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TOPIC HIGHLIGHT

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Single-incision laparoscopic colorectal surgery for cancer: State of art

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Abstract

A number of clinical trials have demonstrated that the laparoscopic approach for colorectal cancer resection provides the same oncologic results as open surgery along with all clinical benefits of minimally invasive surgery. During the last years, a great effort has been made to research for minimizing parietal trauma, yet for cosmetic reasons and in order to further reduce surgery-related pain and morbidity. New techniques, such as natural orifice transluminal endoscopic surgery (NOTES) and single-incision laparoscopy (SIL) have been developed in order to reach the goal of "scarless" surgery. Although NOTES may seem not fully suitable or safe for advanced procedures, such as colectomies, SIL is currently regarded as the next major advance in the progress of minimally invasive surgical approaches to colorectal disease that is more feasible in generalized use. The small incision through the umbilicus allows surgeons to use familiar standard laparoscopic instruments and thus, perform even complex procedures which require extraction of large surgical specimens or intestinal anastomosis. The cosmetic result from SIL is also better because the only incision is made through the umbilicus which can hide the wound effectively after operation. However, SIL raises a number of specific new challenges compared with the laparoscopic conventional approach. A reduced capacity for triangulation, the repeated conflicts between the shafts of the instruments and the difficulties to achieve a correct exposure of the operative field are the most claimed issues. The use therefore of this new approach for complex colorectal procedures might understandingly be viewed as difficult to implement, especially for oncologic cases.

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Key words: Colorectal cancer; Laparoscopic surgery; Single-incision surgery; Single-access surgery; Scarless surgery; Technical challenges

Core tip: During the last years, a great effort has been made to research for minimizing surgical trauma and stress. A new technique, known as single-incision laparoscopy (SIL) has been developed in order to reach this goal. In particular, SIL is currently regarded as the next major advance in the progress of minimally invasive surgical approaches to colorectal disease. However, SIL raises a number of specific new challenges compared with the laparoscopic conventional approach. We aimed at illustrating the potential benefits or efficacy as well as feasibility and safety of this procedure in the treatment of colorectal cancer.

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INTRODUCTION

The laparoscopic technique has been enthusiastically applied to the resection of colorectal cancer for more than 15 years[1]. There is evidence that laparoscopy for colorectal cancer offers the opportunity for a meticulous dissection of the mesocolon and mesorectum under direct vision while facilitating a true no-touch technique[2]. Additional benefits, such as less postoperative pain, reduced need for postoperative analgesia, less ileus, shorter hospital stay, less blood loss, and better cosmesis are also well documented[3,4].

During recent years, great effort has been made to minimize parietal trauma for cosmetic reasons and to further reduce surgery-related pain and morbidity. New techniques, such as natural orifice transluminal endoscopic surgery (NOTES)[5] have been developed in order to reach the goal of "scarless" surgery. Although NOTES actually allows for no scarring of the body surface, it has several disadvantages and limitations with the currently available instruments, including limited access, less familiar working angles and operative approaches. Furthermore, it is associated with possible complications caused by opening of the stomach, colon or vagina, and may not be fully suitable or safe for advanced procedures, such as colectomies[6].

Single-incision laparoscopy (SIL) is currently regarded as the next major advance in minimally invasive surgical approaches to colorectal disease that is more feasible for generalized use[7-10]. SIL reduces the invasiveness of laparoscopic conventional surgery (LCS) by decreasing the number of incisions and ports through the abdominal wall. This theoretically could provide important clinical advantages, including less postoperative pain, reduction of port-site associated morbidity (such as wound infection, bleeding, visceral injury and port site herniation), quicker recovery and shorter hospital stay. The small incision through the abdominal wall allows for "scarless"-surgery as the wound is usually hidden within the umbilicus, thus providing potentially better cosmesis. Moreover, SIL permits surgeons to use familiar standard laparoscopic instruments but also perform complex procedures, such as colorectal operations, which require extraction of large surgical specimens or intestinal anastomosis.

TECHNICAL ASPECTS OF SIL

SIL was first reported in 1992 by gynecologists who performed single-incision hysterectomy[11]. The performance of the first transumbilical cholecystectomy was published in 1999[12] and the first single-incision appendectomy was reported in 1998[13]. The use of SIL in colorectal surgery was first reported in 2008 by Remzi *et al*[8] and Bucher *et al*[14].

