsule and soft tissues surrounding the hip. DM should be considered in elderly patients undergoing THR through the ABMS approach for FNF in the setting of prior lumbopelvic spine fusion or neurologic conditions causing rigidity such as Parkinson's disease. Additionally, when a surgeon is unable to place a large femoral head, one may consider the addition of a DM liner for additional stability in this highly at-risk population. In summary, the use of DM liner should be carefully considered in high-risk instability patients.

Unique Considerations in the Elderly Patient

Postoperative Recovery

Early mobility and ambulation following THR for FNF in the elderly are imperative to prevent medical complications associated with immobility such as deep vein thrombosis, pressure sores, atelectasis, aspiration pneumonia, and severe deconditioning. Chulsomlee et al. retrospectively reviewed hip muscle power recovery using ABMS approach for THR in elderly patients and found that when this approach was utilized, patients had faster hip strength recovery and early mobilization with decreased rates of lateral femoral cutaneous nerve injury compared to the direct anterior approach [32]. Additionally, compared to the posterior approach which often requires posterior hip precautions, we typically do not implement postoperative restrictions in our patients after an ABMS approach. This is beneficial for elderly patients who suffer from dementia who may not be able to comply with postoperative precautions, which can limit their ability to ambulate.

Periprosthetic Fracture

Elderly patients with decreased BMD are at increased risk for PPF following ABMS approach for THR. Age over 70 carries a 2.9 times risk of PPF compared to those less than 70 [33]. The one-year mortality rate after perioperative PPF following a THR ranges from 13% to 18% for all patients [34]. Although the literature is limited, this mortality rate is likely further increased in the subset of patients with original femoral neck fracture. The ABMS approach for THR has been shown to carry a 2% risk of periprosthetic fracture requiring revision surgery within 3 months postoperatively, which is comparable to that of the direct anterior approach [35]. However, Herndon et al. retrospectively reviewed 684 primary THR through the ABMS (4.1% for fracture) and found that when a cemented stem was utilized, the rate of PPF was 0% [35]. This was significantly less than uncemented tapered stems and metadiaphyseal collarless stems that had an overall PPF rate of 9.8% [35]. Additionally, gentle manipulation and broaching of the femur are recommended in the geriatric patient population to prevent calcar fracture and perforation [32]. Therefore, in the geriatric fracture patient population, a cemented collared stem is the preferred femoral component.

There are a variety of treatment options for the PPF, based on its location and timing. If an intraoperative or postoperative calcar fracture is found, the treatment is to place a cerclage cable around the calcar and to restrict postoperative weight-bearing. Postoperative greater trochanter fractures are often managed conservatively with restricted active abduction but at times open reduction and internal fixation with a low-profile locking plate. Vancouver B2 PPFs are mainly managed operatively with a revision arthroplasty with a long diaphyseal fitting uncemented stem. Vancouver C PPFs are managed operatively with open reduction and internal fixation. Given the devastating morbidity and mortality of revision surgery for the geriatric patients, we advise for all patients over 70 years of age to have cemented femoral components to decrease the risk of peri-operative PPF.

Dislocation

The ABMS approach has been shown to have a decreased risk of dislocation following THR compared to the posterior approach (hazard ratio: 0.20, $p = 0.0020$) [36]. Risk factors for dislocation include cup and stem malposition, smaller femoral head size, abductor insufficiency, prior spinopelvic fusion, and neuromuscular rigidity [37, 38]. Traditionally, HA has been preferred over THR for the geriatric femoral neck fracture patient due to its associated lower rate of dislocation. HA allows for a larger femoral head, increasing the jump distance, making dislocations less frequent. A recent meta-analysis comparing HA to THR for displaced femoral neck fractures found a risk reduction favoring HA for dislocation of 0.37 ($p < 0.0001$) [39]. However, the authors state that their analysis is limited because it did not control for the approach utilized. As the ABMS approach has lower rates of dislocation compared to the posterior approach, and with increasing use of DM liners, the risk of dislocation following THR compared to HA may be clinically insignificant [40, 41]. Thus, a THR through an ABMS approach with the addition of a DM liner is an appropriate treatment for a higher-risk elderly patient with a femoral neck fracture.

Conclusion and Author Recommendations

Femoral neck fracture in elderly patients is a serious injury that carries a significant risk of morbidity and mortality. This patient population usually has decreased bone mineral density and multiple medical comorbidities which influence surgical decision-making. Compared to open reduction and internal fixation and closed reduction percutaneous pinning, arthroplasty is the preferred treatment for a displaced FNF due to the high rate of avascular necrosis of the femoral head in this patient population. Furthermore, given the recent advancements with the ABMS approach and improved implant designs and materials, the rate of dislocation following THR has significantly decreased, making it more attractive when deciding between HA. When performing a THR in an elderly patient with FNF, our preference is to use the ABMS approach with a collared cemented femoral component and a cementless acetabular component. When the risks of cementation are deemed too significant due to limited pulmonary reserve, a cementless component may be used along with a prophylactic cerclage cable superior to the lesser trochanter. In patients with increased risks of postoperative dislocation such as those with prior lumbo-pelvic spinal fusions and neuromuscular conditions, we recommend using a dual mobility liner.

References

1. Kannus P, Parkkari J, Sievänen H, Heinonen A, Vuori I, Järvinen M. Epidemiology of hip fractures. Bone. 1996;18(1 Suppl):57s–63s. https://doi.org/10.1016/8756-3282(95)00381-9.
2. Florschutz AV, Langford JR, Haidukewych GJ, Koval KJ. Femoral neck fractures: current management. J Orthop Trauma. 2015;29(3):121–9. https://doi.org/10.1097/bot.0000000000000291.
3. Ju DG, Rajaee SS, Mirocha J, Lin CA, Moon CN. Nationwide analysis of femoral neck fractures in elderly patients: a receding tide. J Bone Joint Surg Am. 2017;99(22):1932–40. https://doi.org/10.2106/jbjs.16.01247.
4. Johnell O, Kanis JA. An estimate of the worldwide prevalence and disability associated with osteoporotic fractures. Osteoporos Int. 2006;17(12):1726–33. https://doi.org/10.1007/s00198-006-0172-4.
5. Veronese N, Maggi S. Epidemiology and social costs of hip fracture. Injury. 2018;49(8):1458–60. https://doi.org/10.1016/j.injury.2018.04.015.
6. Roche JJ, Wenn RT, Sahota O, Moran CG. Effect of comorbidities and postoperative complications on mortality after hip fracture in elderly people: prospective observational cohort study. BMJ.

2005;331(7529):1374. https://doi.org/10.1136/bmj.38643.663843.55.
7. Al-Mohrej OA, Alshaalan FN, Aldakhil SS, Rahman WA. One-year mortality rates following fracture of the femoral neck treated with hip arthroplasty in an aging Saudi population: a trauma center experience. Geriatr Orthop Surg Rehabil. 2020;11:2151459320922473. https://doi.org/10.1177/2151459320922473.
8. Buecking B, Struewer J, Waldermann A, Horstmann K, Schubert N, Balzer-Geldsetzer M, et al. What determines health-related quality of life in hip fracture patients at the end of acute care?–a prospective observational study. Osteoporos Int. 2014;25(2):475–84. https://doi.org/10.1007/s00198-013-2415-5.
9. Lu Y, Uppal HS. Hip fractures: relevant anatomy, classification, and biomechanics of fracture and fixation. Geriatr Orthop Surg Rehabil. 2019;10:2151459319859139. https://doi.org/10.1177/2151459319859139.
10. Kani KK, Porrino JA, Mulcahy H, Chew FS. Fragility fractures of the proximal femur: review and update for radiologists. Skelet Radiol. 2019;48(1):29–45. https://doi.org/10.1007/s00256-018-3008-3.
11. Sheehan SE, Shyu JY, Weaver MJ, Sodickson AD, Khurana B. Proximal femoral fractures: what the orthopedic surgeon wants to know. Radiographics. 2015;35(5):1563–84. https://doi.org/10.1148/rg.2015140301.
12. Keating JF, Grant A, Masson M, Scott NW, Forbes JF. Displaced intracapsular hip fractures in fit, older people: a randomised comparison of reduction and fixation, bipolar hemiarthroplasty and total hip arthroplasty. Health Technol Assess. 2005;9(41):iii–iv, ix–x, 1–65. https://doi.org/10.3310/hta9410.
13. Burgers PT, Van Geene AR, Van den Bekerom MP, Van Lieshout EM, Blom B, Aleem IS, et al. Total hip arthroplasty versus hemiarthroplasty for displaced femoral neck fractures in the healthy elderly: a meta-analysis and systematic review of randomized trials. Int Orthop. 2012;36(8):1549–60. https://doi.org/10.1007/s00264-012-1569-7.
14. Rodríguez-Merchán EC. Displaced intracapsular hip fractures: hemiarthroplasty or total arthroplasty? Clin Orthop Relat Res. 2002;399:72–7.
15. Schmidt AH, Leighton R, Parvizi J, Sems A, Berry DJ. Optimal arthroplasty for femoral neck fractures: is total hip arthroplasty the answer? J Orthop Trauma. 2009;23(6):428–33. https://doi.org/10.1097/BOT.0b013e3181761490.
16. Ekhtiari S, Gormley J, Axelrod DE, Devji T, Bhandari M, Guyatt GH. Total hip arthroplasty versus hemiarthroplasty for displaced femoral neck fracture: a systematic review and meta-analysis of randomized controlled trials. J Bone Joint Surg Am. 2020;102(18):1638–45. https://doi.org/10.2106/jbjs.20.00226.
17. Cichos KH, Mabry SE, Spitler CA, McGwin G Jr, Quade JH, Ghanem ES. Comparison between the direct anterior and posterior approaches for total hip arthroplasty performed for femoral neck fracture. J Orthop Trauma. 2021;35(1):41–8. https://doi.org/10.1097/bot.0000000000001883.
18. Berend KR, Lombardi AV Jr, Mallory TH, Chonko DJ, Dodds KL, Adams JB. Cerclage wires or cables for the management of intraoperative fracture associated with a cementless, tapered femoral prosthesis: results at 2 to 16 years. J Arthroplast. 2004;19(7 Suppl 2):17–21. https://doi.org/10.1016/j.arth.2004.06.008.
19. Fitzgerald RH Jr, Brindley GW, Kavanagh BF. The uncemented total hip arthroplasty. Intraoperative femoral fractures. Clin Orthop Relat Res. 1988;235:61–6.
20. Mont MA, Maar DC, Krackow KA, Hungerford DS. Hoop-stress fractures of the proximal femur during hip arthroplasty. Management and results in 19 cases. J Bone Joint Surg Br. 1992;74(2):257–60. https://doi.org/10.1302/0301-620x.74b2.1544964.
21. Schwartz JT Jr, Mayer JG, Engh CA. Femoral fracture during non-cemented total hip arthroplasty. J Bone Joint Surg Am. 1989;71(8):1135–42.
22. Berry DJ. Management of periprosthetic fractures: the hip. J Arthroplast. 2002;17(4 Suppl 1):11–3. https://doi.org/10.1054/arth.2002.32682.
23. Ekman E, Laaksonen I, Isotalo K, Liukas A, Vahlberg T, Mäkelä K. Cementing does not increase the immediate postoperative risk of death after total hip arthroplasty or hemiarthroplasty: a hospital-based study of 10,677 patients. Acta Orthop. 2019;90(3):270–4. https://doi.org/10.1080/17453674.2019.1596576.
24. Perelgut ME, Polus JS, Lanting BA, Teeter MG. The effect of femoral stem collar on implant migration and clinical outcomes following direct anterior approach total hip arthroplasty. Bone Joint J. 2020;102-b(12):1654–61. https://doi.org/10.1302/0301-620x.102b12.Bjj-2019-1428.R1.
25. Pieristè M, Chauvat M, Kotilainen TK, Jones AG, Aubert M, Robson TM, et al. Solar UV-A radiation and blue light enhance tree leaf litter decomposition in a temperate forest. Oecologia. 2019;191(1):191–203. https://doi.org/10.1007/s00442-019-04478-x.
26. Schmalzried TP, Kwong LM, Jasty M, Sedlacek RC, Haire TC, O'Connor DO, et al. The mechanism of loosening of cemented acetabular components in total hip arthroplasty. Analysis of specimens retrieved at autopsy. Clin Orthop Relat Res. 1992;274:60–78.
27. Clohisy JC, Harris WH. Matched-pair analysis of cemented and cementless acetabular reconstruction in primary total hip arthroplasty. J Arthroplast. 2001;16(6):697–705. https://doi.org/10.1054/arth.2001.24447.
28. Proceedings of the First International Workshop on Nutrition and Metabolism in Hospital Malnutrition. Nutritional Assessment in Hospital Malnutrition. Venice, Italy, April 26–27, 1985. JPEN J Parenter Enteral Nutr. 1987;11(5 Suppl):33s–137s.
29. Miettinen SS, Mäkinen TJ, Laaksonen I, Mäkelä K, Huhtala H, Kettunen J, et al. Early aseptic loosening of cementless monoblock acetabular components. Int Orthop. 2017;41(4):715–22. https://doi.org/10.1007/s00264-016-3254-8.

30. Hsu JT, Lai KA, Chen Q, Zobitz ME, Huang HL, An KN, et al. The relation between micromotion and screw fixation in acetabular cup. Comput Methods Prog Biomed. 2006;84(1):34–41. https://doi.org/10.1016/j.cmpb.2006.08.002.
31. Darrith B, Courtney PM, Della Valle CJ. Outcomes of dual mobility components in total hip arthroplasty: a systematic review of the literature. Bone Joint J. 2018;100-b(1):11–9. https://doi.org/10.1302/0301-620x.100b1.Bjj-2017-0462.R1.
32. Chulsomlee K, Sa-Ngasoongsong P, Kulachote N, Sirisreetreerux N, Tuntiyatorn P, Vasaruchapong S, et al. Hip muscle power recovery after hip replacement using anterior-based muscle-sparing approach in elderly femoral neck fracture: a prospective study in 40 patients. Orthop Res Rev. 2018;10:31–9. https://doi.org/10.2147/orr.S153451.
33. Cook RE, Jenkins PJ, Walmsley PJ, Patton JT, Robinson CM. Risk factors for periprosthetic fractures of the hip: a survivorship analysis. Clin Orthop Relat Res. 2008;466(7):1652–6. https://doi.org/10.1007/s11999-008-0289-1.
34. Drew JM, Griffin WL, Odum SM, Van Doren B, Weston BT, Stryker LS. Survivorship after periprosthetic femur fracture: factors affecting outcome. J Arthroplast. 2016;31(6):1283–8. https://doi.org/10.1016/j.arth.2015.11.038.
35. Herndon CL, Nowell JA, Sarpong NO, Cooper HJ, Shah RP, Geller JA. Risk factors for periprosthetic femur fracture and influence of femoral fixation using the mini-anterolateral approach in primary total hip arthroplasty. J Arthroplast. 2020;35(3):774–8. https://doi.org/10.1016/j.arth.2019.10.011.
36. Sheth D, Cafri G, Inacio MC, Paxton EW, Namba RS. Anterior and anterolateral approaches for THA are associated with lower dislocation risk without higher revision risk. Clin Orthop Relat Res. 2015;473(11):3401–8. https://doi.org/10.1007/s11999-015-4230-0.
37. Jämsen E, Puolakka T, Peltola M, Eskelinen A, Lehto MU. Surgical outcomes of primary hip and knee replacements in patients with Parkinson's disease: a nationwide registry-based case-controlled study. Bone Joint J. 2014;96-b(4):486–91. https://doi.org/10.1302/0301-620x.96b4.33422.
38. Dudda M, Gueleryuez A, Gautier E, Busato A, Roeder C. Risk factors for early dislocation after total hip arthroplasty: a matched case-control study. J Orthop Surg (Hong Kong). 2010;18(2):179–83. https://doi.org/10.1177/230949901001800209.
39. Lewis DP, Wæver D, Thorninger R, Donnelly WJ. Hemiarthroplasty vs total hip arthroplasty for the management of displaced neck of femur fractures: a systematic review and meta-analysis. J Arthroplast. 2019;34(8):1837–43.e2. https://doi.org/10.1016/j.arth.2019.03.070.
40. Favreau H, Ehlinger M, Adam P, Bonnomet F. Total hip arthroplasty with exclusive use of dual-mobility cup after failure of internal fixation in trochanteric fracture. Orthop Traumatol Surg Res. 2020;106(4):645–9. https://doi.org/10.1016/j.otsr.2020.02.011.
41. Terrier A, Latypova A, Guillemin M, Parvex V, Guyen O. Dual mobility cups provide biomechanical advantages in situations at risk for dislocation: a finite element analysis. Int Orthop. 2017;41(3):551–6. https://doi.org/10.1007/s00264-016-3368-z.

