Archives of Orthopaedic and Trauma Surgery (2024) 144:5267–5272
https://doi.org/10.1007/s00402-024-05548-3

KNEE ARTHROPLASTY

Relationship between soft tissue envelope thickness of the lower extremity and acute periprosthetic joint infection of the knee

Mustafa Akkaya[1,2,6] · **Ali Said Nazligul**[3] · **Merve Bozer**[4] · **Kenan Sen**[4] · **Matteo Innocenti**[5] · **Mustafa Citak**[2]

Received: 8 April 2024 / Accepted: 3 September 2024 / Published online: 14 October 2024

Abstract

Background The prevalence of obesity is increasing worldwide and it is known to be associated with many postoperative complications, including infection. Patients' body fat distribution may vary and body mass index (BMI) does not provide sufficient information about adipose tissue thickness of the lower extremities. The aim of this study is to investigate the relationship between thigh diameters and early postoperative prosthesis-related joint infections (PJI) in patients who underwent arthroplasty.

Methods The study included 76 patients and 114 knees who were operated on by a single surgeon and underwent total knee arthroplasty (TKA) due to primary knee osteoarthritis between May 2022 and September 2023 in a tertiary reference hospital. Circumference of the thickest part of the operated thigh (cm), preoperative erythrocyte sedimentation rate (ESR) and C-reactive protein (CRP) levels, height, weight, BMI and the presence of early postoperative prosthesis-related joint infections were evaluated.

Results The mean BMI was 32.6 ± 4.2 (kg/m^2). Two (2.6%) were normal weight, 14 (18.5%) were overweight, 58 (76.3%) were obese and 2 (2.6%) were morbidly obese. The mean circumference of the thickest part of the thigh was 57.56 ± 6.38 (cm). 6 patients were diagnosed with PJI in the acute phase. The mean circumference of the thickest part of the thigh was statistically significantly greater in the group with acute PJI compared to the group without PJI ($p = 0.048$).

Conclusion The incidence of acute PJI was found to be significantly higher in patients with larger thigh diameters, whereas no such relationship was observed for BMI. The incorporation of preoperative soft tissue envelope measurements into routine clinical examination may prove beneficial in reducing the risk of PJI.

Keywords Arthroplasty · Periprosthetic Joint Infection · Obesity · Body mass index

✉ Mustafa Akkaya
mustafa@drakkaya.com

Ali Said Nazligul
alisaid012@hotmail.com

Merve Bozer
dr.bozermerve@gmail.com

Kenan Sen
kenansen06@gmail.com

Matteo Innocenti
innocenti.matteo11@gmail.com

Mustafa Citak
mcitak@gmx.de

[1] Department of Orthopaedics & Traumatology, Ankara Guven Hospital, Ankara 06370, Turkey

[2] Department of Orthopaedics, Helios ENDO-Klinik, Hamburg, Germany

[3] Department of Orthopaedics, Sincan Training and Research Hospital, Ankara, Turkey

[4] Department of Orthopaedics, Ankara City Hospital, Ankara, Turkey

[5] Department of Orthopaedics, Florence University Hospital, Florence, Italy

[6] Deparment of Orthopaedics & Traumatology, Yuksek Ihtisas University, Faculty of Medicine, 06530 Ankara, Turkey

Introduction

The prevalence of obesity is increasing worldwide, and it is associated with many chronic diseases such as diabetes mellitus, hypertension, and hyperlipidemia [1, 2]. In adults, obesity is also associated with a variety of joint disorders. There is evidence that the prevalence of knee osteoarthritis is increasing with the prevalence of obesity [2].

A number of studies have shown an increased rate of complications following total knee arthroplasty (TKA) in obese patients [3–5]. One of the most feared complications of total knee arthroplasty is periprosthetic joint infection (PJI). Previous studies have shown that morbidly obese patients (body mass index (BMI) > 40) have a higher risk of medical complications, surgical complications, and surgical site infections than normal weight patients (BMI < 25) or overweight but not obese patients (BMI 25–30) [6, 7]. In a review study conducted by Samson et al., obesity was found to significantly increase the incidence of deep PJI and surgical site infections (3–9 times) in all studies evaluated [7]. While many studies in the literature have shown that the risk of PJI is increased in obese patients, there are studies that suggest that the risk is not increased [8, 9]. These studies in the literature were based on the patient's BMI. Obesity is defined by the World Health Organization as BMI > 30, but this definition does not take into account fat tissue distribution. Patients' body fat distribution may vary, and BMI does not provide sufficient information about adipose tissue thickness of the lower extremity. In a study conducted by Gupta et al. in 2018, it was observed that the increase in pretubercular thickness in non-obese patients was a protective factor against developing superficial wound problems [10]. In the study, the ideal threshold value for this situation was stated as 12 mm. However, our hypothesis is that in patients with much larger thigh and leg diameters, this situation will be a predisposing factor to surgical complications, especially infection, rather than being a protective factor.