Since these first reports, it has been evident that SIL raises a number of specific new challenges compared with LCS. The skills required for SIL are different from those needed in conventional multiport laparoscopy, even for experienced laparoscopic surgeons[15]. The handling of straight instruments in parallel with the laparoscope through a small single incision decreases the freedom of movement for the surgeon, and complicates the holding of the laparoscope for the assistant and instruments for the surgeon. The most outstanding technical challenges involved in SIL are the following: (1) loss of triangulation with straight instruments: the loss of this dogmatic principle of laparoscopic surgery often imposes the need to operate with crossed hands and does not allow an ergonomically favorable position for the surgeon and assistants. The inherent technical challenge is that the visual axis becomes more axial or in-line, so a movement of the camera often results in a inadvertent movement of an adjacent instrument, thus increasing the difficulty of performing even relatively simple tasks; (2) restricted number of working instruments and thus difficulty of achieving correct exposure and the necessary traction to tissues; (3) restricted external working space: the multiple instruments and laparoscopies required for a procedure are competing for the same space at the fulcrum of the entry port, causing external hand collisions and difficulty with instrument tip manipulation internally; (4) difficulty in maintaining pneumoperitoneum; and (5) requirement of training and adjustment. New operative hardware is being developed to facilitate the technique[16]. Many of the big healthcare manufacturers have developed multilumen access devices to allow for the insertion of several instruments through a single large fascial incision. Initially, these devices offered three openings with limited gas inflow and outflow, but we are now seeing revision of the devices, incorporating more access ports so standard laparoscopic dissection techniques can be utilized. Newly designed equipment, such as articulating or curved instruments and flexible scopes, have been introduced to recreate triangulation. Moreover, the introduction of an extra-long, 5 mm laparoscope allows placement of the camera on a different plane from the other instruments and help in moving the operator's hand further apart to avoid handle collision[17]. All these devices have made single site surgery easier and more efficient.

FEASIBILITY AND SAFETY OF SINGLE-INCISION COLECTOMY

All the challenges encountered with single-port surgery are magnified with colorectal procedures. Unlike laparoscopic cholecystectomy or appendicectomy which involve surgery in only one abdominal quadrant, single-incision laparoscopic colectomy often requires operating in different abdominal quadrants. In addition, the need for adequate oncological margins and the creation of a tension-free anastomosis are essential. Although the use of this new approach for complex colorectal procedures might understandingly be viewed as difficult to implement, over the past few years there has been significant interest in SIL for colonic resections in both benign and malignant conditions. In fact, between 2008 and 2012, a nearly 7-fold increase occurred in the number of articles related

to single-port colorectal surgery[18-20]. Unfortunately, the currently available literature relating to the technique includes mostly case reports or small case series describing the feasibility, safety and technical difficulties of different operations[21-30]. There are very few studies comparing SIL to LCS and there is a need for randomized controlled trials to definitively establish that SIL is no different from standard laparoscopic surgery in terms of completion rates, complications and oncological adequacy but with the advantage of being more cosmetic with subsequently reduced morbidities including pain[31-35]. The studies published to date have a number of other flaws limiting their impact. These include low sample size, selection bias and difficulty in blinding the patients enrolled[36-41]. The vast majority of studies involve a very carefully selected SIL cohort of uncomplicated cases, which significantly limits their generalization.

The most significant datum emerging from the literature is that colonic SIL has been offered to date to a highly selected group of patients[18,19]. This selection is based on two main parameters: body mass index (BMI) that is an indirect measure of visceral fat, and tumor site, that is directly linked to the type of surgical procedure.

It is well known that visceral fat is one the most critical factors in the identification of the correct surgical plane in laparoscopic surgery[42]. This concept is obviously amplified in SIL and visceral obesity is reported as the primary cause of conversion to multiport laparoscopy in most studies[43]. Therefore it is understandable that most patients who are candidates for this type of surgery had a low BMI. Makino *et al*[18] have reviewed 23 studies with a total of 378 patients undergoing single-port colectomy. The mean value of BMI was 25.5 kg/m^2 in these patients. Similar results have been found by Fung *et al*[19] in their recent review. These authors have analyzed 38 colonic SIL articles containing 565 patients and the median BMI was 25.8 kg/m^2. On the basis of these findings, some studies have suggested the use of preoperative abdominal computed tomography to predict accurately the pattern of visceral fat, allowing better selection of patients for SIL colectomy and reducing the number of conversions[42].

