Mini-review

New Frontiers in Mini-invasive Biliary Surgery: Single Incision Laparoscopic Surgery, Natural Orifice Transluminal Endoscopic Surgery, and Robotics

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Abstract

During the last 2 decades, technological advances as high-definition cameras along with three-dimensional vision systems, vessel sealing devices, and articulating instruments have added safety, efficacy, and precision to laparoscopic procedures. The need to develop even more minimally invasive surgical techniques has led laparoscopic surgeons to try to reduce the number of skin incisions or to avoid them altogether, and change the way to approach peritoneal cavity. Natural orifice transluminal endoscopic surgery and single incision laparoscopic surgery represent the surgeon's attempt to reduce invasiveness and body image trauma perception and improved esthetics in comparison with conventional laparoscopic surgery. All these innovations have been successfully applied to laparoscopic cholecystectomy. However, it is still debated when and how to use them instead of conventional procedures.

Key words: Laparoscopic cholecystectomy, natural orifice transluminal endoscopic surgery, robotics, single incision laparoscopic surgery

Introduction

Technological advances have been more safe, effective, and precise to apply to laparoscopic procedures during the last 2 decades. High-definition (HD) cameras along with three-dimensional (3D) vision systems, vessel sealing devices, dedicated staplers, and articulating instruments are only some examples of more recent innovations in laparoscopic surgery. Moreover, the need to develop even more minimally invasive surgical techniques has led laparoscopic surgeons to try to reduce the number of skin incisions or to avoid them altogether. Natural orifice transluminal endoscopic surgery (NOTES) and single incision laparoscopic surgery (SILS) have been proposed as different solutions to further minimize the invasiveness of laparoscopy. Although all these innovations have been successfully applied to laparoscopic cholecystectomy (LC), it is still controversial when and how to use these new types of non-conventional laparoscopic procedures.

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Natural Orifice Transluminal Endoscopic Surgery and Single Incision Laparoscopic Surgery

NOTES and SILS represent the surgeon's attempt to reduce invasiveness and body image trauma perception and improved esthetics in comparison with conventional laparoscopic surgery, however, the potential benefits, such as decreased pain, better esthetics, shorter recovery, and higher patients satisfaction over standard cholecystectomy still have to be demonstrated. In standard LC, the placement of 3–4 ports allows for triangulation of the target anatomy, fewer instrument collisions, wide angles of retraction, and better surgeon ergonomic comfort. In SILS and NOTES, many of these advantages are lost. Instruments enter the abdomen parallel through the umbilicus or vagina, resulting in the loss of the triangulation, impaired vision due to lack of space, and

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greater collisions between instruments.[1] To minimize these issues, transabdominal sutures, articulating instruments, and flexible endoscopic cameras have been used. Several NOTES and SILS procedures have been described.[2,3] There has not been a large clinical trial comparing SILS or NOTES versus standard multiport LC so far. In 2010, we described our personal experience on 100 LC performed either traditionally or by SILS or by NOTES.[4] In both techniques (SILS/NOTES), traction is assured by at least three transabdominal stay sutures passed through the fundus and both medial and lateral aspects of the infundibulum to retract, stabilize, and flag the gallbladder laterally or medially, and expose Calot's triangle while the operating instruments are inserted through a 5 mm trocar placed at the umbilicus. The only difference between SILS and NOTES in our experience is that vision is via an endoscope inserted through the vagina in the NOTES technique and by a 30° angled 5 mm laparoscope inserted through the umbilical scar in the SILS approach. We have outlined selection criteria on who would be offered which operation. Since no definitive information on the impact of the transvaginal approach on subsequent fertility or sexual discomfort exists, we exclude from offering the NOTES to young fertile women. Moreover, patients with previous pelvic surgery or history of pelvic inflammatory disease (PID) were also excluded from the NOTES approach due to potentially catastrophic complications as intestinal perforation or pelvic infections.[5] Therefore, we offered the NOTES approach to women > 40-year-old with no previous pelvic surgery or history of PID. SILS was offered to male patients and women excluded from NOTES approach, with previous surgery in the upper right quadrant being the main contraindication. Totally 67 cases of the 100 cases studied were women, and among these 67 women, 9 cases were candidates to NOTES after exclusion criteria, and among these 9 cases, only 6 cases agreed to the NOTES technique. In this series, only 6 (6.0%) of all patients underwent a NOTES cholecystectomy, and 20 (20.0%) accepted an SILS procedure. All procedures were completed as scheduled without complications and conversions to laparotomy. No significant differences in perioperative outcomes between standard, SILS, and NOTES, LC have been found. Finally, NOTES and SILS seem to be safe and promising techniques although our results highlight the limited applicability of NOTES cholecystectomy, as there are strict inclusion and exclusion criteria, and women often refuse the procedure. It is important to highlight that these results have been obtained by our group, who are well ahead in skill and experience with SILS and NOTES with our first series already published in 1997.[6] In fact, a recent literature review of SILS on 1,166 patients have reported a conversion rate of 9.3%, an intraoperative complication rate of 2.7%, and a postoperative complication rate of 3.4% including bile leak, bleeding, infection, residual common duct stone, and biliary stricture.[2] In our opinion, SILS and NOTES are safe procedures when performed by experienced surgeons and when strict inclusion and exclusion criteria are carefully taken into consideration.

