A high fidelity model for single-incision laparoscopic cholecystectomy

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Abstract

Single-incision laparoscopic surgery (SILS) is a safe approach for cholecystectomy, with the potential to minimise the iatrogenic trauma sustained from the operation. However, a number of reports show SILS to be technically challenging and as such there is expected to be a significant learning curve for expert surgeons adopting the new technique, as well as for junior surgical trainees. There are inherent risks to patient safety associated with practicing and developing new skills in a real-life theatre environment. However, thus far, there have been no realistic SILS training models available. We tested the feasibility of conducting SILS cholecystectomies on a cadaveric porcine model with standard operating equipment, which may provide a platform to facilitate safe training and assessment protocols. In this paper we provide an account of the training model technique, and review the literature surrounding SILS training and performance evaluation.

1. Introduction

Currently, Laparoscopic surgery (LAP) is the gold standard for cholecystectomy. However, it has been suggested that recent advancements such as Single Incisional laparoscopic Surgery (SILS) have to potential to replace LAP in years to come, for procedures such as cholecystectomy, as more evidence is assimilated.1

For general surgical procedures, the LAP approach has many benefits compared to open surgery, including less post-operative pain, reduced blood loss, and earlier return to normal function.2–5 Improvements in these, and other parameters have resulted in improved quality of life indicators.6 For many patients, perhaps the most important long-term benefit has been the improved cosmetic result.7 A single-incision approach may provide a further step in reducing the iatrogenic trauma sustained during surgery. In this paper, we review the current techniques for training and assessing SILS technique, and describe a new, high fidelity model for Single-incision Laparoscopic Cholecystectomy (SILC).

2. The SILS technique

SILS is an innovative technique whereby the surgical instruments and camera are inserted through a single specialised port (or three modified standard ports) in the natural embryological orifice, the umbilicus. This scar is usually well concealed in the umbilical depression. SILS provides access to all four quadrants of the abdomen, allowing versatility in the range of surgeries that can be performed. Initially SILS was used for cholecystectomy8 and appendicectomy,9 but in recent times the technique has been used for more complex procedures including gastric banding,10 right hemicolecotomy,11 sleeve gastrectomy12 and adrenalectomy,13 representing the rising interest in this field.

There are a number of practical differences between SILS and multiport laparoscopic surgery. Restricting access to a single port augments the technical difficulty of the operative platform. Amongst the many physical challenges, the surgeon loses the advantage of instrument triangulation, and must manage an apparent mirror image in the display created by crossing over and rotating instruments. Furthermore, a so-called dynamic camera view is the result of constant adjustments to avoid hand clashes whilst maintaining an optimum view, alongside potential obscuration of the light source from parallel instruments. To achieve a satisfactory surgery outcome, it is vital that the surgeon and assistant perform with effective teamwork and communication in
order to manage the shared port, continual camera adjustments and a busy extracorporeal environment.14

The procedural steps taken in SILS, on the whole, mimic those of conventional laparoscopy. However, with gaining experience and new equipment, modifications are starting to be made for several procedures to manage the limitations that a single port creates. In SILC, for example, a common modification is the introduction of trans-abdominal sutures, allowing manipulation of the gallbladder from outside of the body. This provides safety through effective counter-traction, and facilitates completion of the case using only a single operating instrument and camera through the port. Though this will not particularly improve patient outcome, in theory it will reduce the duration of the procedure and extend the access of SILC (and its potential benefits) to a wider community.

3. Evidence for SILC

The recent literature has shown SILC to be a safe alternative to traditional laparoscopic cholecystectomy.15-17 In addition to the established benefit of improved cosmesis,18 a single-incision approach as opposed to a traditional multiport approach suggests a reduction in haematomas, wound infections and port-site hernias.1

However, large randomised controlled trials comparing SILC and multiport cholecystectomy are yet to emerge in the scientific literature. The main body of evidence consists of case reports and small case series, which show encouraging initial results. It has been shown that SILC is equivalent to multiport laparoscopic cholecystectomy (LC) for a number of parameters including length of hospital stay, blood loss and complications.19-21 Furthermore a recent prospective study has suggested that post-operative pain22 may be reduced when comparing SILC to LC, although no significant difference in pain scores have been found in other studies.23 Some studies have also highlighted difficulties of the SILC technique, including the novel technical skills that need to be learnt,14,24 and the associated increase in operating time.19