The other factor that has markedly influenced the currently available data on SIL for colorectal cancer is the type of surgical procedure. Makino *et al*[18] have reported that 279 (73.8%) of the 378 procedures analyzed in their review were right hemicolectomy, followed by sigmoidectomy (n = 27), performed essentially for diverticular disease, and anterior resection of the rectum (n = 20). Moreover, a high number of published studies have specifically limited the analysis of safety, feasibility and short-term results to only single-port right hemicolectomy[14,26-30,32,36,39,40,43-46], thus demonstrating that this type of procedure is the least complex to perform with the single-port technique at the beginning of the experience. Actually, right hemicolectomy involves surgery only in one/two quadrants while left procedures require operating in a multitude of different and opposite abdominal quadrants, from the hypochondrium for splenic flexure mobilization to the pelvis for a total mesorectal excision (TME). Moreover, in right hemicolectomy the surgeon has the possibility of creating an extracorporeal intestinal anastomosis through umbilical access while in left colectomies and anterior resection of the rectum the anastomosis is intracorporeal, thus augmenting the complexity of the procedure.

These considerations clearly show that there is an inevitable case-selection bias in assessing the outcomes of colorectal SIL from published studies. Although randomized controlled trials comparing single-port and multiport right hemicolectomy have not been reported yet, the most significant data available to date relate to this type of procedure. In 2012, the two largest experiences with single-port right hemicolectomies in a single institution have been reported. Waters *et al*[47] analyzed the short-term outcomes with single-incision right hemicolectomy in 100 patients. Operative indications were oncological in 92 patients, 57 for adenocarcinoma and 35 for polyps not suitable for endoscopic removal. Morbidity (13%) and mortality (1%) rates were acceptable as well as operative time (median value, 105 min) and conversion rate to multiport or open procedures (2% and 4%, respectively). Most importantly, there was no compromise of oncological adequacy with no positive tumor margins and a mean number of 18 lymph nodes retrieved and examined in the surgical specimens. Interestingly, patients with a wide range of BMI measurements were offered single-incision right hemicolectomy, with the largest approaching super-obesity at a BMI of 46 kg/m^2 and a mean patient BMI of 28. Unfortunately, no results regarding postoperative pain, cosmetic results or direct comparison with the multi-port laparoscopic approach were reported.

Chew *et al*[48] have reported the short outcomes of single-incision laparoscopic right hemicolectomy in 40 consecutive patients. These results were compared with those of 104 conventional laparoscopic right hemicolectomies. Indications for surgery were oncological in the majority of patients in the two groups. The authors found that single-incision right hemicolectomy is a feasible and safe procedure with equivalent outcomes in terms of operative time, oncological adequacy, postoperative morbidity, and conversions when compared with conventional laparoscopic right hemicolectomy. In particular, there were no differences in lymph node retrieval (median value of 18 and 19 lymph nodes for multi-port and single-port surgery, respectively) and resection margin clearance.

The data regarding left sided procedures, in particular anterior resection of the rectum for cancer, are much more limited. This is mainly due to the complexity of these procedures, in particular some surgical steps such as mobilizing the splenic flexure and dissection of the mesorectum. The fairly great distance of the spleen and the deep pelvis from the umbilicus amplify the difficulty of creating instrument triangulation, especially when standard, straight laparoscopic instruments are used. Even adequate traction of the rectum and stapling procedures have been associated with technical difficulties and adjunctive methods of traction and suspension such as transparietal suture, are frequently needed to achieve

adequate surgical exposure[49-54]. Bulut *et al*[55] have recently reported their early experience in single-incision surgery for rectal cancer treatment. This study was conducted on 10, highly selected patients: the mean tumor diameter was very small (3.2 cm), BMI was $\leqslant$ 25 kg/m^2 in all patients and 8 of them were females, thus providing the advantages of a wide pelvis and relative lack of visceral fat. Although the authors stated that single-incision surgery for rectal cancer can be performed safely in this kind of patient, the overall mean operation time was quite long (240 min) and 6 patients received stomas (4 had diverting ileostomy after anterior resection of the rectum and 2 had colostomy after Hartmann procedure and abdominoperineal resection). Moreover, mesorectum excision was classified as nearly complete in 4 patients and the median number of examined lymph nodes was quite low, namely 14.

One of the most challenging maneuvers in single-incision rectal surgery is maintaining an adequate operative field during TME. Uematsu *et al*[52] have proposed a new rectum-suspending system composed of a suspending bar and a bowel clamp with an extracorporeal magnetic tool. This apparatus, along with single access through the right iliac fossa instead of the umbilicus, allowed the authors to perform TME and transect the rectum by ensuring a proper tension. Nevertheless, the proposed new technique is actually complex and, as the authors stated, is not recommended for males with narrow pelvis or obese individuals or when mobilization of the splenic flexure is required because of the distance between the spleen and the single access through the right iliac fossa. Altogether, these data clearly show that some unresolved issues still remain in performing SIL for the treatment of rectal cancer.

