JOURNAL OF Surgical Simulation

Journal of Surgical Simulation (2016) **3,** 43–48
DOI: https://doi.org/10.1102/2051-7726.2016.0007

ORIGINAL ARTICLE

Single-incision laparoscopic surgery operative performance by experienced surgeons: a randomized trial comparing articulating versus standard straight instruments

Georgios Pafitanis,[a,*] Damjan Veljanoski[b] and Bijendra Patel[c]

[a]*The Blizard Institute, Barts and The London School of Medicine and Dentistry, Queen Mary University of London E1 2AT, UK;* [b]*Barts and The London School of Medicine and Dentistry, London E1 2AT, UK;* [c]*Barts Cancer Institute, Queen Mary University of London, London EC1M 6BQ, UK*

**Corresponding author at: The Blizard Institute, Barts and The London School of Medicine and Dentistry, Queen Mary University of London, 4 Newark Street, London E1 2AT, UK. Email: g.pafitanis@qmul.ac.uk*

Date accepted for publication: 17 November 2016

Abstract

Background: Single-incision laparoscopic surgery (SILS) is the latest innovation in minimally invasive surgery. Advantages of SILS over conventional laparoscopic surgery include faster patient recovery, reduced peri-operative pain and further improvement in cosmesis. The challenges of SILS are attributed to the coaxial arrangement of the instruments, which requires certain technical skills and manual dexterity different to that of conventional laparoscopic surgery. Technical difficulties due to the loss of triangulation require further investigation to allow this novel technique to be refined. The aim of our study is to compare the operative performance by experienced surgeons using standard straight versus articulating instruments on a simulated SILS box trainer.

Methods: Consultant laparoscopic surgeons performed two basic laparoscopic tasks, according to the Fundamentals of Laparoscopic Surgery (FLS) course: peg transfer and pattern cutting, using two types of instruments in a randomized order. The influence of the instrumentation on the surgeon's performance was measured by calculating time taken, errors and instrument clashes. These parameters reflected the effectiveness of the instrument on the surgeon's laparoscopic skills (hand-eye coordination, depth perception, dexterity and complementary bimanual skills). The difference in performance reflects the effect of instrumentation on the surgeon's laparoscopic skill. Statistical analysis was carried out using an independent-sample t-test. Two parameters were generated in order to avoid multiple comparisons: overall precision (OP) and overall performance time (OPT). All results were presented the as mean ± standard error of the mean with the *P* value.

Results: Ten consultant laparoscopic surgeons from four different specialties were recruited. The average experience in conventional laparoscopic surgery was 11.8 ± 5.2 years. The OPT with articulating instruments was 282 ± 11 s and 275 ± 12 s with standard straight instruments. The difference in operating time between the groups was not statistically significant ($P = 0.856$). The OP with the articulating instruments was 4.2 ± 0.4 and 9.8 ± 0.7 with the standard straight instruments. The articulating instruments demonstrated a statistically significant decrease in both errors and instrument clashes ($P = 0.03$).

Conclusions: The use of an articulating instrument proved to be superior to standard straight instruments in SILS. The increased triangulation improved precision and reduced errors. Novel articulating instruments demonstrate different characteristics, the benefits of which should be established before their application in clinical SILS practice.

Keywords: *SILS; simulation; articulating; instruments; performance*

Introduction

Single-incision laparoscopic surgery (SILS) was developed as an alternative to conventional multi-port laparoscopic surgery. Randomized controlled trials have demonstrated that SILS is as safe as conventional laparoscopic surgery.[1,2] The proposed benefits of SILS include less post-operative pain, improved cosmesis and faster recovery.[3]

The skill set required for SILS is different from conventional laparoscopic surgery and the learning curve is longer.[4] A laparoscopic task performed by a conventional laparoscopic

surgeon without adequate exposure to SILS is characterized by decreased performance and increased workload.[5] The technical challenges of SILS are due to the coaxial arrangement of the instruments through the single incision. The resultant loss of triangulation and depth perception can lead to instrument collisions.[6]

The use of standard straight instruments is the accepted norm in conventional multi-port laparoscopic surgery; however, this approach may not be optimal in SILS. Recent years have seen the development of articulating and pre-bent instruments. Several attempts have been made to demonstrate the benefit of curved, articulating or even intra-corporeal flexible instruments to address these challenges.[7,8] The use of different articulating instruments allows increased triangulation, preventing instrument collisions to enable efficient operating flow. To our knowledge, currently there are a limited number of trials investigating the effect of instruments in laparoscopic simulation.[9] The aim of this study was to compare the performance of experienced laparoscopic surgeons in validated laparoscopic simulation tasks using both standard straight and articulating instruments.

