



Laparoscopic single-site surgery in inguinal hernia repair

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Abstract: Laparoscopic single-site surgery (LSS) aims to expand on the inherent advantages of minimally invasive surgery (MIS). We looked into its application in inguinal hernia repair (IHR), summarized the associated challenges of the technique and gathered the current available literature matching it against the conventional laparoscopic technique. Current literature highlights the associated technical challenges, however emphasize these may be mitigated by employing certain maneuvers and strategies. Operative time for LSS IHR has been frequently cited to be longer than its conventional laparoscopic counterpart. Inconsistently reported was lower pain scores and better cosmetic satisfaction seen with LSS IHR. Outcomes such as complication, duration of stay, and recurrence were found to be comparable. The development and use of robotic-assistance in LSS may bypass some of the challenges, though the higher cost and need for special training are likely to be a concern. The application of LSS in IHR by experienced laparoscopic surgeons is both feasible and safe.

Keywords: Single-site; inguinal; hernia

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Introduction

The application of Minimally Invasive Surgery (MIS) technique to inguinal hernia repair (IHR) started as early as 1982 by Ger (1), with a series of twelve patients having concomitant inguinal hernia repaired laparoscopically by closure of the neck of the hernia sac with stainless steel clips. Subsequent developments of MIS technique for IHR came in the form of the intraperitoneal onlay mesh (IPOM) proposed by Toy and Smoot (2) that is currently infrequently employed; the current standard laparoscopic IHR techniques are: the trans-abdominal pre-peritoneal (TAPP) technique reported by Arregui (3) in 1992, and the totally extra-peritoneal (TEP) Technique described by Dulucq (4) in 1992. The TAPP and TEP techniques allows for the inspection of the bilateral myopectineal orifices and their subsequent repair, while permitting circumvention of

distorted tissue planes in cases of recurrence from a previous anterior repair. In view of these benefits, The current guidelines on IHR by the European Hernia Society (5) and by the International Endo-Hernia Society (6) recommends both techniques as surgical options for cases with bilateral inguinal hernias or of recurrent inguinal hernias from previous anterior repair.

The MIS technique is undoubtedly associated with significant inherent benefits, such as: less post-operative pain, shorter hospital stays, faster recovery, faster return to normal daily activity, and better cosmetic appearance. In the quest to maximize the benefits of MIS, the concept of “Reduced Port” was initiated in 1992 with the report of Pelosi and Pelosi 3rd (7) on their series of 25 cases of laparoscopic appendectomy performed through a single umbilical puncture. MIS technique has developed and evolved since its inception in 1983 by Semm (8) with the

performance of the first laparoscopic appendectomy and subsequently its application to series of cholecystectomies reported Muhe (9) in 1990.

We searched for and reviewed available literature on the application of Laparoscopic single-site surgery (LSS) technique to laparoscopic inguinal hernia repair (LIHR): to detail challenges and limitations of the technique, to summarize maneuvers and strategies to facilitate transitioning to the technique, to review the outcome of LSS-IHR against conventional LIHR, and to view development trends of the LSS technique.

Methodology

We performed search for articles in the PubMed database, employing varying combination the following keywords: “single-access”, “single-incision”, “single-port”, “single-site”, “inguinal hernia”, and “hernia repair”. The output was limited to articles in English language, involving human studies, and adult subjects. Duplicate articles based on the title and authors were eliminated. The remaining articles were scrutinized for relevancy based on their titles and abstracts. The reference lists of relevant articles were subsequently examined to pinpoint additional relevant studies.

Challenges and limitations of LSS

The core concept of LSS is performance of MIS procedures through a single entry-site, with prospect towards improved benefits over that associated with conventional MIS technique. Limitation to a single entry-site through which to perform complex procedures brings about a number of apparent challenges and limitations: small finite area of access, close proximity of instruments and scope, limited number of simultaneous operating instruments, parallel alignment of instruments, limitation of range of motion, and loss of triangulation.