There are more data which are somewhat more reliable regarding other less complex left-sided procedures, such as left hemicolectomy or sigmoidectomy[50,56-58]. In fact, sigmoidectomy is the most frequent procedure performed for benign left-side pathology, predominantly diverticular disease or large colonic polyps not suitable for endoscopic removal. Recently, Vestweber *et al*[59] have reported the largest series of patients undergoing single-incision colorectal surgery in a single institution. One hundred and fifty out of 244 procedures were sigmoidectmy (n = 145) with left hemicolectomies (n = 4) and high anterior resection of the rectum (n = 1). Most of these patients were operated on for diverticular disease (n = 142) followed by colonic polyps (n = 4) and colonic cancer (n = 4). The mean operative time for left-sided procedures was 146 $\pm$ 48 min and in all cases standard straight, non-articulating laparoscopic instruments along with ultrasonic or radiofrequency dissector/sealer were used. It seems that the authors did not experience any particular technical problems in performing these types of procedures which do not actually need wide splenic flexure mobilization or mesorectal dissection. The fairly higher incidence of early postoperative complications (12.6%) than rates stated in the literature, was imputed to the high rate of severe, complicated diverticular disease rather than to the complexity of single-incision procedure.

The literature concerning subtotal colectomy or proctocolectomy (with or without ileoanal anastomosis), at this time consists only of case reports and a few small case series[60-66]. The predominant indication for this type of operation has been ulcerative colitis followed by polyposis coli[62,63,65]. Overall, 36 single-incision total colectomies have been reported in the literature: these studies have demonstrated the feasibility and safety of single-incision technique even in these more complex colonic procedures but cannot provide any comparative results with traditional laparoscopy. It is likely that cosmetic results will be magnified by single-incision total colectomy since patients suffering from ulcerative colitis or polyposis coli are usually young and may prefer a small incision hidden in the umbilicus. If an ileostomy is scheduled, the single incision is usually performed in the right lower quadrant of the abdomen and the terminal ileum is brought out through this port-site, thus minimizing the traumatic and cosmetic impact of the procedure.

COMPARISON BETWEEN SINGLE-INCISION AND CONVENTIONAL LAPAROSCOPIC COLECTOMY

As all these data indicate, there are still several limitations to an analysis of the adequacy of single-incision technique in the treatment of colorectal cancer. The most important limiting factor in the interpretation of reported outcomes is the careful selection of patients, with an almost 3-fold predominance of right-sided pathology, a low to average BMI and non-bulky colonic disease. If this case-selection bias is taken into account and the oncological adequacy of a single-incision procedure is hypothetically accepted, this innovation would be justified only in the presence of clear short-term benefits over conventional laparoscopic colonic surgery. These benefits should comprise a lower complication rate, reduced postoperative pain, faster recovery and better cosmesis.

To date, only two randomized trials have compared short-term outcomes after single-incision and conventional laparoscopic colectomies for colon cancer. In 2011, Huscher *et al*[67] reported the results of a study conducted on 32 patients, with 16 in the single-incision and 16 in the conventional laparoscopic group. Although the authors confirmed the safety and technical feasibility of single-incision colectomy, they did not show any superiority of the procedure over conventional laparoscopy in terms of postoperative morbidity, resumption of oral liquid/solid food intake and length of hospital stay.

More recently, Poon *et al*[68] reported findings from a randomized controlled trial which enrolled 50 patients, 25 in each study group. As expected, the patients were carefully selected in regard to BMI (median value, 23.2 kg/m^2) and tumor size (< 4 cm). On the contrary, there was a predominance of left-sided procedures, with 14 anterior resections, 1 sigmoidectomy, 2 left hemicolectomies

and only 8 right hemicolectomies in the single-incision group. The authors did not find any statistically significant difference in operative outcome and oncological adequacy between the single-incision and the conventional laparoscopic group. Interestingly, they found a lower postoperative pain score and shorter median hospital stay in the single-incision group. Although these findings emerge from a randomized controlled trial, they cannot be considered definitive due the low number of patients involved in the study.