Outcomes of the ABMS THA

18

Adam J. Rana, Callahan M. Sturgeon, Brian J. McGrory, and George Babikian

Key Points

- The anterior-based muscle-sparing (ABMS) approach is a safe and effective approach for performing total hip replacement (THR).
- This approach is safe and efficient, with short and reproducible surgical times and minimal blood loss, and it is associated with a short length of stay.
- A high percentage of patients are discharged home with a low complication and readmission rate.
- These outcome results are comparable and/or superior to the literature results for other surgical approaches to the hip.

A. J. Rana (✉)
Department of Orthopedic Surgery, Maine Medical Center, Falmouth, ME, USA

Tufts School of Medicine, Boston, MA, USA
e-mail: ranaa1@mmc.org

C. M. Sturgeon · G. Babikian
Department of Orthopedic Surgery, Maine Medical Center, Falmouth, ME, USA
e-mail: CMSturgeon@mmc.org; BABIKG1@mmc.org

B. J. McGrory
Department of Orthopedic Surgery, Tufts University School of Medicine and Maine Medical Center, Falmouth, ME, USA
e-mail: mcgrob1@mmc.org

Introduction

The anterior-based muscle-sparing (ABMS) approach is an emerging contemporary muscle-sparing approach that utilizes the interval between the tensor fasciae latae (TFL) anteriorly and the gluteus medius (GMed) muscle posteriorly [6, 11]. This surgical approach was first described in 1854 by Sayre and further modified by Watson-Jones (1936); most recently, Röttinger and Bertin modified the approach further by performing it in either the lateral or supine position for contemporary THA. The ABMS approach differs from the traditional anterolateral or modified Harding approach in that a portion of the abductor muscle is not reflected and repaired during surgery [6]. Studies have shown that the ABMS approach has comparable postoperative results as the direct anterior approach (DAA) [14].

The ABMS approach has been shown to be safe and effective, with a minimal learning curve [6, 12], comparable intraoperative and postoperative complications and accurate implant positioning as compared with the DA and PA approaches. It can be performed with the patient in the lateral or supine position [6, 12]. Our institution evaluated the ABMS approach over a 7.5-year period performed by three separate surgeons. Perioperative and short- to mid-term postoperative outcomes were evaluated and are presented.

J. A. Geller, B. J. McGrory (eds.), *The Anterior-Based Muscle-Sparing Approach to Total Hip Arthroplasty*, https://doi.org/10.1007/978-3-031-02059-9_18

Materials and Methods

Patients were identified through the institution's electronic medical database (EMD); inclusion criteria were a patient who underwent a primary elective unilateral THA performed using the ABMS approach between January 1, 2013, and August 31, 2020. Patients were excluded if their primary diagnosis was fracture.

Patient demographics (gender, age, ASA rating, BMI), primary diagnosis, anesthesia type, procedure duration, intraoperative estimated blood loss, length of hospital stay, and discharge disposition were retrieved from the patient database. Thirty-day emergency department (ED) visits and 90-day unplanned readmissions were recorded. Patient-reported outcome metrics (PROM) were collected pre- and postoperatively.

Patients completed PROM questionnaires preoperatively, six weeks postoperatively, six months postoperatively, and one year postoperatively. Patients completed the HOOS, Jr., visual analog scale (VAS) pain, single assessment numeric evaluation (SANE), University of California and Los Angeles (UCLA), PROMIS-10, and postoperative satisfaction questionnaires. The HOOS, Jr. questionnaire converts a raw score to an interval score from 0 to 100, with 0 representing total hip disability and 100 representing perfect hip health. The VAS pain score ranges from 0 to 10, with 0 representing no pain and 10 representing significant pain. The SANE score represents pain on a 0–100 scale, with 100 representing perfect hip health and 0 representing significant impairments. The UCLA score represents activity level on a 0–10 scale with 0 being completely inactive and 10 being able to actively accomplish any activity. The PROMIS-10 questionnaire calculates a global physical and mental health score that is standardized to the general population with an average score of 50. The postoperative satisfaction was based on a 0–10 scale with 10 indicating full satisfaction.

Heterotopic ossification was assessed by comparing the one-year postoperative X-ray with the patient's immediate postoperative radiograph. Subsidence was determined by evaluating and comparing the immediate postoperative radiograph with the first follow-up radiograph.

Results

The study identified 6251 primary total hip arthroplasties; 818 of those patients had a staged bilateral THA, which represents 5433 unique patients – 2963 are women (55%) and 2470 are men (45%). Of the 6251 arthroplasties, the mean age was 65.3 years old (range, 14–97 years old). The average BMI was 29.4 (median, 28.5; range, 14.3–64.6). Patient distribution among BMI categories was as follows: 0.8% (n = 52) were "underweight," 23.4% (n = 1462) were "healthy weight," 35.6% (n = 2227) were "overweight," and 40.2% (n = 2510) were "obese." Of the patients classified as obese, 58.6% (n = 1472) were "class 1 obese" (low-risk, 30–34.9), 27.6% (n = 692) were "class 2 obese" (moderate-risk, 35–39.9), and 13.8% (n = 346) were "class 3 obese" (high-risk, 40 and higher). The average American Society of Anesthesiologists (ASA) score was 2.1 (median, 2; range, 1–4) (Table 18.1).

Nearly 97% (n = 6065) of patients received general anesthesia and 3% (n = 186) received spi-

Table 18.1 Patient demographics

Variable (mean ± SD)	
Age	65.3 ± 10.2
Sex[a]	
Female	2963 (55%)
Male	2470 (45%)
BMI	29.4 ± 6.0
BMI categories[a]	
Underweight (<18.5)	52 (0.8%)
Healthy (18.5–24.9)	1462 (23.4%)
Overweight (25.0–29.9)	2227 (35.6%)
Obese (≥30)	2510 (40.2%)
ASA rating	2.1 ± 0.5
Primary diagnosis[a]	
Osteoarthritis	6139 (98.2%)
Avascular neurosis	87 (1.4%)
Dysplasia	10 (0.2%)
Post-traumatic arthritis	8 (0.1%)
Rheumatoid arthritis	7 (0.1%)

[a]*N* (%)

nal anesthesia. Three percent (*n* = 191) of arthroplasties utilized a cemented stem. The primary diagnosis for undergoing a THA included osteoarthritis, degenerative joint disease, avascular necrosis, post-traumatic arthritis, rheumatoid arthritis, and developmental dysplasia.

The average procedure duration, incision start to incision close, was 65 minutes (range, 32–177 minutes). The average estimated blood loss (EBL) was 204.1 mL (range, 20–750 mL). The average transfusion rate within 7 days of the index surgery was 0.5%, and the average transfusion rate within 90 days of surgery was 0.7%. The average length of stay was 1.4 days (range, 0.29–13.37 days) with slight variation between surgeons (1.3, 1.4, and 1.5) and essentially no variation over the years. 93.4% of patients were discharged home, of which 32.8% of those patients utilized home health services; 6.4% of patients were discharged to a rehabilitation or skilled nursing facility (Table 18.2).

Overall, 1.9% (*n* = 116) of patients visited the emergency department (ED) within 30 days of their surgery date, and 2.9% (*n* = 179) had an unplanned readmission to the hospital within 90 days. Of the 179 unplanned readmissions, 56% (*n* = 100) of them were direct admissions to the hospital that were not planned prior to their THA admission, and 44% (*n* = 79) of patients were admitted from the ED. Additionally, of the 179 patients readmitted, 66% of patients (*n* = 119) required a surgical procedure, and 44% (*n* = 60) required nonsurgical management (Table 18.2).

Of the 6251 arthroplasties, 1.22% (*n* = 76) of patients had a postoperative complication. Within the first seven days following the THA, 0.13% (*n* = 8) of patients (*n* = 8) had acute myocardial infarction (MI), 0.05% (*n* = 3) developed pneumonia, and none developed sepsis or shock. Within the first 30 days, 0.05% (*n* = 3) had a pulmonary embolism (PE), and 0.02% (*n* = 1) died. Within the first 90 days, 0.06% of patients (*n* = 4) had a mechanical complication, such as mechanical loosening. Peri-prosthetic fracture occurred in 0.37% (*n* = 23) of cases, 0.11% (*n* = 7) of patients sustained a dislocation, and 0.36% (*n* = 23) developed an infection; within that, 0.19% (*n* = 12) developed a deep, joint infection, and 0.11% (*n* = 7) developed a superficial wound infection that required irrigation and debridement (I&D). The intraoperative fracture rate was 0.29% (*n* = 18), with 16 patients sustaining a calcar fracture (0.26%) and 2 greater trochanteric fractures (0.03%) (Table 18.3).

Overall, patients reported their hip function improved, pain reduced, activity levels increased,

Table 18.2 Surgical and postoperative data

Variable (*N* (%))	
Anesthesia type	
General	6065 (97%)
Spinal	186 (3%)
Length of surgery[a]	65 ± 18
Estimated blood loss (mL)[a]	204.1 ± 68.9
Transfusion rate	
7 days	31 (0.5%)
90 days	43 (0.7%)
Length of stay[a]	1.4 ± 0.7
Discharge disposition	
Home/self-care	3789 (60.6%)
Home with home health services	2051 (32.8%)
Rehab facility	60 (1.0%)
Skilled nursing facility	351 (5.6%)
ED visits (within 30 days)	116 (1.9%)
Readmissions (within 90 days)	179 (2.9%)
Medical	60 (1.0%)
Surgical	119 (1.9%)

[a]Mean ± SD (standard deviation)

Table 18.3 Complications

Variable (*N* (%))	Medical	Surgical
Intraoperative fractures		
Calcar fracture		16 (0.3%)
Greater trochanter fracture		2 (0%)
Postoperative complications		
Myocardial infarction (7 days)	8 (0.13%)	
Pneumonia (7 days)	3 (0.05%)	
Sepsis/shock (7 days)	–	–
Pulmonary embolism (30 days)	3 (0.05%)	
Death (30 days)	1 (0.02%)	
Mechanical complication (90 days)		4 (0.06%)
Fracture (90 days)	1 (0.02%)	22 (0.35%)
Dislocation (90 days)		7 (0.11%)
Joint infection – deep (90 days)		12 (0.19%)
Wound infection – superficial (90 days)	4 (0.06%)	7 (0.11%)

Table 18.4 Patient-reported outcome data

Variable (mean ± SD)	Perioperative	Six weeks	Six months	One year
HOOS, Jr. interval score	41.0 ± 15.5	76.5 ± 13.1	86.8 ± 15.3	88.0 ± 14.3
VAS pain	5.6 ± 2.2	1.5 ± 1.7	0.95 ± 1.6	0.90 ± 1.7
SANE	41.6 ± 21.3	77.1 ± 18.0	89.8 ± 15.3	90.2 ± 15.6
UCLA	4.3 ± 1.8	4.9 ± 1.4	6.1 ± 1.9	6.4 ± 1.9
PROMIS-10				
Mental	50.4 ± 7.4	51.6 ± 7.0	51.4 ± 6.9	52.0 ± 7.2
Physical	39.9 ± 5.3	45.0 ± 5.5	46.9 ± 6.2	47.4 ± 6.3
Satisfaction				
Pain	N/A	8.9 ± 1.7	9.4 ± 1.3	9.4 ± 1.3
Functional improvement	N/A	8.6 ± 1.7	9.3 ± 1.4	9.3 ± 1.3
Meeting expectations	N/A	9.0 ± 1.7	9.4 ± 1.5	9.4 ± 1.4

and high satisfaction met. On average, based on the average preoperative score to the one-year follow-up, patients' HOOS, Jr. score increased by 47 points, their VAS pain score decreased by 4.7, their SANE score increased by 48.6, their UCLA score increased by 2.1, and their PROMIS-10 score mentally increased by 1.6 and physically increased by 7.5. The satisfaction rate was between 8.6 and 9.4 (Table 18.4).

There was a total of 6248 patients with pre- and post-follow-up radiographs that were reviewed. There were three patients lost to the follow-up. The average abduction angle of the prosthetic acetabular cup was 45.1°, with a standard deviation of 3.7°. 2.0% (n = 125) of cases had radiographic evidence of subsidence. 13.5% (n = 570) had radiographic evidence of heterotopic ossification at the one-year X-ray.

Discussion

The results and outcomes with the ABMS approach presented in this review reflect the experience of three surgeons performing a high surgical volume of these procedures over a 7.5-year period. Our experience indicates decreased blood loss and lower transfusion rates are two of the most significant objective outcomes from the ABMS approach. Previous research has hypothesized that the ABMS approach has less blood loss and therefore a lower transfusion rate because the surgeon encounters fewer and smaller (more terminal) branches of the lateral circumflex femoral artery during surgery [18]. A 7-day transfusion rate of 0.5% and a 90-day transfusion rate of 0.7% were the lowest identified in comparable research. When compared to a variety of procedure approaches with a patient population greater than 100, there was a blood loss reported range of 138–405 mL and a transfusion rate between 3% and 40% (Table 18.5).

The average procedure duration (incision start to incision close) was favorable to other published studies with an average of 65 minutes. There was slight variation between surgeons; surgeon-specific average procedure durations were 57 minutes, 65 minutes, and 84 minutes. One surgeon takes an intraoperative radiograph which can account for the deviation from the average. Sibia et al. [22] compared the direct anterior approach (DAA) to the posterolateral (PL) approach between five surgeons (1457 DAA vs 1241 PL) and found an average procedure duration of 90.4 and 86.3 minutes, respectively. Conversely, Martin et al. [18] compared the ABMS (Röttinger) approach to the standard lateral transgluteal Hardinge approach and found the ABMS approach to have a slightly longer operating time of 114.12 minutes compared to 95.78 minutes. In studies that compared a variety of procedure approaches in patient population greater than 100, there was a reported range of 58–130 minutes (Table 18.5). Therefore, operative duration, in this cohort of patients, seems to be favorable compared to many of the published reports from other surgical approaches.

