Chapter

LaparoEndoscopic Single-Site Upper Gastrointestinal Surgery

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Abstract

The evolution of minimally invasive surgery has led to the development of laparoendoscopic single-site (LESS) surgery. The feasibility of almost all types of LESS upper (GI) procedures has been shown. During the learning phase, substantial experience in both laparoscopy and upper GI surgery and stringent patient selection criteria is essential for successful and safe application of the technique, especially in complex procedures. Comparative studies between LESS and conventional laparoscopy for various upper GI procedures suggest a non-inferiority of LESS over standard laparoscopy, although the only objective benefit remains an improved cosmetic outcome. Intracorporeal instrument collision, lack of triangulation, and in-line vision are among the main challenges of LESS surgery. The current review provides a comprehensive report of the specific applications of LESS in upper GI surgery, with a special reference to advances made to overcome the current technical difficulties and future perspectives.

Keywords: laparoendoscopic, laparoscopy, foregut, upper GI, cholecystectomy, ergonomics, single-port, single-incision

1. Introduction

Continued efforts to further reduce morbidity and improve the aesthetic outcomes of laparoscopic surgery while maintaining the same degree of safety and surgical efficiency have led to the evolution of single-port or single-incision laparoscopy. A surfeit of acronyms has been used to refer to these techniques until a consensus statement, following the first Laparoendoscopic Single-Site Surgery Consortium for Assessment and Research (LESSCAR), agreed to use the term "LESS" [1]. By reducing the number of transcutaneous points of access, the approach offers numerous advantages including but not limited to improving postoperative recovery time and pain, enhancing cosmesis, and minimizing port-related complications [2, 3].

2. Challenges, instrumentation, and techniques

Despite its early use in upper GI surgery, the LESS approach was slow to gain acceptance until recently, possibly due to technical difficulties, the need for specialized instruments, and the lack of clear benefits in comparison with conventional minimally invasive surgery. Close proximity of laparoscopic instruments and camera lens often results in intracorporeal instrument collision or "sword fighting",

hindering the surgeon from operating dextrously within the operative field. Visibility of the operative field afforded by the camera assistant is also limited because of the restriction in freedom to manoeuvre the camera lens to minimize instrument clashing. Moreover, intracorporeal dissection and suturing are challenging because of the limited range of movement of the laparoscopic instruments working along the same axis with lack of triangulation [3, 4].

Several techniques and advancements have been introduced to overcome constraints associated with LESS approach. New access devices have been designed and commercialized and are chosen according to the discretion of the surgeons in each institute. The most commonly used are multichannel single-port devices (e.g. Quad Port®, Tri Port®, SILS Port®) or single-channel devices in which multiple trocars can be placed (e.g. GelPOINT® and SSL port®) [5]. There are also devices of art which allow the use of items in the operating room, such as surgical glove with adaptation of trocars in each finger [6].

Another important advance in the development of LESS surgery was the appearance of modified curved instruments, articulated and reusable pre-bent, which provide better force application at instrument tip during dissection and improved intraoperative ergonomics [7]. Needlescopic instruments have been rediscovered, as they can be introduced through a small puncture that requires no formal closure [8, 9]. Low-profile camera systems and laparoscopes with high definition and flexible tip options (e.g. ENDOEYE® and Ideal Eyes®) have also been developed to reduce crowding with other instruments and improve visualization [5]. Additionally, instruments clashing can further be ameliorated by the cross-hand technique, which allows surgeons to manipulate instruments in a more intuitive way [10].

Finally, the need for a retraction mechanism that does not require an additional port led to the development of several techniques and manoeuvres such as patient repositioning and utilization of gravity and insertion of gauze between surgical planes [11, 12]. Other procedure-specific manoeuvres for internal retraction are discussed in the relevant sections.

3. Specific LESS applications in upper GI surgery

The application of LESS approach in upper GI surgery was first described in 1997 by Navarra et al. who reported a series of 30 cases of LESS cholecystectomy performed via a single umbilical incision [13]. Subsequently, many clinical series and randomized controlled trials (RCTs) have been reported, and almost the entire spectrum of surgical procedures for upper GI tract diseases has been described and shown to be feasible.