The aim of this study is to investigate the relationship between preoperative lower extremity diameters (determined using a simple tape measure during physical examination) and early PJI (type 1) [11] in patients who underwent arthroplasty.

Materials and methods

Our study was started prospectively after ethical approval was granted by our hospital's research ethics committee (reference number: E1-23-3575) between May 2022 and September 2023, 167 patients with primary knee osteoarthritis underwent TKA by a single surgeon in a tertiary reference hospital. 58 patients were excluded based on pre-established exclusion criteria and 33 patients did not attend the required follow-ups. 76 patients and 114 knees were included in the study (Fig. 1). Of these, 38 patients underwent surgery on one knee, while the other 38 patients underwent surgery on both knees in a single session. In patients who underwent bilateral THA in a single session, different instrument sets were utilized for each knee. Patients with a history of previous surgery on the same knee, rheumatologic disease, chronic kidney disease, presence of immunosuppressive medications, and Hg A1c level ≥ 8% were excluded from the study, as these conditions are known to be predisposing factors for wound infection and PJI[12]. Since lymphedema, chronic venous insufficiency, and heart failure may interfere with thigh circumference measurements as a cause of edema in the lower extremities, patients with these conditions were also excluded from the study. All patients who were < 120 kg were administered 2 g of cefazolin sodium IV and the patients weighing over 120 kg were administered 3 g of cefazolin sodium IV as standard prophylaxis prior to incision. A tourniquet was applied to all patients with a systolic blood pressure of + 130 mm Hg. For surgical field preparation, the lower extremity was cleaned with a chlorhexidine scrub and treated with 10% povidone-iodine. During surgery, diluted povidone-iodine was used as irrigation fluid. Postoperatively, a drain was placed, and the operated extremity was bandaged. All patients were mobilized on the first postoperative day, and their sutures were removed at the end of the second week.

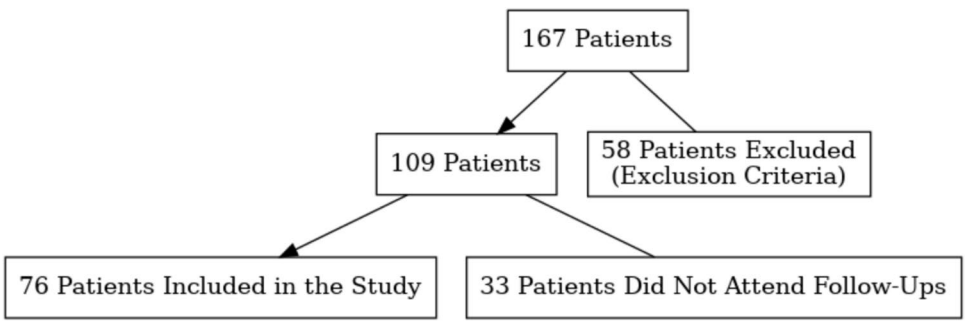

Fig. 1 Study flowchart

One day before surgery, two independent researchers measured the circumference of the thickest part of the operated leg in centimeters (cm). Each researcher took the measurement twice and the average of these measurements was recorded as the final value. Preoperative sedimentation and CRP levels were measured. Height, weight, and BMI were recorded. All patients were called for follow-up at the end of the 2nd and 4th postoperative weeks and then every 2 months until the end of the first year. PJI was diagnosed according to the International Consensus Meeting (ICM) 2018 criteria [13]. In addition to routine blood samples, synovial fluid examination was performed in patients with persistent wound discharge, purulent fluid content, persistent erythema and increased temperature in the surgical area. Persistent elevation of erythrocyte sedimentation rate (ESR) (> 30 mm/h), c-reactive protein (CRP) (> 1 mg/dl), d-dimer (> 860 ng/mL) were considered as 1, 2 and 3 points, respectively. Synovial fluid white blood cell count > 3000 cells/µl is 3 points, an alpha defensin level higher than the cut off value is 3 points, a leukocyte esterase test (++) is 3 points, a polymorphonuclear cell rate > 80% is 2 points, and a synovial CRP value is > 6, 9 mg/L was considered as 1 point. Patients with > 6 points were considered infected. Additionally, the presence of two positive cultures or the development of a sinus tract at the wound site was considered definitive evidence of infection [13]. All patient readmissions and surgical procedures were recorded.

