ORIGINAL ARTICLE

The effect of different single ports on performance in single-incision laparoscopic surgery

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Abstract

Aims: In the rapidly advancing world of laparoendoscopic surgery, surgeons are faced with new devices all of which are aimed towards a single access. Various single-access devices are available on the market. Our study aimed to compare the performance of experienced laparoscopic surgeons on validated laparoscopic tasks using five devices within a simulation setting. **Methods:** Ten experienced consultant laparoscopic surgeons were recruited after completing a questionnaire and meeting the inclusion criteria of the study. Five different single-access devices were assessed. Each participant performed two validated laparoscopic simulation tasks: peg transfer and pattern cut. All surgeons completed both tasks on all five devices in a randomized order. The performance time and the number of errors and instrument clashes on each task were measured. Statistical analysis was carried out using one-way analysis of variance. **Results:** All participants were consultant laparoscopic surgeons with 4–20 years of experience with laparoscopy and fulfilled the selection criteria. One-way analysis of variance revealed no statistically significant differences in performance time (peg transfer, $P = 0.306$; pattern cut, $P = 0.819$), number of errors (peg transfer, $P = 0.182$; pattern cut, $P = 0.478$) or instrument clashes (peg transfer, $P = 0.446$; pattern cut, $P = 0.061$) between the different singe-access devices. **Conclusion:** In our study, the laparoscopy experts performed equally well on all five single-access devices within a validated simulation environment. More and larger studies in simulated as well as clinical environments are required to provide further evidence.

Keywords: *Single-incision laparoscopic surgery; laparoendoscopic single-site surgery; instruments; single port; laparoendoscopy*

Introduction

Laparoendoscopic single-site surgery (LESS) is one of the latest innovations in minimally invasive surgery and there has been an increased uptake of the technique by many surgical specialities.[1] Randomized controlled trials are now emerging, which show that LESS is as safe as conventional laparoscopic surgery.[2] Furthermore, LESS may confer advantages such as better cosmetic results and less post-operative pain.[3,4]

LESS is technically demanding. The challenge is attributed to the coaxial arrangement of the instruments, instrument crowding, loss of depth perception and the loss of triangulation. The technical skills and manual dexterity required are different from standard laparoscopic surgery and LESS has a steeper learning curve. Even experienced LESS surgeons do not perform as well in LESS simulation tasks compared with tasks using conventional laparoscopic access.[5]

Several manufacturing companies have shown great interest in the technological advancement of LESS. Different single-access devices with ergonomic characteristics designed to overcome the inherent limitations of LESS have been developed. Single-access devices combine a camera port and classically two or three working ports (although some devices support a larger number of working ports). The facial incision required, fixation mechanism and other ergonomic characteristics of single-access devices are summarized in Table 1.

Another development has been that of articulating and pre-bent instruments, which permits intra-corporeal triangulation despite crowding in the single-access port.[7]

We have found only one study comparing different commercially available single-access devices in laparoscopic simulation tasks.[8] Our study aimed to compare the performance of experienced laparoscopic surgeons in validated laparoscopic simulation tasks using four commercially

Table 1 Multi-channel ports

	Tri-Port or R Port	SILS (single incision laparoscopic surgery) multiple access port	GelPort laparoscopic system	SSL (single-sited laparoscopic) port	Multiple standard trocar port
Manufacturer	Advanced Surgical Concepts, Bray, Ireland	Covidien, Norwalk, CT	Applied Medical, Rancho Santa Margarita, CA	Ethicon Endo-Surgery	Home-made trans-umbilical port[6]
Lumen sizes	1 × 12 mm port and 2 × 5 mm ports	3 ports from 5 to 12 mm	Gel Seal Cap, variable ports	2 × 5 mm seals and 1 × 15 mm seal	3, 4 or more × 5–12 mm trocars
Fixation mechanism	Self-expanding ring sheath, inner/outer elastic ring	Red-cell shaped elastic polymer	Alexis retractor, inner/outer elastic ring	Fixed length retractors consist of two flexible rings with silicon sleeve connection	Alexis retractor or friction
Facial incision required	1.5–2.5 cm	1.5–2 cm	Variable (1.5–10 cm)	2 cm	Variable (depending on the size of the Alexis retractor)
Range of abdominal thickness	Up to 10 cm	Up to 4 cm	Up to 6 cm	Fixed length retractors: 4 cm and 4–7 cm thickness of abdominal wall	Depends on the length of the Alexis Retractor used

available single-access devices as well as a home-made single-access port.

Materials and methods

Participants and Study Design
Entry criteria for the study included (1) having participated in more than 100 conventional laparoscopic procedures as the main operator, (2) being non-proficient in LESS defined as less than ten procedures as the main operator, and (3) having achieved the Fundamentals of Laparoscopic Surgery (FLS) expert-derived performance level[9] on a pre-test carried out during recruitment. Before recruitment, all surgeons filled in a questionnaire, describing their previous laparoscopic experience.

The surgeons were assessed on a basic (peg transfer, Fig. 1) and an intermediate (pattern cutting, Fig. 2) laparoscopic task on all five single-access devices. These validated tasks have been described in the FLS course[9] and have been used extensively in laparoscopic simulation. Performance on both FLS tasks was assessed by performance time, number of errors (as defined in the FLS Technical Skills Proficiency-Based Training Curriculum[9]) and number of instrument clashes. Each surgeon undertook the tasks in the single-access devices in a randomized order (computer-generated randomization).