3.1 LESS gastric surgery

3.1.1 LESS gastrectomy

Since the first description by Omori et al. in 2011 [14], only few case series have been published on LESS gastrectomy for gastric tumours, mostly from Korea and Japan [11]. *All these series* have reported techniques and outcomes of LESS distal gastrectomy, while LESS total and proximal gastrectomy and LESS wedge resection have only been reported as individual cases [15–18]. This is because the procedure is complex and technically difficult to perform, and there are concerns regarding oncologic safety. Favourable factors for performing LESS distal gastrectomy include previous experience with conventional multiport laparoscopic gastrectomy and low patient BMI [19].

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3.1.1.1 Technical considerations

In early experiences with the technique, additional needlescopic instruments were required outside of the single incision [14, 20]. For pure LESS distal gastrectomy, the access is transumbilical, and a percutaneous suture is often used for liver retraction. Gastric mobilization, lymph node dissection, and reconstruction are generally performed in the same manner as in conventional laparoscopic distal gastrectomy with few modifications. In performing LESS D2 gastrectomy, the suprapancreatic lymph node dissection, especially station 11p, can be technically challenging because it lies behind the pancreas and is vertical to the direction of instruments, and some authors recommend incomplete safe exploration [21]. Alternatively, mid-pancreas mobilization and traction have been described to achieve complete dissection of station 11p lymph nodes without assistance [22]. Billroth II and extracorporeal or intracorporeal uncut Roux-en Y gastrojejunostomy remain the most commonly used methods for reconstruction in pure LESS distal gastrectomy [21, 23]. Recently, unaided delta-shaped (uDelta) gastroduodenostomy has been introduced as a modification of the original advanced assistance-dependent delta-shaped anastomosis, which is considered a safe and more reproducible reconstruction option, with similar anatomical results [24].

3.1.1.2 Outcomes

Comparative series between conventional multiport laparoscopy and LESS approach for distal gastrectomy have recently been reported. These studies demonstrated comparable outcomes in terms of operative time, conversion, postoperative mortality, lymph node harvest, R0 resection, and 5-year overall and disease-free survival between the two groups, illustrating the safety and feasibility of LESS distal gastrectomy for both early and advanced gastric cancer [25–28]. Conversely, while no significant differences in the postoperative complications were noted between the two approaches in patients with early gastric cancer [25, 26], the overall complication rate was significantly lower after LESS distal gastrectomy for advanced gastric cancer [28]. Pointing to faster recovery, studies evidenced earlier initiation of oral intake, lower pain scores on postoperative day 0 and 1, less analgesics requirements, and shorter hospital stay for the LESS approach than the conventional laparoscopic counterpart [26–28]. Only one study evaluated the cosmetic outcomes using the numerical rating scale assessment of the scar and reported more satisfaction in the LESS group [26].

In a separate analysis, when reduced-port laparoscopic and LESS distal gastrectomy for early gastric cancer were compared, no significant differences were observed in the perioperative and oncologic outcomes. However, there were more females and nonobese patients in the LESS group [29]. Recently, Suh et al. reported the results of 16 patients who underwent LESS distal gastrectomy with uDelta gastroduodenostomy or uncut Roux-en Y gastrojejunostomy. There were no significant differences in mean operative time, transfusion rates, hospitalization, anastomosis-related complications, and 30-day mortality. Interestingly, the reconstruction time for uDelta was shorter than that for Roux-en Y anastomosis [24].

3.1.2 LESS intragastric surgery

LESS intragastric resection is a novel approach that has mainly been employed in the management of gastric stromal tumours, although its use for gastric bezoar removal has been described [30]. The procedure is particularly useful in cases of

endophytic tumours <5 cm, with unfavourable locations, such as the fundus, high lying in the posterior wall of the stomach, or close to the gastroesophageal junction or the pyloric ring [31–33]. Several advantages are offered by the LESS intragastric approach including direct visualization of tumours during resection, minimal dissemination of the tumour into the peritoneal cavity, easy delivery of the specimen through the single-site incision, and extracorporeal repair of the gastrotomy site [31]. In addition, it obviates the need for multiple incisions, thus resulting in better cosmesis, and reduces the possibility of deformity by significantly preserving the normal gastric tissue with more precise resection compared with conventional laparoscopic wedge resection [33].