Data analyses

Data were analyzed using IBM SPSS Statistics ver. 25 (IBM Corporation, Armonk, NY, USA) program. The assumptions of normality and homogeneity of variance were investigated by Shapiro–Wilk and Levene tests, respectively. Descriptive statistics were expressed as mean ± standard deviation, median (25th percentile–75th percentile) or median (minimum–maximum) for continuous numerical variables, while categorical variables were expressed as number of cases and (%). The significance of the differences between the groups in terms of averages was analyzed by Student's t test, while the significance of the differences in terms of continuous numerical variables for which parametric test statistical assumptions were not met was evaluated by Mann–Whitney U test.

Fisher's exact test was used for the analysis of categorical data. On the other hand, the effect of the mean circumference of the thickest part of the thigh on the development of PJI was investigated by univariate logistic regression analysis by calculating the odds ratio and 95% confidence intervals. $p \leq 0.05$ results were considered statistically significant.

Based on previous studies [3–6], if the prevalence of periprosthetic joint infection would be 1.5%, considering alpha (i.e., type I error) of 5% and a sampling error of 0.03, at least 63 cases should be included in the study to achieve 80% power. Sample size calculations were made using the relevant application on Raosoft, Inc. (Seattle, WA, US).

Results

The present study evaluated data from 114 lower extremities of 76 patients between the ages of 53 and 89 years who underwent TKA. The mean age of the patients was 67.0 ± 6.9 years, with 9 (11.8%) males and 67 (88.2%) females. The mean BMI was 32.6 ± 4.2 (kg/m2). Two patients (2.6%) were of normal weight, 14 (18.5%) were overweight, 58 (76.3%) were obese and 2 (2.6%) were morbidly obese (Table 1).

The median ESR was 19.0 (25th percentile: 9.25–75th percentile: 25.75) and the median CRP was 4.0 (25th percentile: 1.0–75th percentile: 8.0). The mean circumference of the thickest part of the thigh was 57.56 ± 6.38 (cm). Six patients were diagnosed with PJI in the acute phase as per ICM 2018 criteria (Table 1).

There were three acute PJIs in the bilateral TKA group and three in the unilateral TKA patients group. There was no statistically significant difference between the group with acute PJI and the group without PJI in terms of mean age, male/female distribution, mean BMI, prevalence of

Table 1 Demographic and clinical characteristics of the patients included in the study [age, sex, BMI, prosthetic joint localization, ESR and CRP values, thigh circumference (cm), presence of PJI]

	n = 76
Age (year)*	67.0 ± 6.9
Age range (year)	53–89
Gender	
Male	9 (11.8%)
Female	67 (88.2%)
Body mass index (kg/m^2)*	32.6 ± 4.2
Normal weight	2 (2.6%)
Overweight	14 (18.5%)
Obese	58 (76.3%)
Morbid obese	2 (2.6%)
Localization	
Unilateral	38 (50.0%)
Right	23 (30.3%)
Left	15 (19.7%)
Bilateral	38 (50.0%)
ESR**	19.0 (9.25–25.75)
CRP**	4.0 (1.0–8.0)
Thigh circumference(cm)*	57.56 ± 6.38
PJI	6 (7.9%)

Descriptive statistics were expressed as * mean ± standard deviation or ** median (25th–75th percentile)

Table 2 Demographic and clinical characteristics of the patients according to the groups with and without acute PJI [age, sex, BMI, presence of obesity, ESR and CRP values, thigh circumference (cm)]

	No PJI (n = 70)	Acute PJI(n = 6)	p-value
Age (year)*	67.0 ± 6.6	67.0 ± 10.5	> 0.999†
Gender			> 0.999‡
Male	9 (12.9%)	0 (0.0%)	
Female	61 (87.1%)	6 (100.0%)	
BMI (kg/m^2)*	32.5 ± 4.1	33.6 ± 5.3	0.558†
Obesity	55 (78.6%)	5 (83.3%)	> 0.999‡
ESR**	19.00 (9.00–25.25)	19.50 (10.00–32.25)	0.700
CRP**	4.0 (1.0–8.0)	6.0 (1.5–10.5)	0.561
Thigh circumference (cm)*	57.14 ± 6.16	62.50 ± 7.47	0.048†