Materials and methods

Participants and study design

All participants fulfilled the study inclusion criteria: (1) having performed more than 100 conventional laparoscopic operations, (2) being non-proficient in SILS, defined as having performed less than 10 operations, and (3) having achieved the Fundamentals of Laparoscopic Surgery (FLS) expert-derived performance level[10] on a pre-test undertaken during the recruitment process. All surgeons answered a questionnaire detailing their previous laparoscopic exposure.

All participants performed the same two basic laparoscopic tasks: peg transfer and pattern cutting (Figs 1 and 2) from the FLS course using both types of instruments. The order in which each participant used the standard straight or articulating instruments was randomized. Performance was measured by the time taken to complete the task, the number of instrument clashes, and the number of errors (as defined in the FLS Technical Skills Proficiency-Based Training Curriculum[10]). An error was considered a cut outside the pre-marked area, a drop of the peg, malposition of the peg, as per the FLS manual.[10]

Simulation setup and equipment

The tasks were performed using a box trainer (Fig. 3) modified with a Covidien multiple access SILS port into a single-port laparoscopic simulation suite. A pilot study demonstrated no statistical significance between five different ports during performance in basic laparoscopic tasks, although differences in ergonomics exist.[11] When using the standard straight instruments, the participants used the instruments in both hands. When the articulating instruments were used, participants held a standard straight instrument in their non-dominant hand and an articulating instrument in their dominant hand. The Roticulator articulating instrument was used, which allows 0–80° of articulation (see Table 2). An independent observer documented the operating time as a measure of efficiency and the number of clashes and errors as a measure of accuracy.

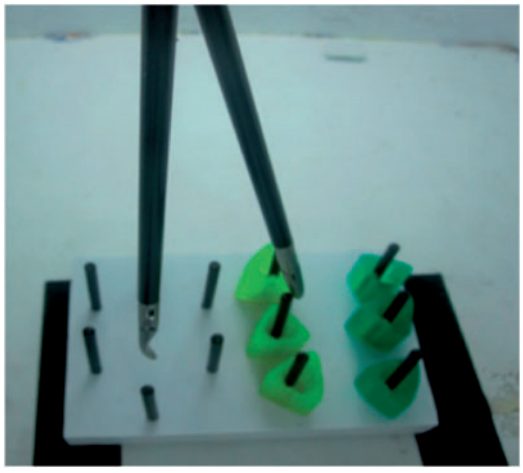

Figure 1 Peg transfer task

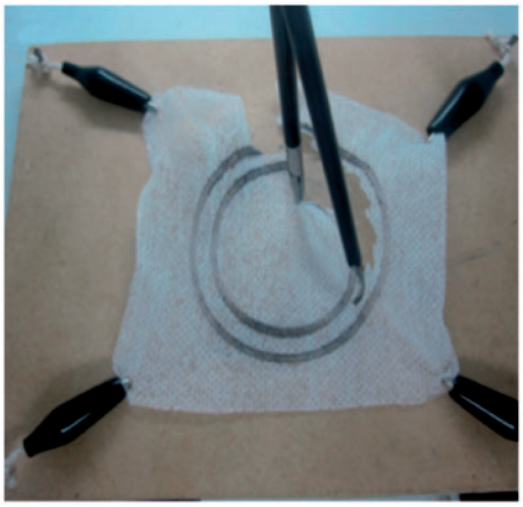

Figure 2 Pattern cutting task

Statistical analysis

Data were analysed using the Statistical Package for the Social Sciences version 14.0. Parametric data analysis was carried out using one-way analysis of variance. The

comparison was based on a multivariate analysis and the independent-sample t-test was used. Two parameters were generated in order to avoid multiple comparisons: overall performance time (OPT; the sum of performance time for both tasks) as a measure of operating efficiency and overall precision (OP; the sum of clashes and errors for both tasks) as a measure of accuracy:

$$\text{Overall performance time (OPT)} = \text{time}_{\text{peg}} + \text{time}_{\text{cutting}}$$

$$\text{Overall precision (OP)} = (\text{errors}_{\text{peg}} + \text{clashes}_{\text{peg}}) + (\text{errors}_{\text{cutting}} + \text{clashes}_{\text{cutting}})$$