With an overall length of stay of 1.4 days, the ABMS approach exhibited a reduced length of stay compared to existing literature on other

Table 18.5 Surgical and short-term postoperative data

Literature source	Approach	Study population (*N*)	Procedure duration (mins)	Blood loss (mL)	Transfusion rate (%)	Length of stay (days)	Discharged home (%)
Aggarwal et al. [1]	DAA	1329	79	315.2		2	93.9
Aggarwal et al. [1]	Northern	165	72	327.5		3.4	67.9
Aggarwal et al. [1]	Posterior	1657	87	329.6		3.2	76.5
Aggarwal et al. [1]	Direct lateral	393	68	345.4		3.3	78.4
Alecci et al. [2]	DAA minimally invasive	221			19.5	7	41.6
Alecci et al. [2]	Standard lateral	198			40	10	11.6
Berend et al. [4]	Less invasive direct lateral	372	68	138	3	2	79
Berend et al. [4]	Anterior supine intermuscular approach	258	69	155	4	1.8	87
Berger et al. [5]	Minimally invasive two-incision	100	101	291			100
Civinni et al. [6]	ABMS	343	58				
Delanois et al. [8]	Anterolateral – Röttinger approach	100	130				
Delanois et al. [8]	Direct lateral	147	111				
Kagan et al. [12]	ABMS	100				1.53	
Klasan et al. [14]	DAA	396		387	5.8		
Klasan et al. [14]	Watson-Jones	396		405	14.1		
Malek et al. [17]	DAA	265				3.7	
Malek et al. [17]	Posterior	183				4.2	
Matta et al. [19]	Anterior approach (tissue sparing)	494	75	350		3	
Sax et al. [20]	Primary – OA	1,57,71,991			13	3.04	
Sax et al. [20]	Primary – ON	55,034			18.9	3.66	
Schairer et al. [21]	All THA – single institution	989				4.05	75.6
Sibia et al. [22]	DAA	1457	90.4			2.3	79
Sibia et al. [22]	Posterolateral	1241	86.3			2.7	68.7
Wayne and Stoewe [23]	Anterior approach	100	115		5	5	
Wayne and Stoewe [23]	Lateral approach	100	98		3	7.1	

approaches and, among other ABMS literature, showed consistency with a less than 2.0-day length of stay [7, 12, 18]. There was minimal variation with the length of stay between 2013 and 2019, while we saw a decrease in 2020 to 1.2 days which was in part due to the COVID-19 pandemic. It is hypothesized that the length of stay of 1.4 days is multifactorial and includes the fact that the surgery is muscle sparing, has less blood loss, and has less postoperative pain during the index stay (not a variable explored in this study). When compared to a variety of procedure approaches with a patient population greater than 100, there was a reported range of 1.53–10 days (Table 18.5).

These study's radiographic findings support the advantageous qualities and reproducibility of the ABMS approach. One benefit of this approach is consistent direct visualization during placement of both the acetabular and femoral components. This is illustrated radiographically by a consistent abduction angle of 45.1° with a standard deviation of ±3.7°. In addition, the visualization allowed during femoral broaching allows for appropriate evaluation of the femoral canal diameter and version which correlates with more appropriate sizing of the femoral prosthesis and dialing in the correct anteversion of the stem. To support this finding, we saw only a 2.0% incidence of subsidence postoperatively. Measures taken by all three surgeons to minimize this risk include cementing the femoral stem in Dorr's type C patients. In addition, one surgeon uses a fit-and-fill-type stem, as opposed to a double-wedge taper stem, for the majority of female patients and older male patients.

While the study demonstrated a short length of hospital stay for the ABMS approach, we did not find a higher than average return to the ED rate. Overall, only 1.9% of patients presented to the ED within 30 days of surgery. Maldonado-Rodriguez et al. [16] summarized available literature on ED visits after total hip and knee replacements, including a total of 27 studies (N = 1,484,043). On average, they found a 30-day ED visit rate of 6.5%. Finnegan et al. [10] reported that ED visits occur more frequently than readmissions and often just for pain (Table 18.6).

Schairer et al. [21] reported on 988 patients who underwent a primary THA at a single institution and found a readmission rate of 4.4%. Our results show that 2.9% of patients were readmitted to the hospital within 90 days of surgery, with 56% of those patients having a direct admission that was unplanned prior to surgery and 44% being readmitted from the ED. ED visits and readmissions are important outcome variables as they represent the quality of the surgery, in relation to perioperative care and time to discharge. The patient-reported outcome measures allow us to measure the quality further from a patients' point of view (Table 18.7).

Maldonado-Rodriguez et al. [16] emphasized the importance of cost-effective ways to manage patients to reduce ED visits to keep overall costs low for the patient and hospital, but it extends further than just ED visits. The key to rapid rehabilitation and postoperative progress is to obtain alignment between the patients' and their care team's expectations, including the anesthesia and surgical teams [5, 9]. Perioperative and postoperative outcomes are favorable or comparable to other orthopedic literature, confirming that the ABMS technique is safe, effective, and with a short learning curve [6–8, 11, 12], all of which allows for easy adoption.

Table 18.6 Postoperative complications

Literature source	Approach	Study population (*N*)	ED visits	Readmissions	Overall complication rate	Myocardial infarction	Pneumonia	Sepsis/ Septicemia/ Shock	Pulmonary embolism	Death	Intraoperative fracture	Fracture	Dislocation	Joint infection	Wound infection
Aggarwal et al. [1]	DAA	1329										8.4	6.5	11	5.7
Aggarwal et al. [1]	Northern	165										1.5	0.8	1.1	0.4
Aggarwal et al. [1]	Posterior	1657										9.9	5.3	8.7	2.7
Aggarwal et al. [1]	Direct lateral	393										2.7	0	1.9	1.9
Barnett et al. [3]	Anterior approach	(5090)				0.12	0.06		0.08		0.81	0.14	0.24	0.1	0.29
Civinni et al. [6]	ABMS	343								0.6		0.6	0.3		
Delanois et al. [8]	Anterolateral – Röttinger approach	100											0		
Delanois et al. [8]	Direct lateral	147											2		
Finnegan et al. [10]	All	1,52,783	5.81	3.42											
Kagan et al. [12]	ABMS	100							10		1	0	10		0
Katz et al. [13]	Primary	32,463										0.7			
Klasan et al. [14]	DAA	396			12.1						0.5	1	2.2		
Klasan et al. [14]	Watson-Jones	396			17.6						0.5	0.5	0.5		
Lee and Marconi [15]	DAA	11,810									2.3				
Malek et al. [17]	DAA	265		6.8								2.6	0.4		
Malek et al. [17]	Posterior	183		2.7								0	0.5		

(continued)

Table 18.6 (continued)

Literature source	Approach	Study population (*N*)	ED visits	Readmissions	Overall complication rate	Myocardial infarction	Pneumonia	Sepsis/ Septicemia/ Shock	Pulmonary embolism	Death	Intraoperative fracture	Fracture	Dislocation	Joint infection	Wound infection
Matta et al. [19]	Anterior approach (tissue sparing)	494											0.61		
Sax et al. [20]	Primary – OA	1,57,71,991				0.2	0.3		0.1				0.1	0.2	
Sax et al. [20]	Primary – ON	55,034				0.2	0.7		0.2				0.2	0.5	
Schairer et al. [21]	All THA – single institution	989		4.4											
Wayne and Stoewe [23]	Anterior approach	100											2	0	0
Wayne and Stoewe [23]	Lateral approach	100											1	3	4

Table 18.7 Patient-reported outcome data

nn	Approach	Study population (*N*)	PROMIS mental (6 weeks)	PROMIS Physical (6 weeks)	UCLA (6 weeks)
Aggarwal et al. [1]	Posterior	1657	53.1	42.3	
Klasan et al. [14]	DAA	396			4.61
Matta et al. [19]	Anterior approach (tissue sparing)	494			4.82
Sibia et al. [22]	DAA	1457	53.2	46.2	

Conclusion

Based on this data, and an exhaustive review of our patient's experience, the authors support the ABMS approach as a safe and effective approach for performing THR. The experience at our institution demonstrates that this approach is safe and efficient, with decreased and reproducible surgical times and minimal blood loss, and it is associated with a short length of stay. These outcome results are comparable if not superior to the published results for other surgical approaches to the hip.

References

1. Aggarwal VK, Elbuluk A, Dundon J, Herrero C, Hernandez C, Vigdorchik JM, Schwarzkopf R, Iorio R, Long WJ. Surgical approach significantly affects the complication rates associated with total hip arthroplasty. Bone Joint J. 2019; 101-B(6):646–51.
2. Alecci V, Valente M, Crucil M, Minerva M, Pellegrino CM, Sabbadini DD. Comparison of primary total hip replacements performed with a direct anterior approach versus the standard lateral approach: perioperative findings. J Orthop Traumatol. 2011;12(3):123–9.
3. Barnett SL, Peters DJ, Hamilton WG, Ziran NM, Gorab RS, Matta JM. Is the anterior approach safe? Early complication rate associated with 5090 consecutive primary total hip arthroplasty procedures performed using the anterior approach. J Arthroplast. 2016;31(10):2291–4.
4. Berend KR, Lombardi AV Jr, Seng BE, Adams JB. Enhanced early outcomes with the anterior supine intermuscular approach in primary total hip arthroplasty. J Bone Joint Surg Am. 2009;91 Suppl 6:107–20.
5. Berger RA, Jacobs JJ, Meneghini RM, Della Valle C, Paprosky W, Rosenberg AG. Rapid rehabilitation and recovery with minimally invasive total hip arthroplasty. Clin Orthop Relat Res. 2004;(429):239–47.
6. Civinini R, Cozzi Lepri A, Carulli C, Matassi F, Villano M, Innocenti M. The anterior-based muscle-sparing approach to the hip: the "other" anterior approach to the hip. Int Orthop. 2019;43(1):47–53.
7. D'Arrigo C, Speranza A, Monaco E, Carcangiu A, Ferretti A. Learning curve in tissue sparing total hip replacement: comparison between different approaches. J Orthop Traumatol. 2009;10(1):47–54.
8. Delanois RE, Sultan AA, Albayar AA, Khlopas A, Gwam CU, Sodhi N, Lamaj S, Newman JM, Mont MA. The Röttinger approach for total hip arthroplasty: technique, comparison to the direct lateral approach and review of literature. Ann Transl Med. 2017;5(Suppl 3):S31.
9. Dorr LD, Maheshwari AV, Long WT, Wan Z, Sirianni LE. Early pain relief and function after posterior minimally invasive and conventional total hip arthroplasty. A prospective, randomized, blinded study. J Bone Joint Surg Am. 2007;89(6):1153–60.
10. Finnegan MA, Shaffer R, Remington A, Kwong J, Curtin C, Hernandez-Boussard T. Emergency department visits following elective total hip and knee replacement surgery: identifying gaps in continuity of care. J Bone Joint Surg Am. 2017;99(12):1005–12.
11. Hansen BJ, Hallows RK, Kelley SS. The Röttinger approach for total hip arthroplasty: technique and review of the literature. Curr Rev Musculoskelet Med. 2011;4(3):132–8.
12. Kagan RP, Greber EM, Richards SM, Erickson JA, Anderson MB, Peters CL. Advantages of an anterior-based muscle-sparing approach in transitioning from a posterior approach for total hip arthroplasty: minimizing the learning curve. J Arthroplast. 2019;34(12):2962–7.
13. Katz JN, Wright EA, Polaris JJ, Harris MB, Losina E. Prevalence and risk factors for periprosthetic fracture in older recipients of total hip replacement: a cohort study. BMC Musculoskelet Disord. 2014;15:168.
14. Klasan A, Neri T, Oberkircher L, Malcherczyk D, Heyse TJ, Bliemel C. Complications after direct

anterior versus Watson-Jones approach in total hip arthroplasty: results from a matched pair analysis on 1408 patients. BMC Musculoskelet Disord. 2019;20(1):77.

15. Lee GC, Marconi D. Complications following direct anterior hip procedures: costs to both patients and surgeons. J Arthroplast. 2015;30(9 Suppl):98–101.
16. Maldonado-Rodriguez N, Ekhtiari S, Khan MM, Ravi B, Gandhi R, Veillette C, Leroux T. Emergency department presentation after total hip and knee arthroplasty: a systematic review. J Arthroplast. 2020;35(10):3038–3045.e1.
17. Malek IA, Royce G, Bhatti SU, Whittaker JP, Phillips SP, Wilson IR, Wootton JR, Starks I. A comparison between the direct anterior and posterior approaches for total hip arthroplasty: the role of an 'Enhanced Recovery' pathway. Bone Joint J. 2016;98-B(6):754–60.
18. Martin R, Clayson PE, Troussel S, Fraser BP, Docquier PL. Anterolateral minimally invasive total hip arthroplasty: a prospective randomized controlled study with a follow-up of 1 year. J Arthroplast. 2011;26(8):1362–72.
19. Matta JM, Shahrdar C, Ferguson T. Single-incision anterior approach for total hip arthroplasty on an orthopaedic table. Clin Orthop Relat Res. 2005;441:115–24.
20. Sax OC, Pervaiz SS, Douglas SJ, Remily EA, Mont MA, Delanois RE. Osteoarthritis and osteonecrosis in total hip arthroplasty: 90-day postoperative costs and outcomes. J Arthroplast. 2021;36(7):2343–7.
21. Schairer WW, Sing DC, Vail TP, Bozic KJ. Causes and frequency of unplanned hospital readmission after total hip arthroplasty. Clin Orthop Relat Res. 2014;472(2):464–70.
22. Sibia US, Turner TR, MacDonald JH, King PJ. The impact of surgical technique on patient reported outcome measures and early complications after total hip arthroplasty. J Arthroplast. 2017;32(4):1171–5.
23. Wayne N, Stoewe R. Primary total hip arthroplasty: a comparison of the lateral Hardinge approach to an anterior mini-invasive approach. Orthop Rev. 2009;1(2):e27.

19 Rehabilitation for THA Using the ABMS Approach

Brian J. McGrory and Kurt K. Jepson

Key Points

- Recovery is accelerated after anterior-based muscle- sparing (ABMS) total hip arthroplasty (THA).
- Pre-surgical optimization and education as well as meticulous perioperative management allow for successful post-operative rehabilitation.
- A stepwise, measured approach to mobilization through the healing process supports accelerated recovery.
- Preoperative muscle weakness and tendionopathy may contribute to slower post-operative recovery.
- Structured physical therapy may at times be beneficial to overcome common challenges in patients recovering from anterior-based, muscle- sparing total hip replacement.

Introduction

Total hip arthroplasty (THA) surgery has improved to a great extent over the last two decades, and anterior-based approaches have contributed to this positive change. More rapid mobilization and rehabilitation of anterior-based approaches are said to be due in part to the preservation of the major abductor muscles of the hip [1]. Hansen and coauthors espouse that the acceleration in early functional outcomes relates to the theory described by Zati et al. [2] and He et al. [3] claiming the dominance of muscle afferent nerve input over the hip capsule receptors [4]. They reason that approaches to the hip involving large muscle tenotomies or muscle splitting will negatively affect sensomotor capacity of the hip. Different innervation pathways of the anterior capsule of the hip, compared with the posterior capsule, may also contribute [5, 6]. Additionally, no need for postoperative precautions for dislocation after the ABMS approach [7, 8] has led patients be discharged to home early and return to aid-free ambulation, side sleeping, driving, and even work activities earlier than muscle splitting, tendon detaching, or osteotomy requiring THA [9]. These differences, in combination with multimodal pain management and protocols to minimize dizziness, nausea, constipation, and urinary retention, make ABMS surgery ideal for outpatient consideration in contemporary surgical practices. In this chapter, we will offer examples of one protocol used at a successful ABMS program, and we will discuss physical therapy approaches to overcoming some common challenges of the recovery phase of surgery.

Advances in evidence-based physical therapy (PT) intervention and usage of clinical practice

B. J. McGrory (✉)
Department of Orthopedic Surgery, Tufts University School of Medicine and Maine Medical Center, Falmouth, ME, USA
e-mail: mcgrob1@mmc.org

K. K. Jepson
Jepson Physical Therapy Consults SP, Saco, ME, USA

J. A. Geller, B. J. McGrory (eds.), *The Anterior-Based Muscle-Sparing Approach to Total Hip Arthroplasty*, https://doi.org/10.1007/978-3-031-02059-9_19

guidelines have certainly contributed to progress in overall THA care [10], and we will incorporate these when applicable. Further research and breakdown by surgical approach are necessary to develop these protocols to include anterior-based THA approaches, specifically the ABMS approach.

Before Surgery

Rehabilitation after THA depends on the specific circumstances that a patient faces going into the surgery as well as the technique of the operation itself [11]. Patients with multiple joint problems and those who are deconditioned will have different challenges and a slower recovery than those with isolated hip arthritis, even with a less invasive surgery. As part of preoperative optimization, individual recovery demands and patient support should be taken into consideration.