Descriptive statistics are expressed as * mean ± standard deviation or ** median (25th percentile-75th percentile)

n/a: No evaluation was performed, † Student's t test, ‡ Fisher's exact test, ¶ Mann-Whitney U test

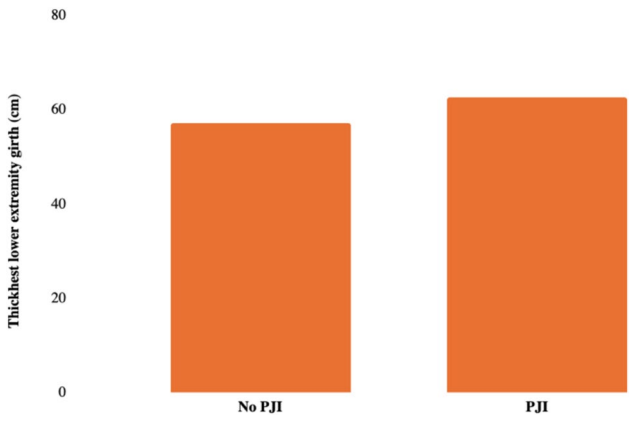

Fig. 2 Width of the thickest part of thigh (cm) between groups

obesity, localization (unilateral/bilateral, left/right knee), ESR and CRP levels (p > 0.05) (Table 2). On the other hand, the mean circumference of the thickest part of the thigh was found to be statistically significantly greater in the group with acute PJI compared to the group without PJI (p = 0.048) (Fig. 2). For each 5 cm increase in the circumference of the thickest part of the thigh, the probability of PJI increased by a factor of 2.186 (95% CI: 0.970–4.926) (p = 0.059).

Debridement, antibiotics and implant retention (DAIR) was performed in all patients admitted with acute PJI. Culture results were negative in three patients. Staphylococcus aureus was isolated in two patients and Klebsiella pneumonia in one patient. During the follow-up period, all patients recovered from the infection. None of the patients required re-operation.

Discussion

Our study findings indicate that a greater circumference of the thigh is associated with a significantly increased risk of PJI, while BMI does not demonstrate such an association. There was no statistically significant difference between the group with PJI and the group without PJI in terms of mean body mass index or prevalence of obesity (p > 0.05). However, the circumference of the thickest part of the thigh in the group with acute PJI (62.50 ± 7.47 cm) was greater than that in the group without acute PJI (57.14 ± 6.16 cm) (p < 0.05). Furthermore, for each 5 cm increase in the circumference of the thickest thigh, the probability of PJI increased by a factor of 2.186 (95% Confidence Interval: 0.970–4.926) (p = 0.059). These data demonstrate that in terms of PJI risk, it is necessary to pay particular attention to patients with large thigh diameters due to regional fat accumulation. In light of the data obtained, it could be beneficial to include thigh diameter measurements in addition to comorbidities, BMI, and obesity as parameters in the evaluation of the risk of acute infection in patients applying for TKA.

Obesity is becoming more prevalent around the world. Today, nearly 30% of people are classified as overweight or obese [14]. The incidence of obesity is rising among patients undergoing TKA for end-stage osteoarthritis [15]. It is known that an increase in BMI leads to an increase in complication rates, especially infection following TKA [16–18]. There may be variations in the distribution of body fat among individuals and BMI may not be a reliable indicator of the risks given that it only considers total bodyweight. In their study on 232 patients, Elkins et al. examined the relationship between periarticular adipose deposition and periarticular osseous geometry and BMI in anteroposterior/lateral direct radiographs [19]. As expected, the thickness of prepatellar and pretubercular adipose tissue was found to be greater in obese patients in this study [19]. In 2016, Watts et al. compared this thickness with the prevalence of wound complications requiring reoperation in a study conducted on lateral radiographs of morbidly obese patients [20]. In this study, a significant relationship was identified between subcutaneous tissue thickness and the occurrence of wound complications necessitating reoperation, irrespective of BMI. The data indicated that the predisposing thresholds for reoperation were 25 mm for pretubercular thickness and 15 mm for prepatellar thickness [20]. A study conducted by Wagner et al. on 572 patients also found a significant relationship between anterior knee subcutaneous fat thickness and the need for early reoperation due to wound complications and PJI [21]. It is apparent that the studies in literature examine the relationship between subcutaneous adipose

tissue thickness and PJI through radiological imaging. In our study, an increase in leg circumference measurement results, which can be easily obtained during a physical examination, was also found to be associated with PJI.