Two recent meta-analyses have addressed the issue of comparison between SIL and LCS for both benign and malignant colorectal diseases[69,70]. Both studies have been published in 2012 and thus have included all the comparative studies published to date with the exception of the above mentioned randomized trial by Poon *et al*[68] Notwithstanding the heterogeneity of the analyzed studies (14 by Zhou *et al*[69] and 15 by Yang *et al*[70]) in terms of type of procedures performed, indication for surgery, different patient inclusion and exclusion criteria, neither meta-analysis found any significant difference in the incidence of postoperative complications or operative time between single-incision and conventional laparoscopic colectomy. Importantly, they show that patients undergoing single-incision colectomy had a significantly shorter length of hospital stay, significantly shorter incision length, significantly less estimated blood loss, and significantly more lymph nodes harvested during oncological resections. Unfortunately, the two pooled analyses were not able to compare the pain score due to lack of data, the differences in scoring methods and in postoperative care and pain management in the available reported data. However, at least three studies[46,71,72] show a significant decrease in pain scores for patients undergoing single-incision colectomy compared to conventional laparoscopy. The decreased pain score is likely due less surgical trauma as a consequence of eliminating the additional ports at separate sites on the abdominal wall. There is no meta-analysis regarding cosmetic results due to absence of adequate information on this interesting outcome in the individual studies. Only one study reported cosmetic score results with an advantage for SIL over LCS[34]. However, it is logical to assume that a shorter final incision length in single-incision surgery results in improved cosmetic satisfaction for the majority of the patients.

Another important issue emerging from the literature data is that almost all single-incision colectomies have been performed by experienced laparoscopic surgeons. This implies that SIL is offered not only to a select group of patients but is also performed by a select group of surgeons. It might appear premature to propose a complex and technically challenging evolution of conventional laparoscopy colectomy when this has yet to be fully accepted as a gold standard in the treatment of colorectal cancer[73]. It must be considered that in 2010, only about 20% of colorectal resections in England and in other countries were performed laparoscopically[74]. Therefore, although the principles of SIL are highly attractive, they might not, at this moment, be transferable and proposed to the general community of surgeons.

The last but not least important concern about single-incision colectomy regards the costs. It is logical to expect an initial increase in costs associated with single incision colectomy over conventional laparoscopic surgery since the additional equipment such as single-incision access ports or flexible/articulating instruments are still relatively new. In their analysis of single-incision right-hemicolectomy, Waters *et al*[44] found a marginal increase in direct operative cost of United States $310 to $410 per case. If patients have a shorter length of hospital stay, and consequently, a quicker return to work and normal activity after single-incision surgery, it is likely there will be an improvement in the cost-effectiveness of SIL in the future.

CONCLUSION

As all these data indicate, most of the current studies on single-incision colectomy for cancer are observational and lack statistical power due to the relatively low number of patients studied. Although meta-analyses can increase the statistical power by pooling results of all available trials, only randomized, controlled studies can provide high levels of evidence. To date, only two randomized controlled studies have compared short term results between single-incision and conventional laparoscopic surgery and, unfortunately, even these studies have enrolled a very low number of patients. Bearing in mind these limitations, we can still glean several important factors from these published series: (1) colonic SIL is technically demanding but the introduction of new specialized equipment including multilumen ports, angled scopes, articulated instruments and instruments of variable length, will eventually reduce this difficulty; (2) principles of colonic SIL are attractive and applicable in carefully selected groups of patients, namely with right-sided pathology, low BMI and non-bulky tumors; (3) in the hands of experienced laparoscopic surgeons, colonic SIL in the above mentioned patients has been demonstrated to be safe and feasible with rates of surgery-related complications and mortality, operative time and oncological adequacy comparable with those of conventional laparoscopy; and (4) two meta-analyses and one randomized controlled study provide evidence in support of some advantages of SIL over conventional laparoscopy, namely, shorter length of hospital stay, significantly shorter incision length and significantly less estimated blood loss; other hypothesized benefits, such as reduction in postoperative pain and improvement of cosmesis remain unproven.

Further high powered randomized studies comparing SIL and LCS by using standardized outcome assessment tools are needed to confirm or not the above mentioned results. But one thing is certain: we will not see the same dramatic clinical advantages with the passage from LCS to SIL as we saw with the advent of laparoscopic technique over open surgery.

Furthermore, the more complex the procedure performed by single-incision surgery, the more likely are

there to be advantages in comparison with conventional laparoscopic procedures. In this prospective, a possible field of investigation might be the assessment of systemic stress response of single-incision versus conventional laparoscopy in colorectal surgery. The reduced parietal trauma and manipulation of the peritoneum could decrease the postoperative inflammatory response to surgical stress and as a consequence, more efficient immunocompetency against tumor cells might be maintained since the earliest postoperative days[75,76]. All these factors might influence the long-term oncological results of SIL with a potential improvement in survival rates of patients operated on for colorectal cancer.

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