Preoperative fitness and strength should be discussed with all surgical patients. Often, hip pain and stiffness preclude focused hip strengthening. Upper extremity strengthening, however, can be pursued by most patients for ambulating with a gait aid, stair-climbing with the use of a bannister, and using support to rise from a seated position. We also recommend that the patient focus on aerobic exercises in the sitting position, so as to increase physiological preparation for the rigors of the surgery and recovery. We encourage all patients to use a gait aid in the opposite hand before surgery to both diminish their arthritis pain and also to practice for cane usage in the recuperation period. This allows the patients and their family to get used to activities of daily living (ADLs) using a gait aid and helps muscle memory for the recovery period. In two systematic reviews, investigators demonstrated that low to moderate evidence demonstrated that preoperative exercise reduces pain for patients with hip osteoarthritis (OA) prior to joint replacement and preoperative exercise with educational programs may improve activity after hip replacement [12, 13]. Conversely, Cabilan and coauthors found that so-called prehabilitation led to no benefits in function, quality of life, and pain but did correlate with avoiding admission to rehabilitation [14]. Specifically for anterior-based approaches, literature on this topic is currently lacking.

Very disabled patients, or those with neurological diagnoses, may benefit from a home safety evaluation to assess challenges for the patient's discharge to home. Likewise, preoperative evaluation and testing by a physical therapist may be of great value to catalogue challenges and offer strategies for achieving independence.

Generally speaking, core muscular function is vital to a sound functional return post-ABMS THA as well as any approach to THA. The anterior and oblique groups are particularly important to the provision of a stable platform from which the hip prime movers can generate force. An anteriorly tilted pelvis in the sagittal plane is common and must be minimized for proper posterior column strengthening. Transverse plane rotational weakness of the core will exacerbate hip rotational insufficiencies and place more demand on such structures as the iliopsoas. Central proprioception and maintenance of a neutral core position during dynamic phases of rehabilitation will enhance comfort, movement competence, and balance.

Peripheral conditioning activities should be undertaken acknowledging that normal kinematic function and physiologic status of hip muscle groups have likely been altered for months or years preoperatively. Sequential reactivation and strengthening may require localized biofeedback. Once volitional contractile control is established, isometric exercises should predominate the program to maximize neuromuscular activity and stimulate beneficial intrinsic tissue morphology changes. Tensile integrity of the various musculotendinous units used will be essential to patient tolerance for closed chain exercise, as well as the resolution of any preexisting tendinopathies.

Resistive exercise loads utilized must be of sufficient intensity to require at a minimum, 40% of maximal volitional contraction (MVC) [15]. This will stimulate lasting neuromuscular adaptations and hence strength gains. Most ADL tasks and basic ambulation do not meet this criterion. Simply, "walking" will not fully rehabilitate a post-ABMS THA patient.

Exercise positions and motion restrictions should honor healing constraints or structural anomalies and be specific to physiologic age, existing fitness level of the patient, or other comorbidities such as lumbar pathology. End-stage functional conditioning tasks such as balance, agility, and reaction training should be tailored to the patients based on the intended use of their "new" hip.

Daily mobility and self-care tasks can include indirect range of motion and strength inputs beneficial to the rehabilitation process. Examples include single limb stance during hygiene tasks to train pelvic leveling and balance. Sitting with the involved lower extremity crossed over the uninvolved side in wide and narrow positions will enhance rotational flexibility. Carrying grocery totes, watering cans, tools, and luggage on the contralateral side can dramatically elevate gluteal activity on the involved side even when the load comprises a small percentage of body weight [16].

Immediately Postoperatively: Day 0

Bracing, abductor pillows, and protected weight-bearing are typically not required after ABMS THA surgery. In our experience, patients are transported from the operating room (OR) to the recovery room (RR) for supportive care immediately after surgery. In our outpatient center, the patient is mobilized when awoken. In our hospital, patients are mobilized with the nursing team and ambulate from their RR bed to a chair or bed in their room when transferred to the floor. In other centers, patients may wait for the physical therapy team to mobilize for the first time. In any of these circumstances, the initial session of mobilization may reveal any pain, nausea, or hemodynamic management needs and at the same time gives the patients' confidence in their recovery [17].

Initiating PT on Day 0 leads to THA patients being more likely to achieve discharge goals on postoperative Day 0 or 1 [18, 19]. More contemporary approaches that include multimodal pain management, short-acting anesthesia management [20], and perioperative side effect management (no IV pain meds, steroid prophylaxis for nausea, polyethylene glycol to avoid constipation, tranexamic acid to avoid anemia, and fluid management to avoid hypotension) achieve day of surgery discharge more commonly [8]. In this single-center study of over 6000 patients using the ABMS approach and early PT, the authors achieved an average length of stay of 1.38 days over an 8-year time frame, with 93.4% discharge to home [8]. Safe discharge home can be assessed postoperatively by a combination of immediate postoperative function [17] and preoperative needs assessment for home support.

Our program focuses on mobilization, exercise review, and activity of daily living (ADL) mastery. Each patient is seen for a single therapy session the day of surgery (Day 0). When safely mobilized without prohibitive discomfort, nausea, or dizziness, the postoperative exercise program is reviewed step-by-step, focusing on the exercises for the first 6 weeks postoperatively (Fig. 19.1). A written description with line drawing examples of each exercise is included in their discharge paperwork. Patients are encouraged to walk each day with a walker or crutches on flat surfaces and to increase distance walked, and therefore their stamina, each week. Next, each patient is instructed in safe transitions from bed-to-stand to sit-to-stand, as well as stair-climbing and dressing. One major point for patients is to avoid "push-off" with the surgical leg in the early phases of recovery. Most of our patients are currently treated with a non-cemented femoral stem, and it is known that periprosthetic femur fracture is more common in ingrowth compared with cemented stems [21]. We believe that excessive out-of-plane forces caused by push-off before stem ingrowth may lead to periprosthetic femoral fracture, based on the most common fracture pattern noted in the literature [22]. An ABMS surgery program with early limitation of operative side push-off has accomplished a very low rate of postoperative fractures (0.37%), even with early mobilization, short length of stay, and discharge to home [8].

We encourage continued work with nursing and physical therapy (PT) in patients who are not ready for discharge on Day 0 and revisit these goals on POD (postoperative day) 1. A small number of patients require discharge to a skilled nursing home (5.61%) or rehabilitation facility (0.96%) in our experience [8]. Even for these patients, early mobilization appears to be beneficial.

Early Postoperatively: First 2 Weeks

Starting on the day of surgery, patients pursue exercises in conjunction with ADLs and ambulation. Exercises include ankle pumps, quadriceps setting, gluteus setting, heel slides, short-arc quadriceps, and supine hip abduction (Fig. 19.1a–f). The program content may be individualized, but we start with these exercises three times each day. During this part of the recovery, a patient walks short distances several times a day, using the walker (in contrast to one longer ambulation session, only one time per day). Pain management and icing of the surgical site allow for increasing progress. Typically, at 10 days to 2 weeks postoperatively, the patient presents for a wound check and radiographs. After confirming that the patient is progressing well, they are next instructed to transition to the use of a cane in the contralateral hand for ambulation.

Weeks 3–4

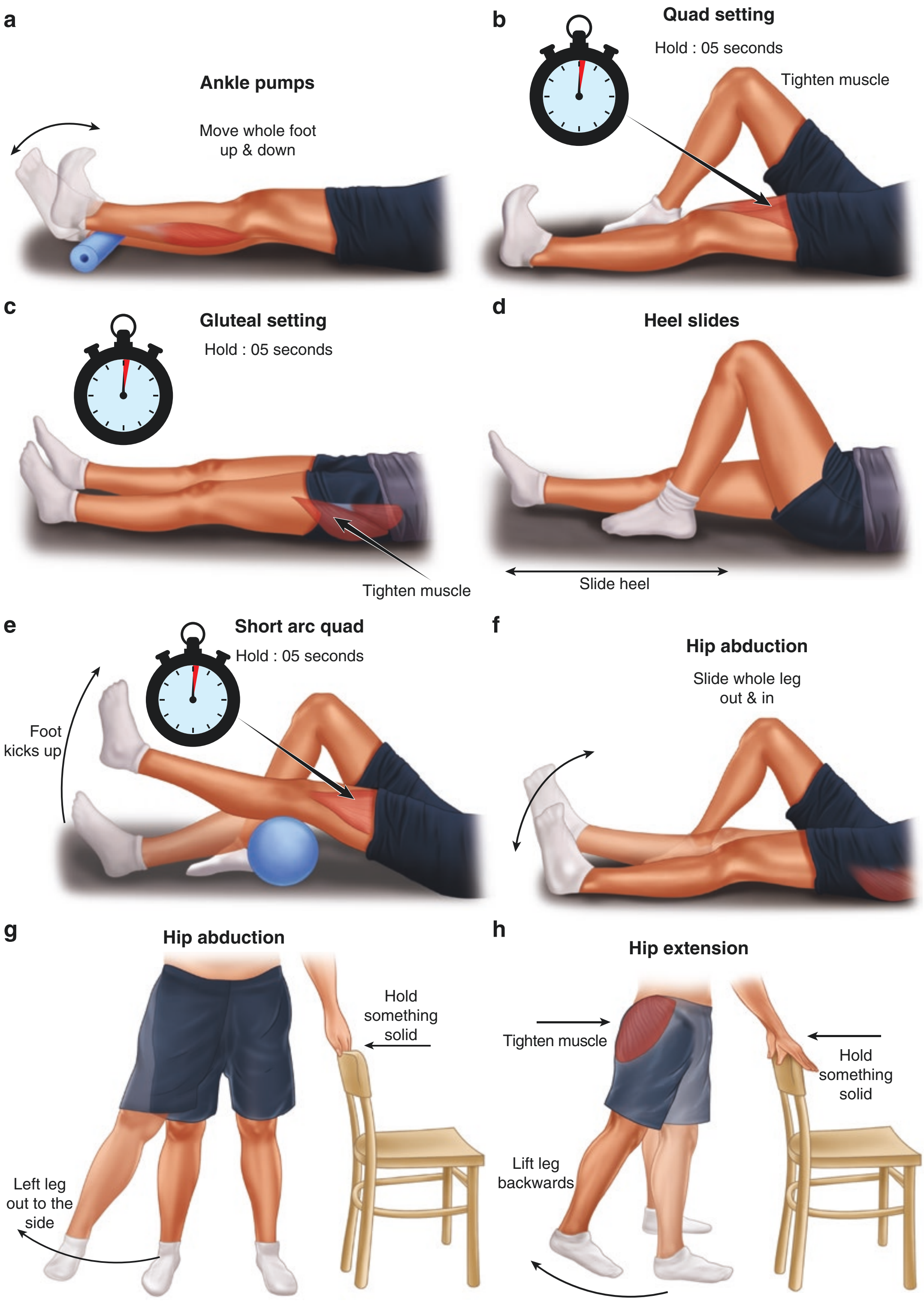
Over the next 2 weeks, the patient is to continue increasing ambulation with the cane, with several longer walks each day. Standing exercises are added to the regime three times each day including hip abduction, hip extension, hamstring curl, and hip flexion (Fig. 19.1g–j). A midday rest with elevation of the feet may be helpful to reestablish lymphatic flow and minimize ankle and leg swelling. At this stage, patients are still advised against doing straight leg raise exercises.

Weeks 5–6

Patients now add more complex movements in conjunction with the exercises learned in the first month postoperatively. Exercise mode progression follows isometric to eccentric to concentric to functional closed chain loading. Progression includes partial (low) squat, sit-to-stand with support from a chair with arms using both legs, and a bilateral knee-to-shoulder stretch in the supine position (Fig. 19.1k–m).

Many patients start using a stationary bike or water walking at this juncture, based on availability. Upright stationary cycling is strongly encouraged as soon as sagittal plane motion and any healing constraints allow. A high seat position is utilized to avoid sub-spine compression and irritation. For the same reason, recumbent bicycles are discouraged. Light to moderate flywheel tension may be applied, and a cadence of at least 60 revolutions per minute (rpm) should be targeted. If the patient cannot maintain 60 rpm for the session, the load is likely excessive. Fifteen progressing to 60 minutes per session is typical and should serve as part of the dynamic warm-up period. Generalized fitness improvements will be addressed with four sessions per week, more if desired. Aquatic exercise can be initiated once the incisional area

Fig. 19.1 Line drawings of exercises used in the Maine Medical Center (Portland, Maine, USA) anterior-based muscle-sparing (AMBS) total hip arthroplasty (THA) program. *Weeks 1–2:* Exercises include ankle pumps (**a**), quadriceps setting (**b**), gluteus setting (**c**), heel slides (**d**), short-arc quadriceps (**e**), and supine hip abduction (**f**). *Weeks 3–4:* Progression exercises include standing hip abduction (**g**), standing hip extension (**h**), standing hamstring curl (**i**), and standing hip flexion (**j**). *Weeks 5–6:* Progression includes partial (low) squat (**k**), sit-to-stand with support from a chair with arms using both legs (**l**), and a bilateral knee to shoulder stretch in the supine position (**m**). *Beyond 6 weeks:* As iliotibial (IT) band tightness is not uncommonly found in this phase of recovery, we encourage hip rotator stretches (**n**), IT band stretches (**o**), side-lying straight leg raises with the knee slightly bent (**p**), and side-lying clamshell exercises (**q**). A single leg stand motion, both on the surgical and nonsurgical sides, will encourage abductor strengthening (**r**). The patients can start this series standing with their back against a wall or holding onto an object for balance. As their strength and balance improve, patients may stand unaided


a
Ankle pumps
Move whole foot up & down
b
Quad setting
Hold : 05 seconds
Tighten muscle
c
Gluteal setting
Hold : 05 seconds
Tighten muscle
d
Heel slides
Slide heel
e
Short arc quad
Hold : 05 seconds
Foot kicks up
f
Hip abduction
Slide whole leg out & in
g
Hip abduction
Hold something solid
Left leg out to the side
h
Hip extension
Tighten muscle
Hold something solid
Lift leg backwards