3.1.2.1 Technical considerations

LESS intragastric resection may be performed either as a "pure" LESS procedure or less commonly as a "hybrid" procedure with intraoperative gastroscopy [33, 34]. Both umbilical and left upper quadrant incision can be used to obtain access to the peritoneal cavity. A 2–3 cm incision is performed on the anterior wall or the lower body greater curvature of the stomach, and a single multichannel port or three standard ports are inserted through the abdominal incision and gastrotomy site [32, 33]. After creating a pneumostomach, the tumour is located, excised, and retrieved through the single-site incision.

3.1.2.2 Outcomes

Despite the small number of cases reported in the literature, the procedure appears to be safe and effective, with favourable outcomes. In previous series, no conversion to conventional laparoscopy or open surgery was necessary nor were additional trocars. Postoperative complications occurred in 0–25% and were mostly intragastric and surgical site bleeding [31, 32, 35, 36]. The operative time, number of used staplers, time to first oral intake, hospital stay, and complications were not significantly different from conventional laparoscopic wedge resection [33]. No local recurrence or distant metastasis was detected during a follow-up period of 8–19 months [31–33].

3.2 LESS hepatobiliary surgery

3.2.1 LESS hepatic surgery

The first report of LESS hepatectomy was published by Aldrighetti et al. in 2010. The authors performed a left lateral sectionectomy via a supraumbilical incision for a solitary colorectal metastasis [37]. Nonetheless, because LESS liver resection requires advanced surgical skills and has a significant learning curve, only a limited number of reports are currently available in the literature. The procedure has been used for wide range of conditions: liver adenoma, focal nodular hyperplasia, haemangioma, hydatid and simple cyst, intrahepatic biliary stones, metastatic liver lesions, and hepatocellular carcinoma [38].

Patients should be cautiously selected for LESS liver resection. Superficial hepatic lesions limited to the left lateral section are preferable, even though bigger or more technically challenging resections for less favourably located tumours have been described with increased experience in the technique [39]. Lesions less than 5 and 10 cm are the recommended cut-off points for malignant and benign tumours, respectively [39]. Other contraindications include vascular or extrahepatic involvement and morbid obesity [40–42].

3.2.1.1 Technical considerations

Transumbilical incision with a 3-trocar technique has been the preferred approach; right upper quadrant or supraumbilical incisions can be useful in the setting of portal hypertension with umbilical varices or lesions in distant segments [43, 44]. Several methods were adopted to avoid instrument collision including the use of single ports with a large outer cap or self-retaining sleeves [38]. During parenchymal dissection, simultaneous in-line radiofrequency precoagulation can be used to reduce the risk of bleeding [45]. Similar to other foregut procedure, the resection specimen is placed into a retrieval bag prior to removal through the port site.

3.2.1.2 Outcomes

Benzing et al. recently performed a comprehensive systematic review on LESS hepatectomy pooling the available data of 124 minor and 7 major resections of 133 patients from 15 studies [46]. The majority of minor resections were left lateral sectionectomies and wedge resections for both benign and malignant diseases; 6 of the 7 major resections were performed due to malignancy, including 4 for colorectal metastasis. Overall, the conversion to multiport laparoscopic/open rate ranged between 0 and 25% which, for the most part, was due to technical difficulties, intraoperative bleeding, and uncertainty of the oncologic margin of the resection. Free resection margins could be achieved in all but one patient with malignancy, demonstrating the efficacy of the technique. The median length of hospital stay was reported between 1 and 21 days, and the overall morbidity and mortality rates were 6.8% (0–33%) and 0.8%, respectively [46].

Few studies have compared the outcomes of LESS and conventional laparoscopic left lateral liver sectionectomy, and the results were inconclusive or conflicting. Including only patients with benign liver diseases, an RCT demonstrated a significantly shorter length of hospital stay in the LESS group [47]. This difference, however, disappeared in the other two non-randomized matched and unmatched comparisons, when patients with malignant tumours were also included [48, 49]. A further advantage observed only by Struecker et al. for the LESS technique was shorter operative time, which was attributed to the easy retrieval of the specimen through the umbilical incision [49]. The intraoperative blood loss, conversion, and postoperative morbidity and analgesics requirements were similar between the two groups in all studies. It was indicated that in well-selected patients with either benign or malignant hepatic lesions, LESS left lateral sectionectomy can provide a safe and effective alternative to multiport laparoscopic surgery [47–49].