Figure 3 Laparoscopic box trainer

The results are presented as the mean ± standard error of the mean with $P < 0.05$ considered statistically significant.

Results

Ten consultant laparoscopic surgeons (four upper gastrointestinal surgeons, two colorectal surgeons, two hepatobiliary surgeons and two gynaecologists) fulfilled the inclusion criteria. One was left-handed and nine were right-handed. They had all performed more than 100 laparoscopic procedures within the year of this study. Their mean experience with conventional laparoscopic surgery was 11.8 ± 5.2 years and the average number of SILS procedures previously performed was 6 ± 3.

The OPT and OP of the simulation tasks with standard straight versus articulating instruments are displayed in Table 1. The OPT with articulating instruments was 282 ± 11 s and 275 ± 12 s with standard straight instruments. The OPT did not significantly differ between the two types of instrumentation ($P = 0.856$). The OP with the articulating instruments was 4.2 ± 0.4 and 9.8 ± 0.7 with the standard straight instruments (Fig. 4). This difference was statistically significant ($P = 0.03$). There were fewer errors and clashes with the articulating instruments compared with the standard straight instruments.

Discussion

This study sought to compare the performance of experienced surgeons using articulating versus standard straight instruments in simulated SILS. Our results demonstrate greater operating accuracy, with fewer errors and instrument clashes in the tasks performed using articulating instruments compared with the tasks performed using standard straight instruments. The OP score was reduced by over 50% when the participants used articulating instruments compared with standard straight instruments. This difference was statistically significant ($P < 0.05$). The use of articulating instruments demonstrated a greater degree

Table 1 Operating performance (OP and OPT) using articulating and standard straight instruments

Parameter	Instruments	Mean ± SD	Standard Error Mean	Independent-sample t-test: *P* value
OPT (s)	Articulating Standard straight	282.36 ± 52.96 275.16 ± 61.16	10.59 12.23	0.856
OP (errors and clashes)	Articulating Standard straight	4.2 ± 2.17 9.8 ± 3.45	0.436 0.690	0.03*

*$P < 0.05$ was considered as statistically significant.

of precision by way of increased triangulation resulting in fewer instrument clashes and errors. These findings are consistent with previous work examining the performance of experienced surgeons using articulating instruments.[9]

The time taken to perform the basic peg transfer and pattern cutting tasks was similar using each of the instrument types. We anticipated that when consultants used the articulating instruments they would take longer to complete the tasks than when using standard straight instruments. In our study, the difference between the OPT for the two types of instrument was not statistically significant. Previous research has found that articulating instruments are associated with longer operating time and more workload compared with conventional instruments.[12]

Peg transfer assesses basic laparoscopic skills such as depth perception, hand-eye coordination, dexterity, and transferring and positioning of the needle. The pattern cut task assesses the skill of traction, bimanual skills and the need to use the non-dominant hand to help the dominant hand for precision cutting. The FLS course was developed by the Society of American Gastrointestinal and Endoscopic Surgeons and has been approved by the American College of Surgeons. It has been validated and used extensively in laparoscopic simulation.[10] The effect of increased precision in simulated basic tasks demonstrated in our study could be reflected when performing advanced laparoscopic tasks and may further predict clinical operating performance.