Studies in cardiac and general surgery have also shown that subcutaneous fat thickness is a risk factor for surgical site infection and other wound site problems. [22, 23]. The higher incidence of surgical site infection in patients with greater subcutaneous fat thickness can be attributed to a number of factors, including longer operative time, increased blood loss, larger incision, more soft tissue dissection, and more dead space [22]. However, it should be noted that we did not evaluate operative time and incision size in our study which may be considered among the limitations of our study.

In our study, there was no statistically significant difference between the group with PJI and the group without PJI in terms of mean age, male–female distribution, ESR, and CRP levels ($p > 0.05$) (Table 2)**.** Although the ESR and CRP values were not different from those of patients without infection, synovial fluid sampling was performed in patients with prolonged wound discharge and clinical suspicion of infection. In cases where the synovial fluid white blood cell count and leukocyte esterase test indicated the presence of infection, the DAIR procedure was performed on the patients.

Our study is not without potential limitations. Smoking history, comorbidities, operative time and incision length were not evaluated as additional risk factors. One of the study's limitations is the relatively small number of patients included, as well as the limited number of cases of PJI. Additionally, the follow-up period after DAIR was less than one year in some patients. Further studies with longer follow-up periods are needed to examine medium and long-term results. Additionally, the study only measured the diameter of the thickest part of the thigh and investigated its relationship with PJI. No direct measurement of intraoperative subcutaneous fat tissue thickness at the incision site was conducted, which represents a significant limitation of the study. Furthermore, the study compared excess leg circumference measurements with PJI rates without differentiating between muscle and fat. Further studies are required to determine the risk based on the amount of fat alone.

The strengths of the study were its prospective nature, inclusion of patients operated by a single surgeon using the same surgical technique, and high interobserver reliability of measurements.

Conclusion

There may be significant variations in body fat distribution among patients. While no such relationship was found with BMI, the incidence of acute PJI was found to be significantly higher in patients with larger thigh diameters. Larger lower extremity soft tissue envelope may be an important risk factor for PJI after primary TKA. Therefore, it may be beneficial to incorporate preoperative soft tissue envelope measurements into routine clinical examination in order to reduce the risk of PJI.

Author contributions All authors contributed to the study conception and design. Material preparation, data collection and analysis were performed by [Mustafa Akkaya], [Ali Said Nazligul], [Merve Bozer] and [Kenan Sen]. Conceptualization: [Mustafa Akkaya], [Mustafa Citak]; Methodology: [Mustafa Akkaya], [Matteo Innocenti], [Mustafa Citak]; Formal analysis and investigation: [Mustafa Akkaya], [Ali Said Naligul], [Merve Bozer]; Writing—original draft preparation: [Ali Said Naligul], [Merve Bozer]; Writing—review and editing: [Mustafa Akkaya], [Matteo Innocenti], [Mustafa Citak]; Supervision: [Mustafa Akkaya]. The first draft of the manuscript was written by [Ali Said Nazligul] and [Merve Bozer] and all authors commented on previous versions of the manuscript. All authors read and approved the final manuscript.

Funding The authors did not receive support from any organization for the submitted work.

Availability of data and materials Data and materials are available.

Declarations

Conflict of interest The authors declare that they have no conflict of interest regarding this manuscript.

Ethical approval Approval was obtained from the ethics committee Ankara Bilkent City Hospital. (No: E1-23-3575) The procedures used in this study adhere to the tenets of the Declaration of Helsinki.

References

1. Flegal KM, Kruszon-Moran D, Carroll MD, Fryar CD, Ogden CL (2016) Trends in obesity among adults in the United States, 2005 to 2014. JAMA 315(21):2284–2291
2. Anandacoomarasamy A, Caterson I, Sambrook P, Fransen M, March L (2008) The impact of obesity on the musculoskeletal system. Int J Obes 32(2):211–222
3. Friedman RJ, Hess S, Berkowitz SD, Homering M (2013) Complication rates after hip or knee arthroplasty in morbidly obese patients. Clin Orthop Relat Res 471(10):3358–66
4. Watts CD, Wagner ER, Houdek MT, Lewallen DG, Mabry TM (2015) Morbid obesity: increased risk of failure after aseptic revision TKA. Clin Orthop Relat Res 473(8):2621–7
5. Werner BC, Evans CL, Carothers JT, Browne JA (2015) Primary total knee arthroplasty in super-obese patients: dramatically higher postoperative complication rates even compared to revision surgery. J Arthroplasty 30(5):849–853
6. Alvi HM, Mednick RE, Krishnan V, Kwasny MJ, Beal MD, Manning DW (2015) The effect of BMI on 30 day outcomes following total joint arthroplasty. J Arthroplasty 30(7):1113–1117. https://doi.org/10.1016/j.arth.2015.01.049
7. Samson AJ, Mercer GE, Campbell DG (2010) Total knee replacement in the morbidly obese: a literature review. ANZ J Surg 80(9):595