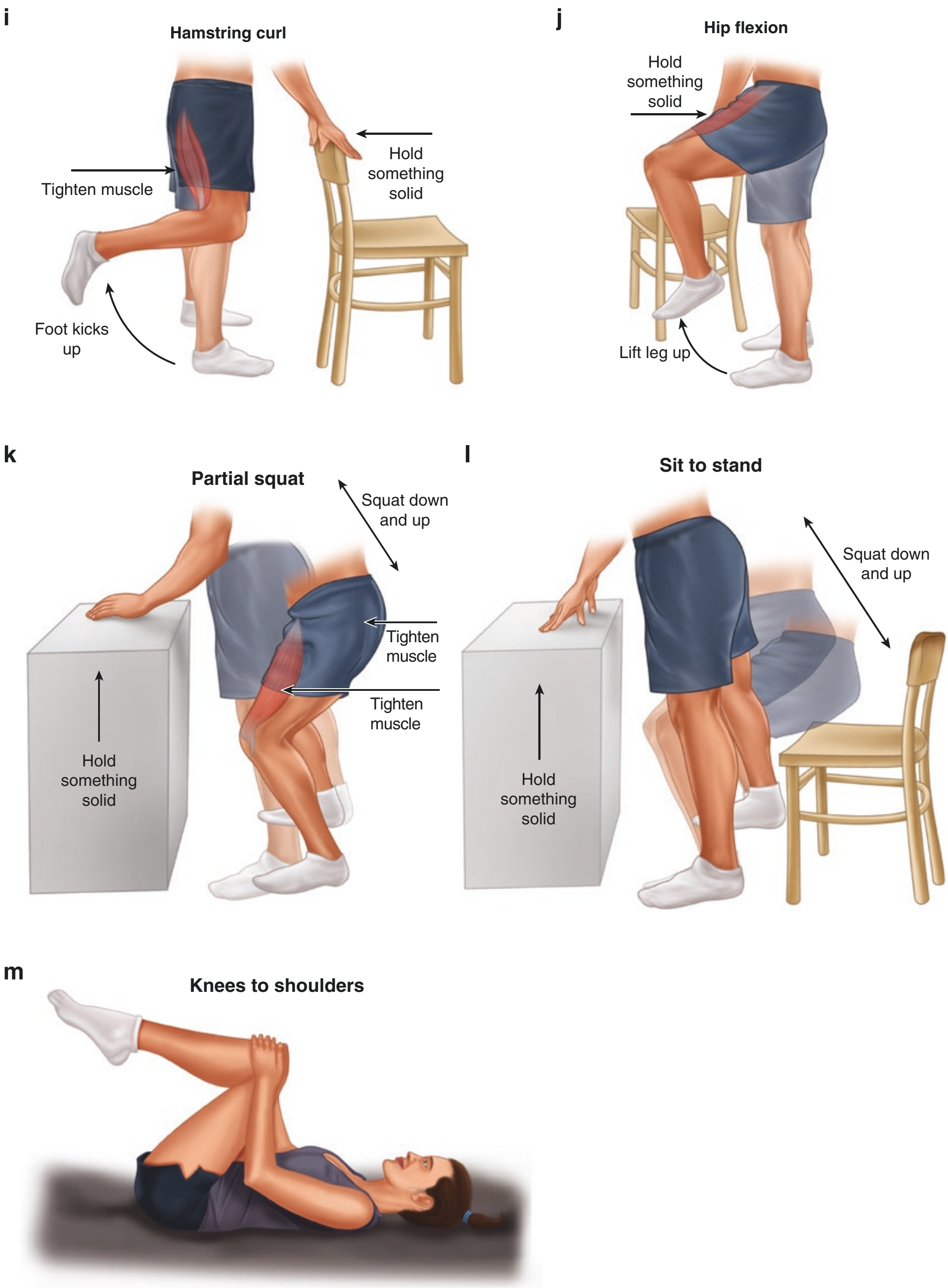


Fig. 19.1 (continued)

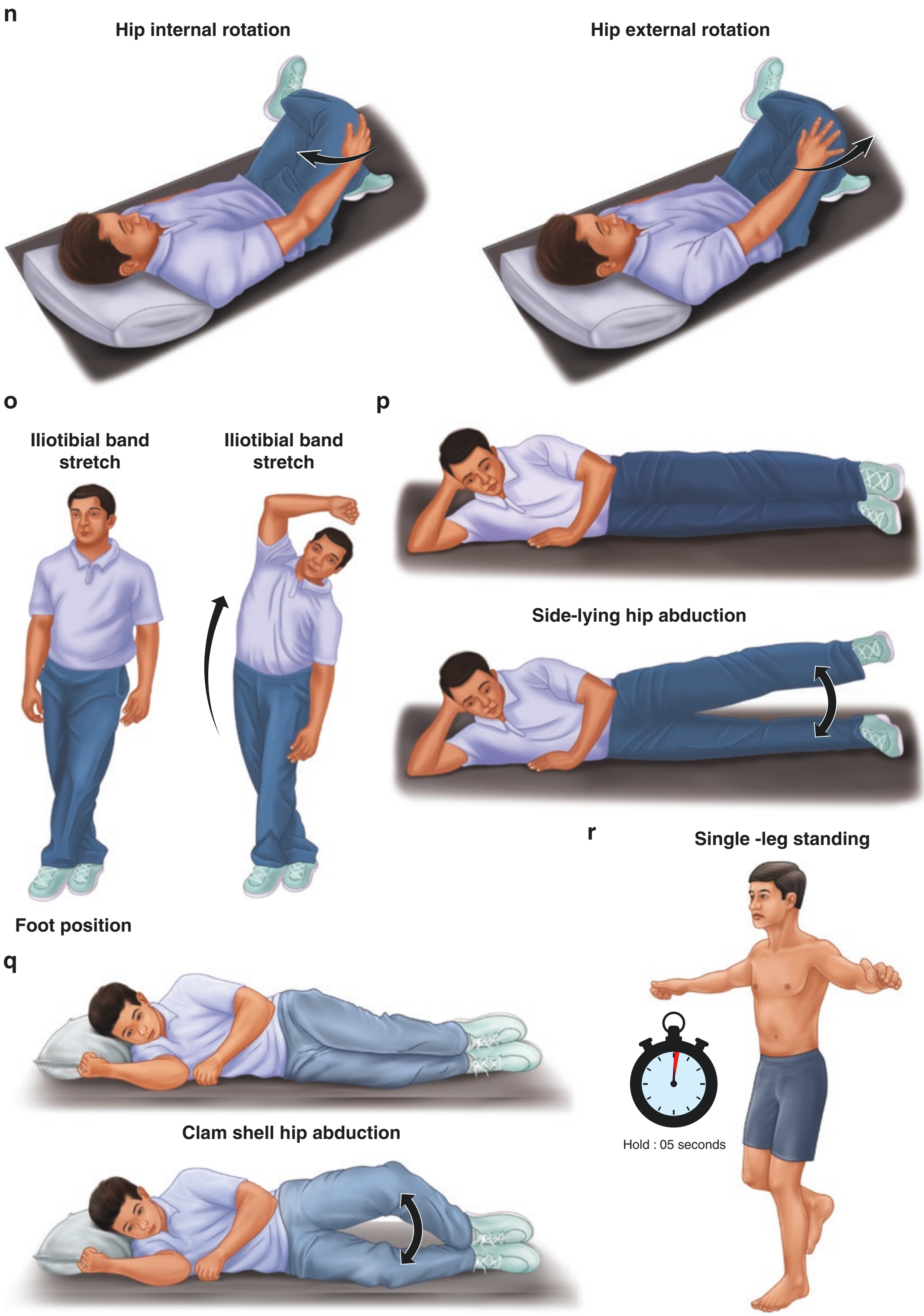


Fig. 19.1 (continued)

achieves adequate maturity. Care should be taken while mounting the bicycle and transferring on wet surfaces so as not to put too much stress on the surgical side. Sustained mild to moderate cardiovascular exercise is vital to building base conditioning and regional capillary exchange important to tissue regeneration.

Beyond 6 Weeks

Six weeks is the inflection point when bone ingrowth is sufficient to safely allow out-of-plane forces and single leg push-off on the surgical side [23]. Patients are encouraged to use reciprocal stair-climbing at this point and can push off with minimal support when rising from a seat or the toilet. A single leg stand motion, both on the surgical and nonsurgical sides, will encourage abductor strengthening (Fig. 19.1r). The patients can start this series standing with their back against a wall or holding onto an object for balance. As their strength and balance improve, patients may stand unaided. As iliotibial (IT) band tightness is commonly found in this phase of recovery, we encourage hip rotator stretches, IT band stretches, side-lying straight leg raises with the knee slightly bent, and side-lying clamshell exercises (Fig. 19.1n–q).

Patients with worse preoperative pain and higher preoperative activity levels are more likely to want supervised formal PT compared to self-directed home exercises, according to one study of an anterior-based THA [24]. In this study, 147 patients were randomized to receive either clinic- or home-based PT after their surgery. No patient-reported outcome measure (PROM) score differences were noted preoperatively or postoperatively. One in five patients in the home-based PT group chose to switch to have formal PT at 6 weeks, and the patients who switched were more likely to have higher preoperative activity or greater preoperative pain than the others. We currently use a shared decision-making discussion with patients at the six-week visit and decide based on their progress, goals, and expectations, whether or not to enroll the patients in structured PT.

Return to a normal gait is the hallmark of a successful recovery, and one measure that appears to differentiate postoperative THA patients from those with normal hips is increased walking velocity. This measure appears to be related to peak hip extension, hip range of motion (ROM), and stride length [25]. More research needs to be performed in this area, but anterior approaches [9, 26] and thrice weekly exercise programs [27] seem to foster the strength and extension range necessary to achieve appropriate gait restoration.

Special Considerations

Supine Versus Lateral Approaches

There do not appear to be significant rehabilitation differences for patients who undergo ABMS THA in the lateral position versus the supine position. Takada and coauthors [28, 29] have noted slight variations in acetabular and femoral positioning in these approaches, and these should be kept in mind as further research in this arena is pursued. Specifically, more precise acetabular inclination was noted when patients were operated on in the supine position and, for a blade-style stem, lateral patient position was associated with more neutral placement in the sagittal plane.

Capsulectomy Versus Capsule Repair

We do not know of a specific study examining this in the ABMS approach. For a direct anterior (DA) approach, capsulectomy had no effect on instability, pain, or range of motion compared with capsular repair [30]. This 5-year study compared 50 hips with a capsulectomy and 48 with capsulotomy. The investigators found no effect on dislocation, pain, or range of motion. In another study on patients with a modified Hardinge approach, capsular repair did diminish early postoperative dislocation [31]. Currently, surgeons in our program repair the anterior and posterior capsular leaves to one another and to the acetabular rim. The anterior capsulotomy is not reattached to the femur.

Common Postsurgical Issues Aided by Structured Physical Therapy

Overview of the Condition of the Hip Before and After Surgery

Functional delays following ABMS THA commonly relate to the structural and physiologic integrity of the posterior-lateral musculature of the hip. The condition of the hip, in turn, is the summation of its preoperative state and any changes brought on by the surgical process. The gluteus maximus (GMax), gluteus medius (GMed), gluteus minimus (GMin), and deep short external rotators (SERs) must return to normal contractile abilities to ensure sound kinematic recovery. Root causes of posterolateral dyskinesia include preexisting factors and the response to the regional physiologic load resultant of surgery. This holds true even for muscle-sparing procedures [32].

Typically, chronic hip pain from preexisting arthritis results in characteristic postural shifts and muscular imbalances. The protective "crouch gait" described by Arnold [33] is a manifestation of unopposed anteromedial muscle activity, posterolateral muscle inhibition, and anterior capsular restrictions. Additionally, pelvic posturing anteriorly and inferiorly, or anterior tilt, results subsequent to insufficient core strength. The limb is fixed via ground reaction forces, and this compounds ipsilateral hemipelvis rotation toward the femur. Anterior thigh muscles utilized for gait are remote to the hip, employ long lever arms, and predominantly invoke adduction and internal rotation moments on the lower extremity and/or hemipelvis [34, 35]. Painful hips, and in particular those involved with osteoarthritis (OA), often exhibit increased adduction and flexion moments approaching 20% during closed chain function compared to uninvolved hips [36–38]. Joint moments are a function of load impulse and duration. Individuals with OA tend to ambulate slower, thus extending load times. OA patients exhibit weakness of all hip muscles and dissipate external loads less efficiently. Weakness can be pronounced and well established and by one study was quantified at 16%–28% in all muscle groups tested [39]. Interestingly, muscular weakness is not always associated with intrinsic morphologic changes in this preoperative situation. Gluteal weakness specifically appears to be neurogenically driven due to regional physiologic load [40–42]. Whether this is related to inflammatory chemotaxis, the motor cortex or synaptic inhibition is unclear.

Prolonged posterolateral weakness can also compromise the trochanteric tendinous structures. Atrophic changes within the tendons of individuals with long-standing gluteal weakness have been identified [43, 44]. Additional risk factors for gluteal tendinopathy, some common in OA patients, include female sex, age over 40 years, elevated BMI, presence of chronic low back pain, TFL restrictions, coxa vara, and greater trochanteric offset [45]. Tendon fibroblasts respond to mechanical strain. A reduction in tendon load due to weakness of the associated musculature leads to degeneration, structural anomaly, and eventually cell death [46].

Pathomechanical positional tendencies arising from a dysfunctional hip must be balanced by vigorous contractions of the gluteal muscles, SERs, and rectus abdominis. For example, flexion moments must be controlled via GMax eccentric contractions and adduction moments via GMed action. Internal rotation must be controlled by the SERs in extended positions of the hip and the superior fibers of the GMax in flexion. In the frontal plane, the force produced by the abductors to maintain pelvic stability and leveling during the single leg support phase of gait accounts for the majority of compressive load between the acetabulum and femoral head. Requirements are significant as the abductor moment arm acting on the femur is a fraction of the midline body weight moment arm. Generated contractile force must be at least twice that of body weight given this relationship in static single limb support and much more while walking or running [35]. Left unopposed, these force moments and joint postures cause focal femoral acetabular loading, contributing to osteoarthritic progression [47].

Gluteal Dysfunction

PT management of gluteal dysfunction postoperatively begins with physician, patient and therapist recognition that the problem is multifactorial and has likely been established over many months and perhaps years. Concomitant lower extremity joint dysfunction or history of the same can also delay gluteal return. A 2016 meta-analysis by Deasy et al. revealed 7–24% isometric abductor weakness and 14%–32% isokinetic abductor weakness in patients with symptomatic ipsilateral knee OA compared with their uninvolved limb [48]. This degree of weakness can certainly manifest as postoperative gait disturbances and other symptoms such as tendinitis.

Physical therapy interventions to address gluteal insufficiencies focus on pain modulation and a step progression regarding exercise dosage. Initial exercises focus on open kinetic chain isometric loading of the gluteal muscles to stimulate histologic changes within the contractile unit to enhance tensile integrity and durability. This helps improve patient tolerance for more functional closed chain activities later in the rehabilitation process including gait training, stair-climbing, and sit-to-stand transitions. Functional electrical stimulation (FES) can be very useful in those patients exhibiting significant weakness of the abductors in side-lying strength against gravity.

Tensor Fasciae Latae Dysfunction, Coxa Saltans Externa, and Iliotibial Band Syndrome

Lateral column symptoms in the postoperative patient are common. The tensor fasciae latae (TFL) complex can be a source of pain, weakness, restriction, and functional deviation at times affecting the knee. Surgical exposure and intraoperative manipulation can contribute to overall physiologic load of the region and delays in lateral column recovery. Various preoperative factors also contribute to dysfunction.

TFL management is important in anterior-based approaches, related not only to muscle protection itself [49] but also protection of the superior gluteal nerve (SGN) [50, 51]. Atrophy of the muscle has been described in the direct anterior (DA) [49, 50] and also the ABMS approach [49, 51, 52]. In a salient randomized bilateral study [53], TFL atrophy was found after both DA and ABMS surgeries in some patients, but significantly more commonly on the DA side, therefore favoring ABMS as the least invasive anterior-based approach of the two.

ABMS surgeons need to be aware of the nerve course variations during surgery and should protect the terminal branches of the SGN at the proximal extent of the exposure. Likewise, maintenance of the epimysium of the TFL and GMed muscles appears to protect these muscles from iatrogenic damage. TFL atrophy and fatty infiltration after the ABMS approach are rare, representing only 8% of cases in a contemporary surveillance study [51]. These authors did note a correlation of abnormal MRI changes in patients with a greater body mass index (BMI), demonstrating an increased risk for heavier patients [51].

The pattern of recovery of TFL atrophy, as well as atrophy of other muscles associated with hip osteoarthritis, is largely unknown. Patients with generalized atrophy appear to have PROM scores comparable to a healthy, age-matched population [54], but functional restrictions may occur because the TFL is an important thigh abductor. It aids in gait by holding the pelvis horizontal during the stance phase of ambulation [55].

Crouch gait and anterior pelvic tilt often present in hip OA patients. The TFL is placed in a shortened position contributing to hip flexor dominance in the sagittal plane. This impedes the stabilizing force couple formed by the TFL muscle and the GMax as they co-contract during the gait cycle. The result often manifests as a shortened stride length, abbreviated stance phase, knee and hip flexion/adduction moments, compromised propulsion, and balance issues due to center of mass deviation.