As the evidence base increases, it is anticipated that the benefits of SILS will become more widely established. This may result in an increased number of SILS operations carried out in the future, potentially replacing the multiport approach for many procedures.1

4. SILS training

Given the technical differences of SILC, there is expected to be a significant learning curve for all surgeons adopting the new technique, as well for junior surgical trainees.25 There are inherent risks to patient safety associated with practicing and developing new skills in a real-life theatre environment.26 These risks may be confounded by the reduced training opportunities available in theatre, under the new European Working Time Directive.27 It is therefore preferable that the learning curve for SILS procedures be somewhat restricted to a simulated training environment, whereby surgical trainees and laparoscopic surgical experts alike learn the new technical skills in the safety of the skills laboratory, before working in the operating room.26

Currently there are no SILS-specific technical skills training programmes available.23,30 Furthermore, given the perceived difficulties of the SILS technique and its relative infancy, it is predominantly expert laparoscopic surgeons who are performing the majority of SILS cases in theatre. The result is a reduction in the SILS learning opportunities for trainee surgeons. Moreover, it must be remembered that even an expert laparoscopic surgeon would still be considered a novice SILS surgeon - given the technical differences outlined above. Thus, there is an increased risk to patient safety during the multiport-to-SILS transition period, as these surgeons are not technically proficient in the procedure before entering the operating room. This emphasises the importance of training surgeons in a simulated environment before performing SILS procedures in theatre.

5. Different training models for SILS

There are several laboratory methods available for surgical technical skills training. These centre around the use of surgical simulation, which can take many forms.

One option is rehearsing the basic technical skills tasks, such as object transfer and precision cutting, on inanimate models. These tasks form the basis of the Fundamentals of Laparoscopic Surgery (FLS) training curriculum. As such, FLS has been successful in enhancing trainees’ technical skills in LAP, ensuring competency is attained before operating on live patients.

Recent work by Lewis et al.23 has shown that an FLS curriculum (with a modified single-port FLS box trainer) may be an effective training platform for trainees learning SILS technical skills. This could prove to be an effective starting point for the establishment of a procedure-specific SILC training programme. However, the main limitation with this model is that the FLS-based tasks are not wholly representative of the different technical skills used in SILS procedures. Thus, it is suggested that a new, specific technical skills training programme be developed for surgeons learning and performing SILS.23 A formal training curriculum with proficiency-based performance parameters specific for SILS could effectively accelerate the learning curve and improve surgeons’ technical competencies, with a similarly positive impact on patient safety in the operating room.14,30,32

When developing a SILS-specific training curriculum, the use of realistic surgical simulation (as opposed to basic skills tasks) should be advocated. This may provide a valid and feasible method of training technical skills, with potentially good transferability from the laboratory to the operating room. There are many forms of simulation currently available for use in surgical training. Virtual Reality (VR) simulation allows trainees to repeatedly practice specific tasks or work through entire simulated procedures, in a safe and relatively realistic manner. Constructive feedback, based on objective performance metrics calculated from the VR simulator, also benefit the trainee in terms of monitoring progression independently and improving technical competency. However, limitations of VR training include a lack of haptic feedback (on all but the most sophisticated VR simulators) and high initial costs of purchasing the simulators, which can limit the feasibility of their widespread use in surgical training. Furthermore, there are currently very few SILS-specific VR simulators which can effectively simulate the ergonomics of a SILS operating room, such as alternative arrangement and design of SILS instruments.

Another useful form of surgical simulation involves the use of cadaveric specimens.23,24 Given the ethical issues surrounding the use of live anaesthetised pigs for training in the United Kingdom, cadaveric simulation is seen as a valuable tool for technical skills training.3 Both human and animal cadavers can be used to safely rehearse specific surgical procedures. For example, porcine liver and gallbladder specimens have been shown to be a practical and high fidelity model for LC training.3 Cadaveric simulation has the benefit of true haptic feedback from the interaction of surgical instruments with real organs and structures, and a realistic surgical set-up. The limitation in realism using cadaveric specimens comes from the lack of respiratory movements, pneumoperitoneum, human anatomy and response to trauma including bleeding and inflammation. Despite these limitations, cadaveric specimen-based simulation provides an invaluable adjunct to surgical technical skills training, which could be effectively implemented into a SILS-specific training programme.
To assess the feasibility of cadaveric porcine SILC, several cases were performed, and we provide a report of the final technique.