8. Suleiman LI, Ortega G, Ong'uti SK, Gonzalez DO, Tran DD, Onyike A et al (2012) Does BMI affect perioperative complications following total knee and hip arthroplasty? J Surg Res 174(1):7–11
9. Stern SH, Insall JN (1990) Total knee arthroplasty in obese patients. JBJS 72(9):1400–1404
10. Gupta VK, Kejriwal R (2020) Pretubercular subcutaneous thickness is a protective factor for superficial wound complications after total knee arthroplasty in nonmorbidly obese patients. J Arthroplasty 35(1):255–258. https://doi.org/10.1016/j.arth.2019.08.046. (**Epub 2019 Aug 27 PMID: 31558297**)
11. Pellegrini A, Suardi V, Legnani C (2022) Classification and management options for prosthetic joint infection. Ann Joint 7:3. https://doi.org/10.21037/aoj-20-86
12. Tande AJ, Patel R (2014) Prosthetic joint infection. Clin Microbiol Rev 27(2):302–345. https://doi.org/10.1128/CMR.00111-13
13. Parvizi J, Tan TL, Goswami K, Higuera C, Della Valle C, Chen AF, Shohat N (2018) The 2018 definition of periprosthetic hip and knee infection: an evidence-based and validated criteria. J Arthroplasty 33(5):1309-1314.e2. https://doi.org/10.1016/j.arth.2018.02.078
14. Chooi YC, Ding C, Magkos F (2019) The epidemiology of obesity. Metabolism 92:6–10
15 George J, Klika AK, Navale SM, Newman JM, Barsoum WK, Higuera CA (2017) Obesity epidemic: is its impact on total joint arthroplasty underestimated? An analysis of national trends. Clin Orthop Relat Res 475(7):1798–806
16. George J, Piuzzi NS, Ng M, Sodhi N, Khlopas AA, Mont MA (2018) Association between body mass index and thirty-day complications after total knee arthroplasty. J Arthroplasty 33(3):865–871
17. Schwarzkopf R, Thompson SL, Adwar SJ, Liublinska V, Slover JD (2012) Postoperative complication rates in the "super-obese" hip and knee arthroplasty population. J Arthroplasty 27(3):397–401
18. Adhikary SD, Liu W-M, Memtsoudis SG, Davis CM, Liu J (2016) Body mass index more than 45 kg/m^2 as a cutoff point is associated with dramatically increased postoperative complications in total knee arthroplasty and total hip arthroplasty. J Arthroplasty 31(4):749–753
19. Elkins JM, Simoens KJ, Callaghan JJ (2018) Lower extremity geometry in morbid obesity-considerations for total knee arthroplasty. J Arthroplasty 33(10):3304–3312. https://doi.org/10.1016/j.arth.2018.03.060
20. Watts CD, Houdek MT, Wagner ER, Taunton MJ (2016) Subcutaneous fat thickness is associated with early reoperation and infection after total knee arthroplasty in morbidly obese patients. J Arthroplasty 31(8):1788–1791
21. Wagner RA, Hogan SP, Burge JR, Bates CM, Sanchez HB (2018) The radiographic prepatellar fat thickness ratio correlates with infection risk after total knee arthroplasty. J Arthroplasty 33(7):2251–2255
22. Kozlow JH, Lisiecki J, Terjimanian MN, Rinkinen J, Brownley RC, Agarwal S et al (2014) Cross-sectional area of the abdomen predicts complication incidence in patients undergoing sternal reconstruction. J Surg Res 192(2):670–677
23. Fujii T, Tsutsumi S, Matsumoto A, Fukasawa T, Tabe Y, Yajima R et al (2010) Thickness of subcutaneous fat as a strong risk factor for wound infections in elective colorectal surgery: impact of prediction using preoperative CT. Dig Surg 27(4):331–335