According to kinesiologic work done by Dostal et al. examining moment arm data influencing the hip, the TFL is a very strong hip flexor, on par with the rectus femoris and sartorius [56]. Additionally, despite only comprising 11% of the cross-sectional areas of all abductor muscles

[57], it approaches the GMed regarding potential abductor force it can generate [56] due to its long anatomy. Despite its slightly medial insertion on Gerdy's tubercle, it has subtle influence about the hip in the transverse plane "directly" but can affect tibial motion, contributing to femoral rotatory position "indirectly." Its internal rotational abilities are enhanced by an anteriorly tilted pelvis. The TFL appears to not only have triplanar actions about the hip but also contributes to lumbosacral postural and gait deviations, acting in concert with the iliopsoas and hamstring groups [58, 59].

The TFL and iliotibial bands' (ITB) primary functional goal relates to dynamic and static tensioning across the acetabulum during single limb stance to negate body weight-induced moment arm torque across the hip joint in the frontal plane. Stabilizing forces produced collectively by the abductor groups are substantial, and three times body weight is typically quoted as the required force necessary for walking without pelvic obliquities [60]. Stair-climbing, stumbling recovery, jogging, and other recreational pursuits require multiples of this [61]. The TFL is most active in relative extension positions of the hip and knee. It demonstrated twice as much activity via EMG data relative to the GMed in the stance limb as well as the moving limb during resisted side-step maneuvers in a study by Berry et al. [62]. The positional shortening of the TFL and ITB led to a significant increase in GMed activity in this study. This concept forms the basis for range-specific hip and core therapeutic exercises in physical therapy. For example, if strengthening the GMed is the goal of an exercise, a flexed knee and hip position would be selected for resistive work. Isolation of GMed activity and minimizing TFL contribution has been previously validated [63]. Similarly, to avoid loading an irritated TFL-ITB complex, again a flexed knee and hip position might be selected. Conversely, if the TFL is the target of strength work, more neutral hip and extended knee positions would be utilized.

Following ABMS surgery, coxa saltans externa (also known as external snapping hip) commonly interferes with the rehabilitation progression. Patients may complain of localized iliac crest and trochanteric or lateral column pain which radiates to the knee. Insertional GMed or TFL irritability is often accentuated as the patient becomes more active with weight-bearing and ambulation. Distracting diagnoses often involve the lumbar spine. GMed dystonia has been documented in OA patients [64]. The TFL is in a paradoxical position of being able to generate large amounts of force in the frontal plane, but risks overuse during the degenerative process preoperatively. This compounds in the post-ABMS patient, especially in the presence of significant GMed weakness.

Chopra et al. documented EMG data on hip and thigh musculature on an individual prior to direct anterior approach arthroplasty as well as at 3- and 12-month postoperative intervals [65]. Preoperative GMed activity was noted to be 27% less on the involved side. This number had degraded another 35% at the three-month postoperative check. The TFL conversely demonstrated 76% more activity relative to the uninvolved side preoperatively. It maintained an elevated level of activity until the 12-month point post-op where it produced data symmetrical with the uninvolved side. The GMed remained 24% deficient versus the uninvolved side, even at the 12-month point. The patient did not receive physical therapy following surgery. This case demonstrates the compensatory tendencies of the TFL preoperatively and postoperatively which often creates problems for it or detracts from GMed normalization.

It also appears that the TFL and GMed may at times be minimally affected by chronic hip pain in terms of morphology. Mastenbrook et al. collected data on 15 women afflicted with chronic hip pain matched to 15 asymptomatic controls. They measured abductor strength deficit as well as gluteal and TFL muscle volume data via magnetic resonance imaging (MRI) [40]. All participants had body mass indices (BMIs) less than 30 kg/m^2. Despite a 20.3% abductor weakness demonstrated via dynamometer, no gluteal or TFL atrophy was identified; in fact, slight volume increases in the symptomatic individuals were observed. Similar findings in OA patients have been published by other investigators [41, 42]. The results seem to point to the connection between chronic joint pain/dysfunction and neurogenic weakness of the surrounding musculature. Neuromuscular reactivation is a critical early goal of physical therapy. TFL weakness related to atrophy following ABMS procedures may be the combined result of preexisting arthrogenic neuromuscular inhibition and intraoperative inputs enhancing regional physiologic load. Long periods of compensatory activity and functional shortening predispose the TFL to elevated irritation post-ABMS surgery. Trochanteric snapping hip, frictional musculotendinous syndromes, and gait-induced strains are all possible sequelae of a restricted TFL-ITB complex.

Physical therapy should focus on tissue mobility via manual therapy and stretching when indicated. Postural reconciliation through anterior and rotatory core strengthening is equally important. Iliopsoas and rectus femoris stretching will help negate an anteriorly tilted hemipelvis if present. Gluteal strength must return to acceptable levels prior to allowing the patient to ambulate without restrictions. Extension and abduction exercises should be selected based on those that target the gluteal groups while minimizing TFL contribution. Examples include unilateral bridging, quadruped hip extensions, clamshell exercises, squats, and side stepping in a squat position [66]. External resistance sources should be utilized in the progression to ensure adequate neuromuscular adaptation. Those activities inducing less than 50% MVC (maximal volitional contraction) will provide minimal stimulus for tissue adaptation and strength gain [67]. Functional electrical stimulation (FES) may provide enhanced activation input during the initial exercise phase [68].

A progression involving isometric, eccentric, concentric resistive exercise forms an effective loading strategy. Late-stage functional triplanar movement and balance training in closed chain postures prepare the individual for ADL, occupational, and recreational demands. Late-stage exercises, including core stability activities, should be incorporated into a generalized fitness program and must be completed on a regular basis to avoid regression. Daily tasks such as walking and light recreation do not provide an adequate degree of specific muscle MVC stimulus to retain optimal function and avoid recurrent symptoms [69].

Psoas and Coxa Saltans Internus

Irritations may also occur in the anterior or anteromedial hip following ABMS THR. Isolating the dysfunctional tissue as well as implementing a remedy can be a complex clinical undertaking. A “layered approach to evaluation and treatment,” as suggested by Sommer Hammoud MD and coauthors, is clinically practical and efficacious when addressing coxa saltans internus (internal snapping hip) in the postoperative patient [70] (Table 19.1). Again, it is important to acknowledge that symptoms emanating from the anterior or anteromedial hip following ABMS THR are compounded by months or years of preceding aberrant structural and pathomechanical regional input. The additional physiologic load of surgery may lead to the failure of some patients to thrive in the short term following arthroplasty. Also, the presence of a dysplastic hip can lead to iliocapsularis muscle hypertrophy and motion restriction [70]. The pubic symphysis is particularly susceptible to irritation [70]. When functional demands for range of motion and dynamic stabilization about the hip exceed pathophysiologic availability, injury often results.

During rehabilitation, the physical therapist must differentially diagnose, specifically treat, and monitor the involved “layer” as well as address all preexisting and current contributing factors. The time frame postoperatively at which a patient develops a particular symptom will help direct the clinician’s management pathway. A patient may have an extraordinary return to function in the short term, only to develop a function-limiting issue months down the road. Obtaining a thorough history of chronological and causative factors is therefore paramount to success.

When addressing coxa saltans internus, the therapist must appropriately identify the layer, or layers, of involvement. Treatment programs

Table 19.1 A layered approach to evaluation and treatment of hip pain as suggested by Sommer Hammoud MD and coauthors when addressing coxa saltans internus (internal snapping hip) in the postoperative patient [70]

Layer	Potential symptom origin	Presentation	Treatment
1. Osteo-prosthetic	Component positioning Preexisting hemipelvis injury, specifically pubic symphysis pathology Lower extremity idiopathic malalignment	Pain with loading in closed chain Rotational range of motion limits Abbreviated stance phase Positive FABER and FAI tests Sacroiliac dysfunction and/or low back pain Athletic pubalgia Weak core and SLR MMT Persistent limb length asymmetries	Capsular mobility enhancement while honoring healing and procedural constraints Reactivation and strengthening of all femoral acetabular force couples Anterior core conditioning Hamstring and gastrocnemius flexibility exercise Serial isometric loading of the pubic conjoined tendon region Gluteus medius exercises Retro-ambulation drills Foot orthoses
2. Capsulo-ligamentous, bursal	Unbalanced capsular tension Excessive "flap" scarring Early gait-induced capsulitis Layer 1 anomalies Sub-spine impingement Inactive gluteus minimus Capsular hypermobility	Capsular pattern of restriction Restricted active pelvic posterior tilt abilities in standing, anterior pelvic tilt Shortened stride length Ischiofemoral symptoms Anterior "snapping syndrome" Pain with hip flexor load at 50 degrees of flexion Position-specific selective tension, distraction testing response Deep gluteal syndrome	Local thermal, electrical modalities Manual and active release techniques Position-specific sustained elongation PNF techniques High repetition AAROM Proprioceptive to kinetic balance tasks Force couple conditioning, abdominals, and hip extensors
3. Musculotendinous	Interface scarring Psoas frictional syndromes Psoas impingement Anterior bursal syndromes Neurogenic weakness and insertional atrophy Hip flexor strain, retraction, contusion Anterior capsular incompetence	Local tenderness Positive contractile selective tensioning tests, weak and painful Positive FABER and Thomas tests Anterior "snapping" syndrome, position specific Psoas tightness and/or spasm Anterior pelvic tilt, increased lumbar lordosis, and "dumped pelvis" Femoral anteversion Deep gluteal syndrome Significant gluteus medius weakness Tendonitis Trendelenburg variations "Crouch gait"	Local modalities as indicated Manual tissue release techniques Gentle flexibility and antagonist self-mobilization exercise AROM Sustained low-intensity isometrics for tendinopathies, FES augmented as needed Selective rotational hip musculature activation and force couple coordination exercise Posterior core stretching, Williams flexion program if hyperlordotic Triplanar neutral core recognition and stabilization Isometric to eccentric to concentric to functional movement ARROM of posterolateral column musculature without psoas activation if indicated High seat stationary cycling and aquatics Proprioceptive drills progressing to kinesiologic agility Gait training progressing to walking program

(continued)

Table 19.1 (continued)

Layer	Potential symptom origin	Presentation	Treatment
4. Neurokinetic	Spinal referral patterns Peripheral nerve dysfunction Neuritis	Lumbosacral pain Positive neural tension signs Abbreviated stance phase and shortened stride length, gait Hypersensitivity Recalcitrant weakness	Pain modulating modalities Desensitization techniques Lumbar "unloading" techniques Neutral spine recognition and utilization for exercise and ADL Functional electrical stimulation-assisted muscle reeducation Layer 3 therapeutic exercise progression concepts

FABER flexion, abduction, and external rotation, *FAI* femoroacetabular impingement, *SLR MMT* straight leg raise manual muscle test, *PNF* proprioceptive neuromuscular facilitation, *AAROM* active-assisted range of motion, *AROM* active range of motion, *ADLs* activities of daily living

should utilize lesion-specific interventions in combination with frequent reassessment, to direct adaptations such as exercise mode or dose (Table 19.1).

There are basic rehabilitation concepts that apply to most coxa saltans internus patients. Activity modification will allow the involved tissue to return to a physiologic baseline as well as allow clinician's confidence in assessing what is working or not. Structured walking programs and vigorous ADLs such as house or yard work are rarely tolerated well until the patient has adequate motion and strength about the core and hemipelvis to counter the significant demands of unilateral stance and moving or carrying objects. Conversely, prolonged sitting will adversely affect tissue regeneration and general mobility. A graduated return to a full day's activity typically serves patients best.

Independent program compliance is vital to success. Formal PT sessions in isolation rarely provide adequate stimulus for tissue adaptation in isolation. Mobility and flexibility exercises must utilize sustained low to moderate end pathologic range load to promote plastic deformation of the target tissue. Sixty- to 90-second hold times are recommended [71]. Mobility and stretching exercises are best completed after some form of repetitive motion activity such as stationary cycling. They should not be completed immediately prior to any drill or task requiring substantial muscle contraction or power production. Static stretching has been correlated with reduced peak torque abilities in the short term [72].

Layer 3 components of the rectus femoris origin and iliopsoas insertional areas are commonly involved with anterior tendinopathy and associated pain. A so-called dumped pelvis is often associated. Correction occurs via flexibility improvements in these groups, adequate capsular mobility, and anterior core strength gain, allowing lordosis reduction, neutral lumbar stability, and enhanced length tension positioning of hip musculature. The psoas is particularly adept at compensating for a weak core and hip rotators, so it is often overused in this population. Its fibers maintain a near parallel orientation to the origin and insertion throughout hip flexion and extension. It does not undergo "action inversion" as hip angle changes, common to other hip joint muscles. Because of this, the psoas is highly susceptible to overuse irritation both pre- and postoperatively. The aforementioned pelvic positional correction and early activation of all hip internal and external rotators diminish the workload requirements of the psoas.

Physical therapy management of coxa saltans internus should follow a similar algorithm utilized in other regions of the body. Order of emphasis includes isolation of the offending tissue, activity modification, tissue durability, central working toward distal strength enhancement, balance improvements, general endurance, and lastly functional closed chain progression.

Lateral Femoral Cutaneous Nerve (LFCN) Irritation

LFCN injury is rare in the ABMS approach, compared with the minimum of 30–40% damage noted in the DA approach [53, 73]. This difference relates to the fact that the intermuscular interval for the ABMS approach is more lateral than that of the DA, and therefore the incision is lateral to the course of this nerve (and its variations). That being said, neuropraxia of one or more branches can occur with retraction, so transient sensory neuropathic symptoms may occur. The most common symptom may be numbness on the anterior and lateral thigh. If present, transcutaneous electrical nerve stimulation (TENS) may provide pain relief. Additionally, desensitization techniques performed at home or under supervision may be helpful. Finally, gabapentin may offer an additional benefit for neuropathic pain.

Conclusion

Recovery after ABMS THA is accelerated compared with historic and contemporary non-muscle-sparing approaches, leading to an earlier discharge home, a quicker return to driving and work, and a higher level of patient satisfaction. Successful rehabilitation starts with presurgical considerations and depends on meticulous perioperative pain, nausea, and hemodynamic management and then a stepwise, measured approach to mobilization through the healing process. In this chapter, we discussed a process to support accelerated recovery from ABMS THA with a goal of the least chance of postoperative complications. We also offered an example of one protocol used at a successful ABMS program with a variety of PT methods which have been successfully utilized to overcome some common challenges in patients recovering from ABMS surgery.