Access and maintenance of the working space for LSS may be realized through several methods: single-incision with multiple fascial punctures, use of an improvised access device, or use of a commercial multi-ported access device. Several variables have to be considered in the choice of access methods, includes: availability, cost, durability, handling characteristics, ease of use, reusability, etc. The single-incision with multiple fascial puncture (SIMP) method is unlikely to entail additional cost, as standard MIS access cannulas and instruments are used; however, it

concentrates tissue trauma to a small area, and limits the instrument performance through fixed puncture points, and the standard cannulas are not designed to function in close proximity to each other, their protruding parts will limit movement. An improvised access device is bound to cost between the SIMP method and that of a commercial multi-port access device, the necessity of setting up this contraption during each operation will likely increase the operative time (10) and raise concerns of reliably maintaining work space pressures. The use of a commercial multiport access device will likely be the costliest of the options, though a reusable access device may spread the acquisition cost with each reuse among several patients. Some other advantages of commercial access devices: they are designed to minimize trauma to the access site, allow some degree of “play” within the access site, reliably maintain work space pressures, may allow use of specialized bent instruments, or flexibility to allow some degree of freedom of movement for the instruments.

The small size of the access site results to restriction of the number of instruments that may be used simultaneously, as well as positions the instruments and scope in close proximity promoting clashing and significant limitation of their freedom of movement (11,12). Adaptation of certain strategies such as using a single instrument at a time, using uniquely designed instruments (articulating or bent), employing varying lengths of instruments, use of low-profile cannulas, using small diameter scopes, or adapting certain maneuvers (10) such as keeping instrument for tract static and alternating the status of dynamic and static instruments to lessen clashing, or crossing of instruments. LSS also tends to align the instruments and scope along their long axis with resultant loss of triangulation and degradation of spatial perception. The use of specialized articulating or bent instruments may minimize clashing and improve triangulation; their availability and acquisition cost are of concern, as well as trepidation for their intuitiveness of use compared to conventional straight instruments. The use of small diameter, angled laparoscope or steerable flexible scope is particularly beneficial, they allow improvement of spatial perception and allow means position the laparoscope clear of the instruments’ plane of movement (11).

The study on the mechanics of LSS by Kawamura and Ishii (13) revealed that instruments had a tendency to arrange into either of two configurations during the performance of LSS procedures: the “cross configuration” with an instrument passing between the other two, or the “rotation configuration” with the three instruments

rotating in a clockwise or counter-clockwise direction within the access-site. It was also noted that the “rotation configuration” had a larger motion area than the “cross configuration”, implying that a greater degree of freedom of movement can be achieved with said configuration. During LSS procedures, close coordination between the surgeon and the camera operator is essential to minimize clashing of instruments and the laparoscope (11).

Outcome of LSS application in IHR

From the literature search, five relevant meta-analyses were obtained comparing outcome of IHRs performed using LSS technique versus using conventional laparoscopic technique: three studies (14-16) analyzed and compared various IHR techniques against their conventional laparoscopic IHR counterparts; and the other two studies (17,18) focused on the TEP technique.

Two studies which looked into the outcomes of LSS TEP versus conventional laparoscopic TEP were that by Siddiqui *et al.* (17) in 2014 and by Lo *et al.* (18) published in 2016. The Siddiqui *et al.* study included three cohort studies (19-21) for its quantitative analysis, with a total of 287 patients: 128 in the LSS group against 159 in the conventional laparoscopic group. The more recent study by Lo *et al.* had seven additional studies (22-28) for its quantitative analysis, with a total of 1,109 patients: 595 in the LSS group and 514 in the conventional laparoscopic group. In both studies, they noted comparable results for LSS TEP and conventional laparoscopic TEP with respect to duration of operative time for bilateral repairs, duration of hospital stays, incidence of intra-operative complications, time to return to normal activity, and incidence of recurrence; no significant heterogeneity was noted in the data for each variable between the included studies. The updated 2016 study by Lo *et al.* with additional data from three studies (22,25,28) reversed the initial conclusion of Siddiqui *et al.*, it found that the duration of unilateral hernia repair using the LSS TEP took significantly longer than conventional laparoscopic TEP, with mean difference of 4.11 (95% CI: 0.76, 7.46) $P=0.02$. The additional data to Lo *et al.* analysis allowed conclusion that there was no significant difference between the techniques with respect to incidence of conversion, incidence of post-operative complication, and degree of post-operative pain; the pain data however, showed significantly wide variation among the studies (21,23,28,29) with heterogeneity $\tau^2=0.19$, $\chi^2=24.23$, $df=3$ ($P<0.0001$). Both studies looked into cosmetic outcome,

but were unable to draw specific conclusion due to the wide variation of how this was recorded and reported.