Three-dimensional Vision Systems and Robotics

The major limitation of two-dimensional (2D) HD laparoscopy is the lack of depth perception, thus increasing the visual and physical strain for the surgeon. Spatial depth information loss in a 2D imaging system is compensated for to a high degree by the experience of the operator and by the ability of the human brain to interpret secondary spatial depth cues with education. The main advantages of the robotic system are represented by better ergonomic surgeon position, deeper HD 3D vision, articulating instruments with 7 degrees of freedom, motion scaling, and tremor filtration. The merit of the penetration of robotic surgery (RS) in the surgical community is mainly attributable to urologists who, in the last few years, widely adopted it to perform prostatectomy. Although RS has been approved for clinical application since 2000, however, very few hepatobiliary surgical procedures have been approached in this way. RS has been shown to offer some advantages compared with conventional laparoscopic surgery (3D vision and reduction of tremor interference), but after the first excitement, some concerns have been arising due to very high costs and long learning curve of this type of surgery.[7,8] What's more, when considering the overall costs even if in high-volume centers, many robotic procedures are not cost-effective particularly for simple routine operations, such as cholecystectomy for gallbladder disease. The gallbladder is approachable in the classic way by the robotic interface, with excellent results, or using a single incision.[9,10] Moreover, near-infrared technology can be of help in the visualization of biliary anatomy and its variants.[11] However, the cost-effectiveness of robotic cholecystectomy makes its routine use questionable. 3D HD laparoscopy has taken laparoscopic surgery to a new orbit. 3D HD laparoscopy is not as expensive as the robotic kind, yet it has the same advantages of 3D vision with a very short learning curve for an established laparoscopic surgeon.[12] Some experimental studies have reported that the 3D systems improve task efficiency in laparoscopic manipulations, whereas other reports found no significant difference between 3D and 2D systems.[13] The synthetic phantom task setup used and the involvement of medical students during experimental studies simulate only partial surgical procedures, do not reflect the complexity of clinical conditions, and could lead to unreal results. Moreover, clinical comparative studies are lacking in the literature. The real advantages of 3D versus 2D imaging for LC are still not known. Only one prospective randomized study, conducted by Hanna *et al.*,[14] exists in the literature and shows no statistically meaningful differences between the two imaging systems. To address the issue of whether 3D offers real operative time advantages to the laparoscopic surgical procedure, we have recently designed a prospective randomized comparison of 3D versus 2D imaging during elective LC, performed both by an advanced laparoscopic surgeon and by a surgeon experienced in open surgical procedures but a novice in laparoscopy.[15] A

total of 80 patients were randomized the day of surgery by random computer-generated allocation list to receive either a 3D or 2D HD imaging system LC by 2 surgeons with differing experience. After the insertion of the access ports, the surgical procedure was divided into two component tasks (dissection of the cystic duct and artery in Calot's triangle, and separation of the gallbladder from the liver bed). Operative times of the two component tasks and the entire procedure were recorded. The execution times for the 2 component tasks and the entire procedure were not significantly different between the 2D and 3D groups for the experienced laparoscopic surgeon. However, the execution times for the two component tasks and the entire procedure were significantly faster during 3D compared with 2D for the novice surgeon. Both surgeons experienced better depth perception with the 3D system and subjectively reported less strain using 3D rather than 2D vision. 3D imaging seems not to influence the performance time of LC by an experienced laparoscopic surgeon. Less experienced laparoscopic surgeons could benefit from shorter performance time with 3D imaging due to no need to adapt to 2D vision. Most of the studies that showed the superiority of a 3D over a 2D imaging system have been conducted using an experimental surgical model. van Bergen *et al*.[16] reported no significant differences in execution times between 3D and 2D vision in a model with five standardized tasks. In an experimental study performed by Storz *et al.*,[17] it was demonstrated how both difficult and easy tasks were completed with greater precision and shorter performance time when medical students were working under 3D vision rather than 2D vision. Conversely, in the same setting, advanced laparoscopic surgeons, although faster and more accurate than medical students, did not show any significant difference in performance time and precision for an easy task under both 3D and 2D vision but were faster during difficult tasks as suturing and stitching. As previously mentioned, only one prospective randomized study, by Hanna *et al.*,[14] exists in the literature, and it showed no statistically meaningful differences between the two imaging systems. It is noteworthy that surgeons involved in this study were all novice surgeons (fewer than 20 LCs performed), but probably the use of a first-generation single-lens laparoscope, which does not project a true stereoscopic vision to the operator, may have influenced their results. A more recent study by Bilgen *et al.*[18] reported a significant reduction in the performance time of LC performed under 3D vision. Surgeons participating in their study were all experienced in laparoscopy, but the 2D group was artificially created by computer and in our opinion negatively influenced their results. Further comparative studies are necessary to verify on great numbers of cases whether 3D can reduce intraoperative complications such as biliary lesions.

Discussion

In conclusion, NOTES and SILS are promising techniques that need new, dedicated instrumentations to reduce technical limitations. Randomized studies comparing SILS/NOTES and traditional laparoscopy are necessary to evaluate the safety, efficacy, and potential benefits. 3D imaging seems not to influence the performance time of LC by an advanced laparoscopic surgeon. Less experienced laparoscopic surgeons could benefit from shorter performance time with 3D imaging due to no need to adapt to 2D vision. Further comparative studies are necessary to verify on great numbers whether 3D can reduce costs and, even performed in a similar operative time, decrease intraoperative complications such as biliary lesions.

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Conflicts of interest

There are no conflicts of interest.

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