References

1. Manrique J, Hozak WJ. Chapter 14: Direct anterior approach without a special table for primary total hip arthroplasty. In: Berry DJ, Lieberman JR, editors. Surgery of the hip, vol. 1. 2nd ed. Philadelphia, PA: Elsevier; 2020. p. 199.
2. Zati A, Degli E, Spangnoletti C, Martucci E, Bilotta T. Does total hip arthroplasty mean sensorial and proprioceptive lesion? A clinical study. Chir Organi Mov. 1997;82:239–47.
3. He X, Tay S, Ling E. Sensory nerve endings in monkey hip joint capsule: a morphological investigation. Clin Anat. 1988;11:81–5.
4. Hansen B, Hallows R, Kelley S. The Röttinger approach for total hip arthroplasty: technique and review of the literature. Curr Rev Musculoskel Med. 2011;4(3):132–8.
5. Short A, Barnett J, Gofeld M, et al. Anatomic study of innervation of the anterior hip capsule: implication for image-guided intervention. Reg Anesth Pain Med. 2018;43(2):186–92.
6. Wertheimer L. The sensory nerves of the hip joint. J Bone Joint Surg. 1952;34-A(2):477–87.
7. Peak EL, Parvizi J, Ciminiello M, et al. The role of patient restrictions in reducing the prevalence of early dislocation following total hip arthroplasty. A randomized, prospective study. J Bone Joint Surg. 2005;87-A(2):247–53.
8. Rana A, Babikian G, McGrory BJ, Sturgeon C, Barraud J. ABLE advanced anterior approach for total hip arthroplasty: a single center case series of over 6000 patients. White paper: Smith and Nephew; 2021.
9. Ostojic M, Kordic D, Moro G, Ostojic Z. Anterolateral minimally invasive hip approach offered faster rehabilitation with lower complication rates compared to the minimally invasive posterior hip approach- a University clinic case control study of 120 cases. Arch Orthop Trauma Surg. 2021; Online ahead of print.
10. Peter WF, Nelissen R, Vlieland T. Guideline recommendations for post-acute postoperative physiotherapy in total hip and knee arthroplasty: are they used in daily clinical practice? Musculoskeletal Care. 2014;12(3):125–31.
11. Masonis J, Bourne R. Surgical approach, abductor function, and total hip arthroplasty. Clin Orthop. 2002;405:46–53.
12. Wallis JA, Taylor NA. Pre-operative interventions (non-surgical and non-pharmacological) for patients with hip and knee osteoarthritis awaiting joint replacement surgery–a systematic review and meta-analysis. Osteoarthr Cartil. 2011;19(12):1381–95.
13. Moyer R, Ikert K, Long K, Marsh J. The value of preoperative exercises and education for patients undergoing total hip and knee arthroplasty: a systematic review and meta-analysis. JBJS Rev. 2017;5(12):e2.
14. Cabilan CJ, Hines S, Munday J. The impact of prehabilitation on postoperative functional status, healthcare utilization, pain, and quality of life: a systematic review. Orthop Nurs. 2016;35(4):224–37.
15. Andersen L, Magnusson S, Nielsen M, Haleem J, Poulsen K, Aagaard P. Neuromuscular activation in conventional therapeutic exercises and heavy resistance exercises: implications for rehabilitation. Phys Ther. 2006;86(5):683–97.

16. Neumann D, Hase A. An electromyographic analysis of the hip abductors during load carriage: implications for hip joint protection. J Orthop Sports Phys Ther. 1994;19(5):296–304.
17. Gautreau S, Haley R, Gould ON, Canales DD, Mann T, Forsythe ME. Predictors of farther mobilization on day of surgery and shorter length of stay after total joint arthroplasty. Can J Surg. 2020;63(6):E509–16.
18. Karim A, Pulido L, Incavo SJ. Does accelerated physical therapy after elective primary hip and knee arthroplasty facilitate early discharge? Am J Orthop. 2016;45(6):E337–42.
19. Okamoto T, Ridley RJ, Edmondston SJ, Visser M, Headford J, Yates PJ. Day-of-surgery mobilization reduces the length of stay after elective hip arthroplasty. J Arthroplast. 2015;31(10):2227–30.
20. Herndon CL, Drummond N, Sarpong NO, Cooper HJ, Shah RP, Geller JA. Direct anterior versus mini-anterolateral approach for primary total hip arthroplasty: early postoperative outcomes and complications. J Arthroplast. 2020;6:257–61.
21. Abdel MP, Watts CD, Houdek MT, Lewallen DG, Berry DJ. Epidemiology of periprosthetic fracture of the femur in 32644 primary total hip arthroplasties. Bone Joint J. 2016;98-B:461–7.
22. Karam J, Campbell P, Shivang D, Hunter M. Periprosthetic proximal femoral fractures in cemented and uncemented stems according to Vancouver classification: observation of a new fracture pattern. J Orthop Surg Res. 2020;15:100. https://doi.org/10.1186/s13018-020-01619-4.
23. Zweymuller K, Linter F, Semlitsch M. Biologic fixation of a press-fit titanium hip joint endoprosthesis. Clin Orthop Relat Res. 1988;235:195–206.
24. Rao B, Cieslewicz T, Sochacki K, Kohlreiser D, Moylan D, Ellis T. Worse preoperative pain and higher activity levels predict patient choice of formal physical therapy after primary anterior total hip arthroplasty. J Arthroplasty. 2021; Pre publication, online proof.
25. Langley B, Whelton C, Page R, et al. Understanding why well-functioning THA patients fail to achieve normal walking velocity. British Orthopaedic Research Society annual meeting 2020 7–8 September 2020: Bone Joint J. 2020.
26. Yoo J, Cha Y, Kim K, Kim H, Choy W, Hwang S. Gait analysis after total hip arthroplasty using direct anterior approach versus anterolateral approach: a systematic review and meta-analysis. BMC Musculoskelt Disord. 2019;20(63):2450–2.
27. Jan M, Hung J, Lin J, Wang S, Liu T, Tang P. Effects of a home program on strength, walking speed, and function after total hip replacement. Arch Phys Med Rehabil. 2004;85(12):1943–51.
28. Takada R, Jinno T, Miyatake K, et al. Supine versus lateral position for accurate positioning of the acetabular cup in total hip arthroplasty using the modified Watson-Jones approach: a randomized single-blind controlled trial. Orthop Traum Surg Res. 2019;105(5):915–22.
29. Takada R, Jinno T, Miyatake K, et al. Difference in tapered wedge stem alignment between supine and lateral position in cementless THA via modified Watson-Jones anterolateral approach. Eur J Orthop Surg Traumatol. 2021; https://doi.org/10.1016/j.otsr.2019.05.004.
30. Schwartz A, Goel R, Sweeney A, Bradbury T. Capsular management in direct anterior total hip arthroplasty: a randomized, single blind, controlled trial. J Arthroplast. 2021;36(8):2836–42.
31. Lu Y, Wu Z, Tang X, Gu M, Hou B. Effect of articular capsule repair on postoperative dislocation after primary total hip replacement by the anterolateral approach. J Int Med Res. 2019;47(10):4787–97.
32. Bergin P, Doppelt J, Kephart C, et al. Comparison of minimally invasive direct anterior versus posterior total hip arthroplasty based on inflammation and muscle damage markers. J Bone Joint Surg. 2011;93-A(15):1392–8.
33. Arnold A, Anderson F, Pandy M, Delp S. Musculature contributions to hip and knee extension during the single limb stance phase of normal gait: a framework for investigating the causes of crouch gait. J Biomech. 2005;38(11):2181–9.
34. Annaswamy T, Giddings C, Della Croce U, Kerrigan D. Rectus Femoris: its role in normal gait. Arch Phys Med Rehabil. 1999;80(Aug):930–4.
35. Neumann D. Kinesiology of the hip: a focus on muscular actions. J Orthop Sports Phys Ther. 2010;40(2):82–94.
36. Harris-Hayes M, Czuppon S, Van Dillen L, et al. Movement pattern training to improve function in people with chronic hip joint pain: a feasibility randomized clinical trial. J Orthop Sports Phys Ther. 2016;46:452–61.
37. Harris-Hayes M, Steger-May K, Van Dillen L, et al. Reduced hip adduction is associated with improved function after movement pattern training in young people with chronic hip joint pain. J Orthop Sports Phys Ther. 2018;48:316–24.
38. Liao T, Samaan M, Popovic T, et al. Abnormal joint loading during gait in persons with hip osteoarthritis is associated with symptoms and cartilage lesions. J Orthop Sports Phys Ther. 2019;49(12):917–24.
39. Harris-Hayes M, Mueller M, Sahrmann S, et al. Persons with chronic hip joint pain exhibit reduced hip muscle strength. J Orthop Sports Phys Ther. 2014;44(11):890–8.
40. Mastenbrook M, Commean P, Hiklllen T, et al. Hip abductor muscle volume and strength differences between women with chronic hip joint pain and asymptomatic controls. J Orthop Sports Phys Ther. 2017;47(12):923–30.
41. Marshall A, de Noronha M, Zacharias A, Kapakoulakis T, Green R. Structure and function of the hip abductors in patients with osteoarthritis: systematic review and meta-analysis. J Back Musculoskelet Rehabil. 2016;29(2):191–204.
42. Zacharias A, Pizzari T, English D, Kapakoulakis T, Green R. Hip abductor muscle volume in hip osteoarthritis and matched controls. Osteoarthr Cartil. 2016;24:1727–35.
43. Pfirrmann C, Notzli H, Dora C, Hodler J, Zanetti M. Abductor tendons and muscles assessed at

MR imaging after total hip arthroplasty in asymptomatic and symptomatic patients. Radiology. 2005;253:969–76.
44. Woodley S, Nicholson H, Livingstone V, et al. Lateral hip pain: findings from magnetic resonance imaging and clinical examination. J Orthop Sports Phys Ther. 2008;38:313–28.
45. Grimaldi A, Fearon A. Gluteal tendinopathy: integrating pathomechanics and clinical features in its management. J Orthop Sports Phys Ther. 2015;45(11):910–22.
46. Howell G, Biggs R, Bourne R. Prevalence of abductor mechanism tears of the hips in patients with osteoarthritis. J Arthroplast. 2001;16(1):121–3.
47. Kumar D, Wyatt C, Chiba K, et al. Anatomic correlates of reduced hip extension during walking in individuals with mild-moderate radiographic hip osteoarthritis. J Orthop Res. 2015;33:527–34.
48. Deasy M, Leahy E, Semciw A. Hip strength deficits in people with symptomatic knee osteoarthritis: a systematic review with meta-analysis. J Orthop Sports Phys Ther. 2016;46(8):629–38.
49. Kawasaki M, Hasegawa Y, Okura T, Ochiai S, Fujibayashi T. Muscle damage after total hip arthroplasty through the direct anterior approach for developmental dysplasia of the hip. J Arthroplast. 2017;32(8):2466–73.
50. Grob K, Manestar M, Ackland T, Filgueira L, Kuster M. Potential risk to the superior gluteal nerve during the anterior approach to the hip joint: an anatomical study. J Bone Joint Surg. 2015;97-A(17):1426–31.
51. Takada R, Jinno T, Miyatake K, Hirao M, Yoshii T, Okawa A. Incidence of tensor fascia lata muscle atrophy after using the modified Watson-Jones anterolateral approach in total hip arthroplasty. Eur J Orthop Surg Traumatol. 2021;31:533–40.
52. Unis D, Hawkins E, Alapatt M, Benitez C. Postoperative changes in the tensor fascia lata muscle after using the modified anterolateral approach for total hip arthroplasty. J Arthroplast. 2013;28(4):663–5.
53. Takada R, Jinno T, Miyatake K, et al. Direct anterior versus anterolateral approach in one-stage supine total hip arthroplasty. Focused on nerve injury: a prospective, randomized, controlled trial. J Orthop Sci. 2018;23(5):783–7.
54. Rasch A, Bystrom A, Dalen N, Martinez-Carranza N, Berg H. Persisting muscle atrophy two years after replacement of the hip. JBJS. 2009;91-B:5: published online 1 May 2009.
55. Gottschalk F, Kourosh S, Leveau B. The functional anatomy of tensor fasciae latae and gluteus medius and minimus. J Anat. 1989;166:179–89.
56. Dostal W, Soderberg G, Andrews J. Actions of the hip muscles. Phys Ther. 1986;66:351–61.
57. Clark L, Haynor D. Anatomy of the abductor muscles of the hip as studied by computer tomography. J Bone Joint Surg. 1987;69-A:1021–31.
58. Delp S, Hess W, Hungerford D, Jones L. Variation of rotational moment arms with hip flexion. J Biomech. 1999;32:493–501.
59. Hicks J, Schwartz M, Arnold A, Delp S. Crouched postures reduce the capacity of muscles to extend the hip and knee during the single-limb stance phase of gait. J Biomech. 2008;41(5):960–7.
60. Johnson J, Noble P, et al. Biomechanics of the hip. Philadelphia: Lippincott, Williams and Wilkins; 1998. (Callaghan JJ, Rosenberg AG, Rubash HE, eds. The hip and its disorders).
61. Bergmann G, Graichen F, Rohlmann A. Is staircase walking a risk for the fixation of hip implants. J Biomech. 1994;28(5):535–53.
62. Berry J, Lee T, Foley H, Lewis C. Resisted side-stepping: the effect of posture on hip abductor muscle activation. J Orthop Sports Phys Ther. 2015;45(9):675–82.
63. Wilcox E, Burden A. The influence of varying hip angle and pelvis positions on muscle recruitment patterns of the hip abductor muscles during the clam exercise. J Orthop Sports Phys Ther. 2013;43:325–31.
64. Casartelli N, Maffiuletti N, Item-Glatthorn J, et al. Hip muscle weakness in patients with symptomatic femoroacetabular impingement. Osteoarthr Cartil. 2011;19(7):816–21.
65. Chopra S, Taunton MJ, Kaufman K. Muscle activation pattern during gait and stair activities following total hip arthroplasty with a direct anterior approach: a comprehensive case study. Arthroplast Today. 2018;4(1):27–32.
66. Selkowitz D, Beneck G, Powers C. Which exercises target the gluteal muscles while minimizing activation of the tensor fascia lata? EMG assessment using fine wire electrodes. J Orthop Sports Phys Ther. 2013;43:54–64.
67. Atha J. Strengthening muscle. Exerc Sport Sci Rev. 1981;9:1–73.
68. Alon G. Functional electrical stimulation (FES): clinical successes and failures to date. J Nov Physiother Rehabil. 2018;2:80–6.
69. Lee S, Lee S, Jung J. Muscle activity of the gluteus medius at different gait speeds. J Phys Ther Sci. 2014;26(12):1915–7.
70. Hammoud S, Bedi A, Voos J, Mauro C, Kelly B. The recognition and evaluation of patterns of compensatory injury in patients with mechanical hip pain. Sports Phys Ther. 2014;6(2):108–18.
71. Bandy W, Orion J. The effect of time on static stretch on the flexibility of the hamstring muscles. Phys Ther. 1994;74(9):845–50.
72. McHugh M, Cosgrave C. To stretch or not to stretch: the role of stretching in injury prevention and performance. Scand J Med Sci Sports. 2010;20:169–81.
73. Rudin D, Manestar M, Ullrich O, Erhardt J, Grob K. The anatomical course of the lateral femoral cutaneous nerve with special attention to the anterior approach to the hip joint. JBJS. 2016;98(7):561–7.