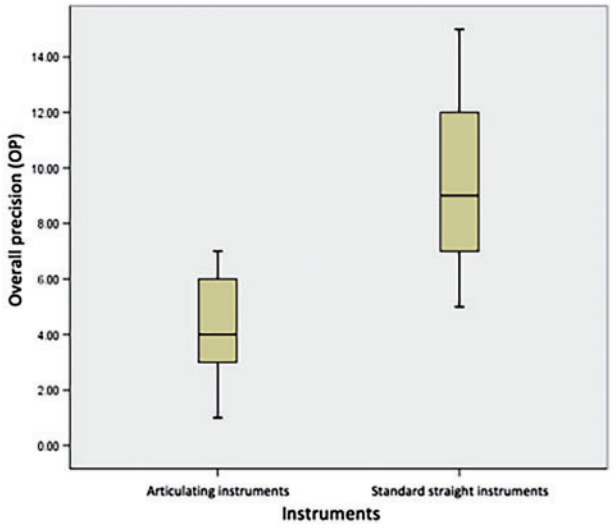

Figure 4 Box-plot diagram showing difference in OP between articulating and standard straight instruments

SILS is a time-consuming and technically challenging procedure, which requires different laparoscopic skills compared with conventional laparoscopic surgery. Current literature demonstrates that it takes longer to complete a procedure with articulating instruments than with conventional standard straight instruments[7]; others have found no statistically significant difference.[9] In our study, there was no statistically significant difference in the OPT of the two types of instruments while performing basic laparoscopic tasks, which potentially reflects no difference in overall operating performance. Even though the difference in OPT was not statistically significant and this study could not identify the magnitude of the effect of articulation on operating time, our results can guide future larger trials to investigate this further. On the other hand, the use of articulating instruments enabled a significant improvement in OP in our study ($P = 0.03$). Articulating instruments sustain the effect of triangulation and minimize errors and instrument clashes.

Table 2 presents the current most commonly used laparoscopic articulating instruments available. The shaft length and diameter along with the degree of articulation are given. Manufacturers have modified these instruments in response to expert feedback based on clinical procedure-specific goals. The BD Babcock and the Flex Lap articulating instruments provide 40° and 70° of articulation, respectively. A number of manufacturers have developed instruments that offer higher degrees of articulation. The Snowden-Pencer instruments offer 90° and the Ethicon ENSEAL G2 instruments provide 110° of articulation. The Intuitool offers 120° of articulation, although this is a

Table 2 Most commonly used laparoscopic articulating instruments

Manufacturer	BD Babcock grasper	Intuitool	Snowden-Pencer	Covidien Roticulator	Ethicon ENSEAL G2	Flex Lap
Shaft length (cm)	45	–	34 or 45	31	35 or 45	40
Shaft diameter (mm)	5	–	5	5	5	5
Degree of articulation (°)	40	120	40 or 90	0 - 80	110	70

non-functioning prototype. In our study, we used the Roticulator articulating instrument, which provides a flexible 0–80° of articulation with an additional financial cost. In our study, the degree of articulation used when operating with the Roticulator was 40°, which reflects the degree of articulation currently available in clinical practice. Our study investigated the Roticulator versus standard straight instruments to demonstrate the effect of articulation rather than proving the differences between all currently available articulating instruments.

A randomized controlled study comparing standard straight and articulating instruments in SILS found that using one standard straight and one articulating instrument improved performance in the peg transfer task.[9] In our study, we used the articulating instrument in the dominant hand of all expert surgeons in order to magnify the effect of triangulation while performing basic laparoscopic tasks. The effect of articulation has multiple factors influencing performance in advanced laparoscopic surgery. One study investigated different articulating instruments in advanced laparoscopic tasks. It demonstrated the superiority of an articulating device over a modified instrument capable of unilateral articulation and rotation in SILS suturing.[13] Another study found that using two instruments with dynamic articulating tips is the least adequate setup compared with other approaches, such as pre-bent instruments, when learning SILS for the first time.[7] Articulating instruments and cross-handed manipulation are associated with a longer procedure time and higher workload compared with conventional laparoscopic instruments and manoeuvres.[12] Single-curved and articulating instruments have been found to be more effective than conventional standard straight and double-curved instruments, and are favourable for novice learners.[8] Our study also supports these findings, however, with the use of a hand motion analyser, this effect could be potentially highlighted by more objective measures.[9]

The use of articulating instruments proved to be superior to standard straight instruments in SILS. The increased triangulation offered by articulation improves operating accuracy and efficiency. There is a need for clinical studies to investigate the effect of novel articulating instruments with different characteristics on the precision and efficiency of experienced laparoscopic surgeons during the early SILS learning curve to ensure safety in clinical practice.