The study by Lai *et al.* (15) in 2014, analyzed various IHR techniques performed using the LSS technique versus those performed using the conventional laparoscopic technique, with subgroup analyses of each IHR technique. It included 8 clinical trials [2 on percutaneous extra-peritoneal closure (PEC) (30,31), 1 on TAPP (32), and 5 on TEP (19-22,33)] for the quantitative analysis, with a total of 926 patients. It reported that LSS versus conventional laparoscopic technique in both the overall and the subgroup analysis had similar outcomes with respect to length of operative time for bilateral repairs, duration of hospital stays, incidence of perioperative complications, need for conversion, and incidence of recurrence. They reported that operative time was significantly longer for unilateral repairs in both the overall and the TEP subgroup; with standardized mean difference of 0.23 (0.09, 0.38) $P<0.01$ and 0.39 (0.21, 0.57) $P<0.01$, respectively. In 2017, Luo *et al.* (16) updated the report by incorporating 9 new studies: 1 for TAPP (34), and 8 for TEP (23-26,28,33,35,36), increasing the total number of patients to 1,737. The updated meta-analysis reported that the duration of hospital stays, incidence of complications, rate of conversion, and incidence of recurrence were comparable between LSS and conventional laparoscopic technique in both the overall and the subgroup analyses. The additional data supported the previous finding of longer operative time for unilateral repairs, however it found that it took significantly longer to perform bilateral repairs using the LSS technique for both overall and in the TEP subgroup. Luo *et al.* found that post-operative pain was comparable for both groups during the first 24 hours, but significantly favored the LSS group after 7 days with SMD -0.27 (-0.46 , -0.08), $P=0.021$. With regards to these two studies, we have subjectively decided to exclude the subgroup analysis involving LSS PEC *vs.* conventional PEC, and LSS TAPP *vs.* conventional TEP; the thought behind such was (I) PEC is solely performed in the pediatric age group and is technically dissimilar (minimal pre-peritoneal dissection, no implantation of mesh, does not require fixation, and does not require peritoneal flap closure) to either TAPP or TEP techniques, and (II) TAPP *vs.* TEP, is likewise comparing technical different procedures particularly to the pre-peritoneal dissection and need for the flap closure. Our opinion is that these differences may likely influence the outcome of certain variables (i.e., operative time). Another concern to be noted concerns that of the Luo *et al.* study, we noted

that they included both the interim (28) and final (36) study by Wijerathne *et al.*; however, we did not perform any quantitative analysis excluding the interim data to determine eventual influence on the outcomes.

Sajid *et al.* (14) compared outcomes of LSS versus conventional laparoscopic technique of various IHRs with overall analysis and randomized controlled trials-only subgroup analysis. The study included 15 studies [2 involving PEC (30,31), 1 on TAPP (32), 11 on TEP (19-28,35), and 1 with combination of both TAPP and TEP (37)]. In the overall analysis, there was no significant difference between LSS and conventional laparoscopic technique with respect to length of operative time for unilateral and for bilateral repairs, duration of hospital stay, incidence of complications, incidence of recurrence, and pain scores at 24 hours and 1 week; their analysis noted significantly shorter recovery time for LSS IHRs [SMD -0.35 (-0.57, -0.14), $P=0.001$]. In the RCTs-only subgroup analysis, pain score at 24 hours was significantly better among the LSS group [SMD -0.43 (-0.71, -0.16), $P=0.002$]; no significant difference was noted with respect to length of operative time, duration of hospital stay, incidence of complications, and pain score at 1 week.