Choi et al. described the surgical outcomes of LESS- and standard laparoscopy-assisted donor right hepatectomy. The LESS group had significantly shorter operative time, less blood loss, earlier resumption of enteral feeding, and lower pain scores. There were no significant differences between the groups with respect to length of hospital stay, R0 resection, and postoperative morbidity and mortality [50]. These results were replicated by Han et al. who described the surgical outcomes of LESS and conventional laparoscopic method for major and minor hepatectomies. Nevertheless, in this retrospective study, patient background and the type of procedures differed between the two groups, meaning the analysis was constrained by selection bias [51].

3.2.2 LESS cholecystectomy

The LESS approach has been increasingly used in gallbladder surgery, and its indications are expanding by virtue of the advances in instrumentation and surgical

experience. Over the last two decades, hundreds of studies have been published reporting outcomes of LESS cholecystectomy and describing different operative techniques for the procedure with variable success rates [52].

3.2.2.1 Technical considerations

The access to the peritoneal cavity in LESS cholecystectomy is obtained through paraumbilical or more commonly intraumbilical incision, which, although provides the best cosmetic outcome, is associated with higher rates of wound complications and incisional hernia [52]. A single 20–30 mm fasciotomy incision with a reusable or disposable single-access device can be used. "Swiss cheese" technique, a multiple facia puncture technique using multiple low-profile ports, is an acceptable alternative though carries risk of air leak and facial weakness [52, 53]. Various types of instruments have been used in LESS cholecystectomy including standard straight and curved instruments, with the latter offers the advantage of triangulation within the operative field [53]. During dissection, several technical variations are adopted to achieve adequate gallbladder anchorage and a clear critical view of safety while obviating the necessity of an extra port: suture suspension ("puppet technique"), internal retraction, transabdominal endoloop, and magnet grasper [54]. Gallbladder is thereafter delivered through a single-access device or connected facial openings with or without the use of a retrieval bag.

3.2.2.2 Outcomes

Several meta-analyses have compared the outcomes of LESS cholecystectomy with traditional multiport (three or four ports) laparoscopic cholecystectomy [55–66]. Although early reports showed no significant differences in terms of reported pain and quantity of on-demand analgesics delivered, the three most recent meta-analyses included more RCTs with different inclusion criteria and showed less postoperative pain following LESS cholecystectomy particularly in the first 24 h [64–66]. This discrepancy in results is possibly ascribable to the less tissue trauma in LESS cholecystectomy as surgeons progress along the learning curve and gain experience with the technique. The operative time was significantly longer in the LESS group in all meta-analyses, whereas open conversion rate and length of hospital stay were nearly identical between the two groups. Conversion to multiport and/or open cholecystectomy in the LESS group was mainly due to omental adhesions, obesity, Mirizzi syndrome, and obscure anatomy of Calot's triangle [59, 62]. Of note, the overall short-term postoperative morbidity rate, surgical site infection, and port-site hernia were consistently higher, though not statistically significant, in the LESS group than the conventional group [55–65]. This was further bolstered by a recent large pooled analysis indicating that mild and severe adverse events were significantly higher in LESS cholecystectomy than in conventional laparoscopic cholecystectomy. When the results were adjusted to the type of technique used (4-port or 3-port), statistically significant differences were still noted [66]. Possible explanation of this raised risk of complications is the impaired exposure of the operative field in LESS cholecystectomy and the technical difficulty encountered by surgeons early during their learning phase. Moreover, the natural progression of this new technique to broader indications such as acute cholecystitis entails higher rates of adverse events.