Conflict of interest

None of the authors has any conflict of interest to declare.

References

1. Song T, Kim M-L, Jung YW, Yoon BS, Joo WD, Seong SJ. Laparoendoscopic single-site versus conventional laparoscopic gynecologic surgery: a metaanalysis of randomized controlled trials. Am J Obstet Gynecol 2013; 209: 317.e1-9. https://doi.org/10.1016/j.ajog.2013.07.004.
2. Lai ECH, Yang GPC, Tang CN, Yih PCL, Chan OCY, Li MKW. Prospective randomized comparative study of single incision laparoscopic cholecystectomy versus conventional four-port laparoscopic cholecystectomy. Am J Surg 2011; 202: 254–258. https://doi.org/10.1016/j.amjsurg.2010.12.009.
3. Cheng Y, Jiang Z-S, Xu X-P, Zhang Z, Xu T-C, Zhou C-J, et al. Laparoendoscopic single-site cholecystectomy vs three-port laparoscopic cholecystectomy: a large-scale retrospective study. World J Gastroenterol 2013; 19: 4209–4213. https://doi.org/10.3748/wjg.v19.i26.4209.
4. Park Y, Yong YG, Yun SH, Jung KU, Huh JW, Cho YB, et al. Learning curves for single incision and conventional laparoscopic right hemicolectomy: a multidimensional analysis. Ann Surg Treat Res 2015; 88: 269–275. https://doi.org/10.4174/astr.2015.88.5.269.
5. Montero PN, Acker CE, Heniford BT, Stefanidis D. Single incision laparoscopic surgery (SILS) is associated with poorer performance and increased surgeon workload compared with standard laparoscopy. Am Surg 2011; 77: 73–77. PMid:21396310.
6. Madhoun N, Keller DS, Haas EM. Review of single incision laparoscopic surgery in colorectal surgery. World J Gastroenterol 2015; 21: 10824–10829. https://doi.org/10.3748/wjg.v21.i38.10824.
7. Sánchez-Margallo FM, Matos-Azevedo AM, Pérez-Duarte FJ, Enciso S, Martín-Portugués ID-G. Performance analysis on physical simulator of four different instrument setups in laparo-endoscopic single-site (LESS) surgery. Surg Endosc 2013; 28: 1479–1488. https://doi.org/10.1007/s00464-013-3337-1.
8. Wang D, Shi L-Q, Wang J-M, Jiang X-H, Ji Z-L. Comparison of different sets of instruments for laparoendoscopic single-site surgery in a surgical simulator with novices. ANZ J Surg 2013; 86: 264–269. https://doi.org/10.1111/ans.12447.
9. Corker HP, Singh P, Sodergren MH, Balaji S, Kwasnicki RM, Darzi AW, et al. A randomized controlled study to establish the effect of articulating instruments on performance in single-incision laparoscopic surgery. J Surg Educ 2015; 72: 1–7. https://doi.org/10.1016/j.jsurg.2014.08.004.
10. Ritter EM, Scott DJ. Design of a proficiency-based skills training curriculum for the fundamentals of laparoscopic surgery. Surg Innov 2007; 14: 107–112. https://doi.org/10.1177/1553350607302329.

11. Pafitanis G, Loizides S, Patel B. The effect of different single ports on performance in single-incision laparoscopic surgery. J Surg Simul 2014; 1: 6–11. https://doi.org/10.1102/2051-7726.2015.0002.
12. Xu AA, Zhu JF, Xie X, Su Y. Mechanical evaluation of articulating instruments and cross-handed manipulation in laparoendoscopic single-site surgery. Surg Innov 2014; 21: 398–402. https://doi.org/10.1177/1553350613509727.
13. Santos BF, Enter D, Soper NJ, Hungness ES. Single-incision laparoscopic surgery (SILS^{TM}) versus standard laparoscopic surgery: a comparison of performance using a surgical simulator. Surg Endosc 2010; 25: 483–490. https://doi.org/10.1007/s00464-010-1197-5.