6. Cadaveric porcine SILS cholecystectomy

A cadaveric porcine liver with gallbladder in situ was placed inside a video box trainer rotated 180° supero-inferiorly as prescribed by standardised training courses16 (Fig. 1). Before the box is closed, a diathermy patient return pad (dispersive electrode) was placed underneath the liver with the cable passing outside of the box and into the diathermy machine. A SILS port (Covidien, Inc., Norwalk, Connecticut) was used in the umbilical position (although two small standard ports can be used) through a 2 cm incision in the synthetic, neoprene abdominal wall. A thirty-degree 5 mm laparoscope was used, connected to a light source, with a monitor at eye level.

Standard laparoscopic instruments were used, including straight needle holders, endoscopic grasping forceps, straight electrocautery hook, mini-retract, curved scissors and clip applicator (Fig. 2). Both the forceps and scissors had a roticulating function, which was occasionally used.

The so-called ‘puppeteering’ technique for SILC was used by two SILS experts (PP, SP), described by Chow et al.35 and above (Fig. 3). Exceptions to the technique due to the limitations of the model were few. Firstly, due to the rotated position of the specimen in the box trainer, only one counter traction suture was needed. This suture was placed through the most superior midline position on the synthetic abdominal wall, through Hartmann’s pouch, and out through the most lateral position on the ‘patient’s’ left side, before being secured by clips. Secondly, manipulation of the free specimen using the suture can result in it being lifted of the bottom of the box, and so sutures were used to fasten the specimen to material on the base of the box. Also, the angle of approach differed to that of a human case due to the depth of the box trainer (and lack of other abdominal viscera), and impenetrable plastic perimeter forced surgeons to place the exit point of the suture more medially than usual. Raising the specimen on a small platform inside of the box trainer may improve the operating angles.

Two expert SILS surgeons completed two SILCs each and both reported that they found the model very realistic, apart from the aforementioned differences in anatomy. Though more expert opinions are necessary to show face validity of the model, initial reports have been very positive. Further, for the model to be used as an assessment tool, construct validity must be shown by evaluating the strength of the model to differentiate between surgeons of varying experience.

Using this model, trainees would be able to rehearse and develop a realistic appreciation of specific technical skills used in SILC. This would be enhanced by using the SILC-specific instruments in a SILC-specific simulation model. This set-up would facilitate concurrent training of technical skills with teamwork and communication skills between the surgeon and assistant (for efficient coordination of camera and instruments).36

7. Measuring technical performance

In order for the proposed SILC model to provide most value, an objective measurement of trainees’ technical skills is required. The Objective Structured Assessment of Technical Skill (OSATS) tool has demonstrated high reliability and construct validity,37 suggesting

Fig. 1. Cadaveric porcine SILS cholecystectomy model set-up.

Fig. 2. Laparoscopic view of cadaveric porcine SILS cholecystectomy.
that it could be an effective method of measurement. Procedure-specific rating scales (PSRS) have been shown to be able to distinguish between surgeons of variable surgical experience and a reliable tool for assessing performance of multiport laparoscopic cholecystectomy (LC). However, given the significant differences in techniques used between SILC and LC (outlined above), a new PSRS would be needed to accurately assess SILC performance.

As an alternative, or an adjunct, a motion analysis tool such as the Imperial College Surgical Assessment Device (ICSAD) may be techniques used between SILC and LC (outlined above), a new PSRS would be needed to accurately assess SILC performance.

8. Conclusion

The potential advantages of the SILS approach suggest it will soon become a key component of a surgeon’s armory. Additional pressure for surgeons to adopt this approach may come from increased patient demand following publicity from so-called ‘scarless’ surgery. As such, there must be an emphasis on providing adequate training for surgeons. The learning curve for SILS procedures is best restricted to the simulation environment, with surgeons preferably achieving proficiency before entering the operating room. This is important, not only for junior trainees learning the technical skills for the first time, but also for expert laparoscopic surgeons, who have to relearn how to perform common procedures with the SILS approach.

Given the procedural and technical differences of SILS, it is necessary to develop high fidelity models to be implemented in a valid, SILS-specific training curriculum. In combination with a PSRS, the SILC simulation model described in this paper may form an ideal platform for safe, cost effective adoption of a single-incision laparoscopic approach.

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References