We were found recent studies: an RCT by Choi *et al.* (38) published in 2016 on TEP, and that by Ece *et al.* (39) a cohort study of TAPP published 2017. The RCT by Choi *et al.* involved a total of 99 patients (50 in LESS and 49 in conventional group), both groups with comparable demographics and hernia characteristics. Pain score at POD 7 was the only variable with significant advantage for the LSS group ($P=0.017$); pain scores of the conventional group improved and was comparable to that in LSS group by week 4. Incidence of intra- and post-operative complications was similar for both groups. There were no conversions nor recurrences reported in the study. This study measured patient-rated cosmetic satisfaction, similar to that by Fuentes *et al.* (40); the patient-rated satisfaction of cosmetic result was similar for both groups. The Ece *et al.* study allowed the patient to select their preferred surgical technique (LSS versus conventional TAPP), they noted the mean age of patients in the LSS group was significantly lower (50.7 ± 10.1 vs. 57.1 ± 12.4 years, $P=0.001$). This finding was consistent to the survey by Rao *et al.* (41) looking into patient preference of particular surgical technique, which revealed that young patients were more inclined to choose LSS technique than those over the age of 60. Long-term post-operative follow-up by Ece *et al.* revealed higher incidence of port-site hernia (PSH) (3 vs. 0, $P=0.001$) among those who underwent LSS TAPP. Agrawal *et al.* (11)

suggested that TEP may not predispose to development of port-site hernias in view of the intact posterior rectus sheath beneath the port-site; this is not so in TAPP, as the entire abdominal wall is penetrated to gain access into the abdominal cavity. Notable also is that LSS technique tends to require a slightly longer single incision to accommodate the access port which may be another factor for higher incidence of PSH.

Robot-assisted LSS IHR

LSS technique with its single incision has likely advantage for better cosmetic outcome against conventional MIS technique, however is associated with significant challenges that further restricts the already limited 5-degree of freedom in conventional MIS, contributing to a steep learning curve for LSS adaptation. The use of robotic-assistance provides the surgeon with added dexterity, with a wrist-like articulation of the instrument increasing it to 7-degree of freedom. Corcione *et al.* (42) reporting on their initial experience with robotic-assisted laparoscopic surgery, mentioned advantage of three-dimensional vision in the robotic system; and cited limitations of number of usable instruments was dependent to the number of robotic arms, and need for larger incision due to large diameter of the robotic instruments (8 mm). Initial application of robotic-assistance in LSS IHR was done by Tran (43) in his 2011 study of 17 cases of robotic LSS TEP compared to conventional LSS TEP, the camera-assistant was replaced by a robotic camera controller; he noted comparable operative time between robotic LSS TEP and conventional LSS TEP, and also noted less time was engaged in the cleaning of the scope (1.5 vs. 8.5 min). Cestari *et al.* (44) reported the first use of Da Vinci Single-Site Surgical Platform a specifically designed robotic system for LSS; performed on three patients with a reported mean operative time of 98.6 min (range of 55–155 min), without complication or conversion. They equally cited the stable 3D vision, and restoration of adequate triangulation as factors contributing to feasibility and efficacy robotic-assisted LSS TEP.

Summary

The current literature points out presence of significant challenges and limitations to adaptation of the LSS technique. These obstacles can be overcome by adapting certain maneuvers and strategies that minimize the instrument clashing and improve freedom of movement.

The application of LSS in IHR is feasible and safe in the hands of experienced minimally invasive surgeons. The lack of experience with the LSS technique may initially result in longer operative time, but is likely to improve over time. Surgeons experienced with LIHR are able to perform LSS IHR and achieve comparable outcome to that performed using the conventional laparoscopic technique. Current evidence indicate LSS application tend to increase the operative time, currently with inconsistent outcome regarding pain scores, and to date, does not confer advantage with respect to hospital stay, complications, return to activity, conversion, and recurrence. Younger patients tend to be more concerned about cosmetic outcome and are more likely to prefer LSS technique for its potential for superior cosmesis. Advances in robotics may culminate in a platform that will allow consistent, reliable and safe performance of LSS.

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