Compared to conventional cholecystectomy, the inherent benefits of the LESS technique, specifically postoperative satisfaction and cosmetic outcomes, were significantly in favour of LESS cholecystectomy at different time points during the first postoperative year, which was at the expense of higher surgery costs. These results were replicated in most RCTs and all pooled analyses regardless of the scoring

system employed: visual analogue scale (VAS), body image and cosmesis (BIQ), cosmesis, and wound satisfaction scores [56–66]. Meanwhile, apart from marginal advantage of LESS cholecystectomy early in the postoperative course, studies could not demonstrate any significant differences in the quality of life between LESS and conventional laparoscopic cholecystectomy in the first 12 months postoperatively [58, 63–66]. It is noteworthy to mention that despite the evidence for better patients' satisfaction and cosmetic results in LESS cholecystectomy, cosmetic outcome is not the main factor that drives patient preference. Rather the risk of complications seems to exercise a higher influence on patients in determining the choice of procedure [67]. This indicates that an improved postoperative morbidity rate is a prerequisite for LESS cholecystectomy to become widely accepted.

3.2.3 LESS common bile duct exploration

While the past decade has seen a dramatic increase in the adoption of LESS technique in gallbladder surgery, technical limitations have restricted its use in bile duct surgery to only highly selected cases. LESS exploration of the common bile duct (CBD) allows for combined treatment of cholelithiasis and choledocholithiasis using cholecystectomy and CBD drainage, a one-stage minimally invasive procedure with cosmetic advantage. At present, only a few case series of LESS CBD exploration have been reported in the literature, using either a single multichannel port or multiple trocars through a single intraumbilical or paraumbilical incision. Both transcystic and choledochotomy approaches with or without the assistance of a needlescopic grasper have been employed in LESS CBD exploration with successful ductal clearance rates ranging between 75 and 100%; conversion to open and conventional laparoscopic surgery was reported in 0–7.7% and 0–8.3%, respectively, and postoperative complications occurred in 0–25% [68–72]. Furthermore, Chuang et al. described a novel LESS transfistulous bile duct exploration and stone removal without drainage for Mirizzi syndrome type II with 80% success rate [73]. Supporting previous results and adding more evidence to the safety of the technique, the same authors reported 101 consecutive cases of successful LESS CBD exploration and concluded that in experienced hands, the procedure is feasible and a safe option for treatment of complicated and noncomplicated choledocholithiasis under low threshold for conversion [74].

In a series comparing 17 LESS and 17 conventional laparoscopic cholecystectomy and CBD exploration, Kim and colleagues reported (the study evidenced) a longer operating time in the LESS cohort but with less analgesics requirement and a shorter hospital stay. The stone clearance rate (100%) and incidence of complications were similar between the two groups [71]. A subsequent similar analysis by Chuang et al. did not show any significant difference in the operative outcomes between LESS and conventional laparoscopic CBD exploration. The former group however had a significantly higher rate of acute cholecystitis than the latter group, and this may have influenced the results [72].

3.3 LESS pancreatic surgery

The application of LESS approach to pancreatic surgery still remains an open debate. This procedure is generally considered as technically demanding due to its complexity and the need to perform fine dissections in a narrow surgical space. Indications for LESS pancreatic surgery include splenic artery aneurysm, pancreatic fibrosis, cysts, and benign and malignant neoplasms [12, 75]. The most commonly performed procedure is LESS distal pancreatectomy with or without spleen preservation for localized lesions; others include pancreatic necrosectomy and staging laparoscopy for advanced pancreatic cancer [76, 77].

3.3.1 Technical considerations

The approach in LESS distal pancreatectomy is mostly transumbilical. Occasionally, an additional 5 mm trocar is inserted in the left upper quadrant to be used by the surgeon's right hand and subsequently for drainage [78]. Various modifications of gastric suspension technique have been developed to facilitate better exposure of the pancreas [79–81]. The Lasso technique, in which a ribbon tape is looped around the pancreas body or tail, can be used to provide additional traction, particularly in cases of LESS distal pancreatectomy without splenic preservation [81, 82]. The pancreatic mobilization and dissection follow the principles of standard laparoscopic pancreatic resection, and the resected specimen is extracted through the umbilical site.

3.3.2 Outcomes

In a recent review, Chatzizacharias et al. analysed the data on LESS distal pancreatectomy from eight case studies. Conversion to open rate was 0–19%, and postoperative complications, mainly pancreatic fistula, were reported in 22% (0–50%) of patients. The length of hospital stay ranged between 1 and 15 days [39].