Index

A
Abdelaal, M.S., 43–46, 48, 49, 51
Abductors, 23
Acetabular bone deficiency, 161
Acetabular cementing technique, 79, 80
Acetabular component navigation, 121
Acetabular exposure, 112–113
Acetabular implant selection
  acetabular preparation techniques, 96
  dual-mobility, 96
  hemiarthroplasty, 96
  implantation, 96, 97
Acetabular orientation (AO), 120
Acetabular point acquisition, 125
Acetabular retractors, 38
Acetabular revision
  acetabular component extraction, 163
  acetabular exposure, 162
  causes of, 159
  cup-cage and triflange reconstruction, 165
  hemisphere porous acetabular components, 165
  indications and exclusions, 161
  intraoperative fluoroscopy, 166
  jumbo cup, 165
  laboratory workup, 160
  patient positioning and surgical approach, 162
  polyethylene liner exchanges, 164, 165
  posterior approach, 166
  preoperative patient evaluation, 159, 160
  preparation, 163, 164
  radiographic workup, 160
  trabecular metal cups and augments, 165
Adverse local tissue reaction (ALTR), 160
Aebi, J., 119–122, 125, 126
Aggarwal, V.K., 209
Albana, M.F., 129–136
Albert S.L., 2
American Association of Hip and Knee Surgeons, 44
American College of Chest Physicians clinical practice guideline, 60
American orthopedic surgeon, 21
American Society of Anesthesiology (ASA) score, 57
Amlie, E., 132
Anesthesia Severity Score, 85
Annual Meeting of the American Orthopaedic Association in Charleston, 2003, 4
Anterior-based muscle-sparing (ABMS) approach
  acetabular component, 38, 39
  acetabular exposure and preparation, 18, 48, 49
  acetabular retractors, 38
  advantages, 15, 19, 44
  anatomical landmark and incision, 46, 47
  bent-angled retractor, 19
  bone anatomy, 22, 23
  broaching, 39
  capsular osteotomy, 40
  capsulotomy and femoral neck osteotomy, 47
  capsule for closure, 41
  capsuloligamentous structures, 27, 28
  capsulotomy, 34, 35
  DAIR procedure, 140
  description, 15
  disadvantages, 45
  dislocation with bone hook, 40
  fascia incision, 33, 34
  femoral broaching, 19
  femoral head removal, 37
  femoral neck osteotomy, 35
  fragility fractures (*see* Fragility fractures)
  femoral preparation, 48–52
  history of, 21
  Hohmann-Wagner-like retractor, 18
  in situ femoral neck cut, 18
  incision planning, 16, 33
  learning curve effect, 16, 17, 31
  metaphyseal envelope for femoral stem, 40
  Mueller-type two-prong retractor, 37
  multimodal pain management, 32
  musculature, 23, 25
  neck fragment removal and observation, 36, 37
  neurovascular anatomy, 25–27
  one-two-stage revision, 141–143
  patient positioning and draping, 16, 32, 33, 45, 46
  posterior retractor, 35
  postoperative complications, 17
  postoperative computed tomography analysis, 16

J. A. Geller, B. J. McGrory (eds.), *The Anterior-Based Muscle-Sparing Approach to Total Hip Arthroplasty*, https://doi.org/10.1007/978-3-031-02059-9

Anterior-based muscle-sparing (ABMS) approach (*cont.*)
postoperative standing radiographs, 17
retractor, 34
screw utilization, 38
short-term outcomes, 16
step-by-step description, 31
straight 1-inch osteotome, 35
surface anatomy, 21–22
THR, 133–136
Anterior capsulotomy, 18
Anterolateral approach, 2
Anterolateral mini-incision hip replacement surgery, 4
Arnold, A., 219
Atraumatic surgical techniques, 1

B
Baba, T., 166
Barrack classification, 90
Bauer modification/Bauer approach, 2
Bedard, N.A., 78
Berger, R. A., 5, 55–63
Berry, D.J., 4
Berry, J., 221
Bertin, K.C., 89, 130, 136
Beverland, D., 4
Bone cement implantation syndrome (BCIS), 86
BrainLab navigation station, 122
BrainLab™, 121
Brekke, A., 169–185
Broach-only systems, 71, 72

C
Cabezas-Davalos, J., 119–122, 125, 126
Cabilan, C.J., 212
Capsular incision, 109, 110
Capsulectomy, 109
Capsulotomy, 34, 35, 109
Cemented stems, 176
Cemented total hip and press-fit hemiarthroplasty, 69
Cemented total hip replacement
acetabular cementing technique, 79, 80
acetabular component, 78
advantages, 81, 82, 84
decreased risk of intraoperative and postoperative periprosthetic fracture, 81–84
intraoperative advantages, 84
survivorship, 84, 85
bone cement components, 79
cement mantle quality, 90
disadvantages
BCIS, 86
increased operative time, 85
long-term aseptic loosening rates, 86–88
revision difficulties, 88, 89
femoral cementing technique, 80, 81
femoral component, 78
first-generation techniques, 79
fourth-generation techniques, 79
intraoperative fluoroscopy, 89
Müller-type stem, 77
periprosthetic fractures, 83, 84, 90
second-generation techniques, 79
third-generation techniques, 79
Cement-in-cement revisions, 182
Cementless total hip arthroplasty
broach-only systems, 71, 72
cerclage cabling, 74
contraindications, 73
cup position, 70
implant selection, 70, 71
indications, 67
intra-operative complications, 69
patient selection, 67
posterior/direct lateral approaches, 69
ream and broach systems, 72, 73
screw placement, 70
Steinman pin, 70
well-accepted indications, 68
Centers for Medicare and Medicaid Services (CMS), 56
Charlson comorbidity index (CCI), 57
Charney, M., 150
Charnley, J., 2, 4, 77, 87
Chopra, S., 221
Chulsomlee, K., 197
Civinini, R., 45, 145–154
Closed reduction percutaneous pinning (CRPP), 190
Cobb elevator, 112, 113
Cobra retractor, 112
Component malposition, 95
Computer-assisted surgery (CAS), 119
Computerized tomography (CT), 120
CORAIL™, 126
COVID-19 pandemic, 206
Coxa saltans externa, 220–222
Cozzi-Lepri, A., 145–154
Cup offset, 120

D
D'Arrigo, C., 135
Dall technique, 3
Danford, N.C., 21–25, 27, 28
Darrith, B., 197
Dastane, M., 120
Deasy, M., 220
Debridement, antibiotics, and implant retention (DAIR) procedure, 139–141
Deep surgical interval, 108, 109
Delanois, R.E., 129–136
deMeireles, A. J., 77–80, 82–91
Desai, S.S., 77–80, 82–91
Digioia, A.M., 120
Direct anterior approach (DAA), 44, 90, 132, 133
Dislocation and leg length discrepancies prevention, 116
Dorr ratio, 79
Dorr, L.D., 4
Double-offset retractors, 115
Dual mobility (DM) liners, 197
Duensing, I., 67, 169–185
Duraprep, 32

E
Ekhtiari, S., 191
Enocson, A., 151
Erickson, J., 15–19
Extended trochanteric osteotomy (ETO), 177

F
Fascial incision, 107, 108
Femoral cementing technique, 80, 81
Femoral head removal, 110–111
Femoral implant selection, 97–100
Femoral mobilization, 111, 112
Femoral neck cuts, 110
Femoral neck fracture (FNF)
  classification, 189
  history and physical examination, 188
  incidence and prevalence, 187
  morbidity and mortality, 188
  radiographic workup, 189
  risk factors, 187, 188
  surgical treatment
    CRPP, 190
    THR *vs.* hemiarthroplasty, 190, 191
Femoral nerve palsy (FNP), 146, 147
Femoral nerve palsy prevention, 114–115
Femoral offset restoration, 122
Femoral revisions
  anterior osteotomy, 177–183
  approach and mobilization, 173–175
  calcar and shoulder regions, 170, 171
  complications, 170
  etiology, 170
  history, 170
  indications and contraindications, 170, 171
  patient factors, 169
  periprosthetic fractures, 183–185
  planning implant removal, 171, 172
  preoperative planning, 171
  reconstruction, 171, 172, 181–183
  setup and equipment, 173
  stem design, 169
  stem removal
    cemented stems, 176
    implant-bone interface, 175
    medial calcar, 175
    noncemented stems, 175, 176
    well-fixed stem, 176, 177
  wound closure and postoperative protocol, 185
Femoral-sided complications prevention, 115–116
Femur preparation, 113–114
Finnegan, M.A., 206
Fitmore™, 126
Fragility fractures
  acetabular component, 196
  in elderly patient
    dislocation, 198
    periprosthetic fracture, 197, 198
    postoperative recovery, 197
  femoral component, 195, 196
  femoral head and liner, 196, 197
  FNF
    classification, 189
    history and physical examination, 188
    incidence and prevalence, 187
    morbidity and mortality, 188
    radiographic workup, 189
    risk factors, 187, 188
    surgical treatment, 190, 191
  total hip replacement
    acetabular preparation, 193, 194
    femoral preparation, 194, 195
    patient positioning and surgical exposure, 191–193
    postoperative care, 195
Functional electrical stimulation (FES), 220

G
Garden classification, 189
Geller, J.A., 152, 187–198
Giraud, M., 119–122, 125, 126
Glück, 77
Gluteal dysfunction, 220
Gluteus medius (GMed), 162
Gluteus minimus (GMin), 162
Greenhill, D.A., 153
Greenky, M., 67
Greidanus, N.V., 135

H
Hallows, R., 17, 67
Hammoud, S., 222–224
Hansen, B., 211
Hardinge direct lateral approach, 16
Hardinge, K., 3, 131
Harris hip score, 8, 85
Harris, W.H., 3
He, X., 211
Held, M.B., 77–80, 82–91
Hemiarthroplasty (HA), 96, 190
Hemisphere porous acetabular components, 165
Hernandez, N.M., 105, 107, 108, 110, 111, 113, 114, 116
Herndon, C.L., 135, 152, 197
Higgins, B.T., 150
Hip lateralization, 122
Hohmann-Wagner-like retractor, 18
Hohmann retractor, 22
Hueter, C., 2, 132

I
Iliac crest pins, 123
Iliocapsularis, 25
Iliopsoas, 25
Iliotibial band syndrome, 220–222
Inaba, Y., 135
Inferior capsular release, 110
Initial Harris hip scores (HHS), 84
Innocenti, M., 145–154

Internus, 222–224
Intraoperative periprosthetic fractures (IPPF), 152, 153
Islocation and leg length discrepancies prevention, 116

J
Jennings, J.D., 166
Jepson, K.K., 211–225
Judet, J., 2
Judet, R., 2, 22
Judet's modification, 3

K
Kahn, T., 15–19
Karas, V., 55–63
Keating, T.C., 55–63
Kelley, S.S., 17, 89, 105, 107, 108, 110, 111, 113, 114, 116, 169–185
Klasan, A., 152, 209

L
Laffosse, J.M., 45, 135
Lambers, A.P., 126
Lateral femoral cutaneous nerve (LFCN) injury, 132, 133, 147, 148, 225
Learmonth, I.D., 77
Letournel, E., 22
Levitsky, M.M., 159–166
Lewinnek description, 121
Low-dose stereoradiography (EOS), 120

M
Maldonado-R.N., 206
Mandereau, C., 134
Maratt, J.D., 131
Martin, R., 44, 135, 204
Martz, P., 44
Matta, J.M., 132, 133, 209
McCormick, K.L., 187–198
McFarland, B., 3
McGrory, B.J., 95, 96, 98, 100–102, 201–209, 211–225
McKee-Farrar hip prosthesis, 44
Mears, D.C., 3
Mehta, N., 55–63
Metal-on-metal (MoM) implants, 95
Minimally invasive solution (MIS)
  anterolateral approach, 4
  definition, 3
  direct lateral approach, 4
  functional recovery, 1
  incision length, 3
  posterior approach, 4
  Röttinger approach, 5–8
  two-incision technique (2IT), 3–5
Minimally invasive (MIS) technique, 95
Mjaaland, K.E., 135
Moore technique, 3
Moskal, J.T., 78
Mueller retractor, 111
Mueller-type two-prong retractor, 37
Müller, M., 119, 132, 139–142, 148
Müller-type stem, 77
Muscle damage prevention, 116

N
Nakai, T., 152
Nerve injury
  FNP, 146, 147
  incidence, 146
  LFCN, 147, 148
  sciatic nerve injury, 149
  SGN, 148, 149
Neuwirth, A.L., 21–25, 27, 28
New Zealand Joint Registry report, 85
Non-cemented femoral fixation, 101
Noncemented stems, 175, 176
North Atlantic divide, 77

O
Ogonda, L., 4
Osborne, G., 3
Outpatient arthroplasty risk assessment (OARA), 57
Outpatient total hip arthroplasty
  abductor-sparing, 56
  adequate pain control, 60
  ambulatory surgery centers (ASCs), 56
  care pathways, 56
  Charlson comorbidity index (CCI), 57
  cost reduction, 56
  day of surgery, 58–60
  discharge medications, 60
  follow-up protocols, 62
  in-home physical therapy and nursing visits, 58
  medical comorbidities, 57
  multimodal analgesia, 60
  pain medication, 61
  patient communication, 62
  patient selection, 57
  post-discharge care protocols, 60
  postoperative medication plan, 56
  preoperative medical clearance, 57
  psychological counseling, 57
  rehabilitation, 61, 62
  Watson-Jones approach, 56

P
Paprosky classification, 172
Paprosky, W.G., 161
Periprosthetic fracture (PPF), 195, 196
Periprosthetic hip infection treatment
  chronic infections, 139
  complications, 139
  DAIR procedure, 140, 141
  one- or two-stage revision, 141–143
Peters, C.L., 15–19
Pflüger, G., 152
Physical therapy (PT)
  gluteal dysfunction, 220
  hip before and after surgery, 219
  LFCN injury, 225
  psoas and coxa saltans internus, 222–224
  TFL dysfunction, coxa saltans externa, and iliotibial band syndrome, 220–222
Picture archiving and communication system (PACS), 19
Plate, J.F., 105, 107, 108, 110, 111, 113, 114, 116
Polyethylene liner exchanges, 164, 165
Psoas and coxa saltans internus, 222–224

R
Rana, A.J., 101, 201–209
Rectus femoris, 24
Rehabilitation
  abductor muscles, 211
  before surgery, 212, 213
  capsulectomy *vs*. capsule repair, 218
  early postoperatively, 214
  immediately postoperatively, 213, 214
  physical therapy
    gluteal dysfunction, 220
    hip before and after surgery, 219
    LFCN injury, 225
    TFL dysfunction, coxa saltans externa, and iliotibial band syndrome, 220–224
  six weeks, 218
  supine *vs*. lateral approaches, 218
  weeks 4–6, 214, 218
Röttinger approach, 4–8, 130
Röttinger, H., 1–8, 21, 89, 130, 136
Rudin, D., 26, 147

S
Sayre, L.A., 21, 201
Schairer, W.W., 206
Schanz pin, 113
Sciatic nerve injury, 149
Shah, R.P., 77–80, 82–91, 159–166
Sharkey, P.F., 43–46, 48, 49, 51
Sheth, D., 151
Short external rotators (SER), 25, 150
Sibia, U.S., 204
Skin incision, 105–107
Sköldenberg, O.G., 151
Smith-Petersen, Marius Nygaard, 2
Staphylococcus aureus colonization, 57
Steinman pin, 70
Steri-Drape, 32
Sturgeon, C.M., 201–209
Superior gluteal nerve (SGN), 148, 149
Swedish hip arthroplasty registry, 87

T
Takada, R., 149, 218
Tensor fasciae latae (TFL), 23, 162, 220–222
Thaler, M., 133, 148
3D CT-based or biplanar reconstruction (EOS)-based planification, 119
Thromboembolism-deterrent (TED) hose, 60
Tissue- and muscle-sparing approach, 4
Toossi, N., 87
Total hip arthroplasties (THAs), 129
  acetabular bone deficiency, 161
  acetabular revision
    acetabular component extraction, 163
    acetabular exposure, 162
    causes of, 159
    cup-cage and triflange reconstruction, 165
    hemisphere porous acetabular components, 165
    indications and exclusions, 161
    intraoperative fluoroscopy, 166
    jumbo cup, 165
    laboratory workup, 160
    patient positioning and surgical approach, 162
    polyethylene liner exchanges, 164, 165
    posterior approach, 166
    preoperative patient evaluation, 159, 160
    preparation, 163, 164
    radiographic workup, 160
    trabecular metal cups and augments, 165
  clinical outcome
    BMI, 202
    complications, 203
    ED rate, 206
    materials and methods, 202
    patient demographics, 202
    patient population, 204, 206
    patient-reported outcome data, 204, 206, 209
    surgical and postoperative data, 203
    surgical approach, 201
  rehabilitation (*see* Rehabilitation)

Total hip replacement (THR)
  ABMS, 130, 133–136
  complications, 145
    clinical incidence, 146
    dislocation, 149–151
    femoral nerve injuries, 146, 147
    IPPF, 152, 153
    LFCN, 147, 148
    sciatic nerve injury, 149
    SGN, 148, 149
  DAA, 132, 133
  direct lateral approach, 131, 132
  fragility fractures
    acetabular preparation, 193, 194
    femoral preparation, 194, 195
    patient positioning and surgical exposure, 191–193
    postoperative care, 195
  vs. hemiarthroplasty, 190, 191
  posterolateral approach, 130, 131
  Röttinger approach, 130
  THA, 129
Trochanteric osteotomy, 3
Tsai, S.W., 152

V
Vastus lateralis, 25
Villano, M., 145

W
Watson-Jones approach, 4
Watson-Jones interval, 133–136
Watson-Jones, R., 2, 21, 201
Well-fixed stem, 176, 177
Wu, E.S., 129–136

Z
Zhao, R., 152
Zati, A., 44, 211