More importantly, Han et al. compared the outcomes between patients undergoing LESS and conventional laparoscopic distal pancreatectomy. With the exception of significantly longer operative time and duration of hospital stay reported with the LESS approach, perioperative outcomes did not differ between the two groups [83]. Likewise, two comparative analyses, including a case-control study, yielded no significant differences between conventional laparoscopic and LESS distal pancreatectomy in the operative time, intraoperative bleeding, conversion rate, resection status, hospital stay, and complications [75, 84]. The spleen was preserved more in the conventional group than in the LESS group, but this difference was not significant [83, 84]. A recent comparison between LESS and the more widely accepted robotic distal pancreatectomy has evidenced a significantly longer operative time and hospital stay, larger intraoperative blood loss, less spleen preservation, and higher grade II/IIIa postoperative complications in the LESS group. There were no significant differences in pain scores, tumour size, conversion rate, and overall complications between the two groups [85]. Overall, although it has been shown to be safe and feasible, these findings highlight the question of any real value of LESS approach in the context of pancreatic surgery.

3.4 LESS splenic surgery

Despite the scarcity of high-level evidence, there has been a dramatic increase in the number of laparoscopic splenectomies performed over the last 2 decades. The procedure is currently considered the gold standard for management of surgical diseases in normal or slightly enlarged spleens [86]. More recently, and as a bridging procedure towards pure natural orifice transluminal endoscopic surgery, Barbaros and Dinççağ were the first to describe LESS splenectomy in two female patients with idiopathic thrombocytopenic purpura [87]. Other common indications for this approach are splenic cystic disease, hereditary spherocytosis, myeloproliferative disorder, and splenic aneurysms and neoplasms [88].

3.4.1 Technical considerations

For LESS splenectomy, either a transumbilical or a lateral rectus incision can be utilized depending on the size of spleen. The technique used for splenic

dissection is similar to multiport laparoscopic splenectomy. Not uncommonly, a 3 mm instrument is inserted through the left flank to facilitate spleen retraction and dissection of retroperitoneal adhesions [89]. Others used a cloth tape to encircle and tug the splenic hilum, therefore providing better exposure and easy introduction of the stapler into the splenic hilum [90]. Once the spleen is completely free, an endobag is deployed, and the spleen is retrieved intact or morcellated.

3.4.2 Outcomes

A systematic review published by Fan et al. summarized the evidence on LESS splenectomy from 29 articles, with a total of 105 patients. The median length of hospital stay varied from 1 to 11 days. The postoperative complication rate was 0–33.3%, and the rates of conversion to open and multiport laparoscopic surgery were 1.9 and 2.9%, respectively. Bleeding from the splenic or short gastric vessels were the main reasons for conversion. No perioperative death was observed [88]. In a comparison between reduced-port, multiport, and LESS splenectomy, Monclova et al. reported significantly longer operative time in the LESS group, and this was partly related to the higher spleen weight. Importantly, there was a significant advantage in the LESS and reduced-port groups in the body image index with respect to the multiport group, pointing to better cosmetic outcome. Other perioperative outcomes were comparable among the two groups [91]. Wu et al. conducted a comprehensive meta-analysis comparing the outcomes of LESS and conventional laparoscopic splenectomies. They pooled and meta-analysed the data of 332 patients from nine comparative and one prospective case-control study. While postoperative pain scores favoured the LESS approach, the conversion rate and operative time slightly favoured conventional laparoscopic surgery, though without statistical significance. Ultimately, no differences were observed with regard to morbidity, mortality, analgesics requirements, and postoperative hospitalization. The authors pointed out that LESS splenectomy is safe and feasible with no obvious advantages over multiport laparoscopic splenectomy [92].

4. Conclusions

The current evidence shows that LESS upper GI surgery is feasible, and its adoption is expanding worldwide. A successful LESS procedure requires proper instrumentation, adequate laparoscopic experience, and careful patient selection. The demonstration of a significant and consistent increase in the adverse events associated with certain LESS applications in upper GI surgery should represent a word of caution in performing these procedures. While cosmetic improvement is a natural corollary to LESS, real advantages of the approach in upper GI surgery are still controversial. Prospective randomized studies are largely awaited to further explore the benefits of this technique for patients as well as to elucidate the cost-effectiveness of the approach. The advent of new instruments and platforms may significantly counteract technical issues associated with LESS surgery and facilitates the current steep learning curve.

Conflict of interest

The authors declare no conflict of interest.

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