Simulation Setup and Equipment
Experiments were conducted on a LESS box trainer (Fig. 3) in a laparoscopic simulation suite. The surgeons used
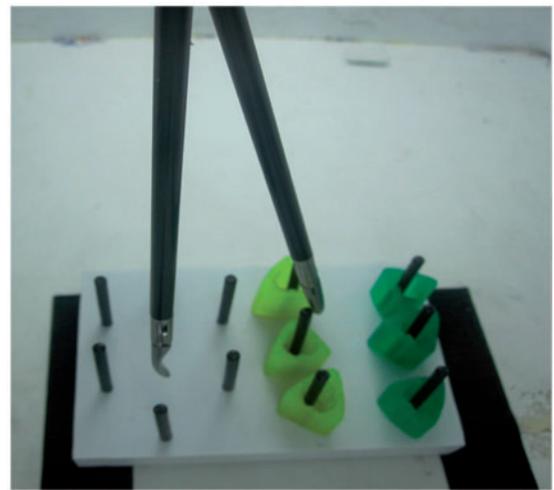

Figure 1 Basic laparoscopic task: peg transfer.

conventional straight laparoscopic instruments to perform the tasks. Five different single-access devices were utilized: four commercially available devices and a home-made multi-access port (Table 1 and Figs 4–8).[6]

Statistical Analysis
The data were tabulated and analysed in SPSS version 14.0 (Statistical Package for the Social Sciences). Parametric data analysis was carried out using one-way analysis of variance (ANOVA). Tukey's multiple comparison test was used to compare all possible pairs of single-access devices. The results are presented as means ± standard error
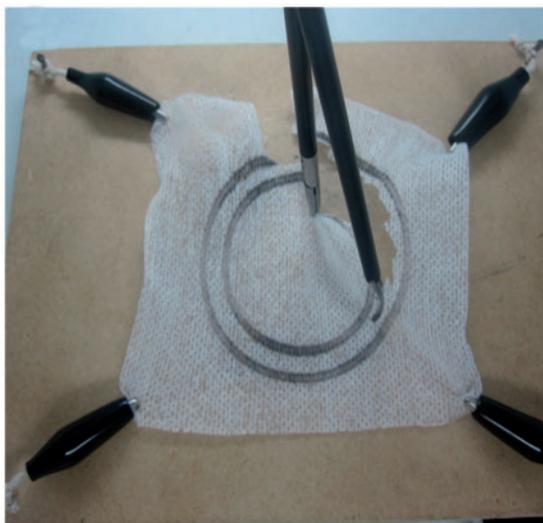
Figure 2 Intermediate laparoscopic task: pattern cutting.

of the mean (SEM) with $P < 0.05$ considered statistically significant.

Results

Ten consultant laparoscopic surgeons, one left handed and nine right handed (four general surgeons, two colorectal surgeons, two hepatobiliary surgeons and two gynaecologists) met the inclusion criteria of the study. Their mean experience with conventional laparoscopic surgery was 11.8 ± 5.2 years. In terms of LESS, the average number of procedures performed by the participants was 6 ± 3.

The performance times for each of the simulation tasks are shown in Table 2. These results were not significantly different between the different single-access devices (ANOVA test: peg transfer, $P = 0.306$; cut pattern, $P = 0.819$). Tukey's multiple comparison test did not demonstrate any statistical significance when comparing pairs.

In order to assess performance precision, we looked at the number of errors performed and instrument clashes. The number of errors performed for peg transfer and pattern cut are presented in Table 2. One-way ANOVA showed no significant difference between devices with regard to the mean number of errors for peg transfer ($P = 0.182$) or pattern cut ($P = 0.478$). There were no significant differences when comparing in pairs (Tukey's multiple comparison test).

We then looked at the number of instrument clashes (Table 2). There was no significant difference in the mean number of clashes for peg transfer ($P = 0.947$) or pattern cut ($P = 0.061$) between devices.

Figure 3 Box trainer.

Discussion

LESS has potential advantages over conventional laparoscopy including improved cosmesis, less pain and higher patient satisfaction.[4] As with any surgical innovation, LESS has been fraught with problems. It is time consuming and requires advanced laparoendoscopic technical skills, which are difficult to acquire. As a result, simulation may be a useful stepping stone in the development of better understanding of the technical difficulties, the devices and smart instruments, as well as improvements in LESS skills before clinical application.

The initial steps of LESS involved multiple ports placed through separate facial incisions but one single skin incision at the umbilicus. Manufacturing companies have since developed different types of single-access devices with certain ergonomic characteristics designed to facilitate operative performance. The cost of LESS single-access devices and smart instruments is a significant issue that might decelerate its uptake.

Surgeons keen on LESS have chosen to use a home-made single-access multi-port setup.[10] In our study, the home-made

Figure 4 Tri-port or R port.

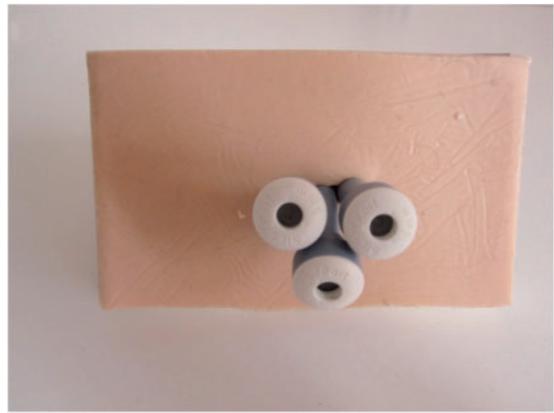**Figure 7** GelPort laparoscopic system.

Figure 5 SSL port.

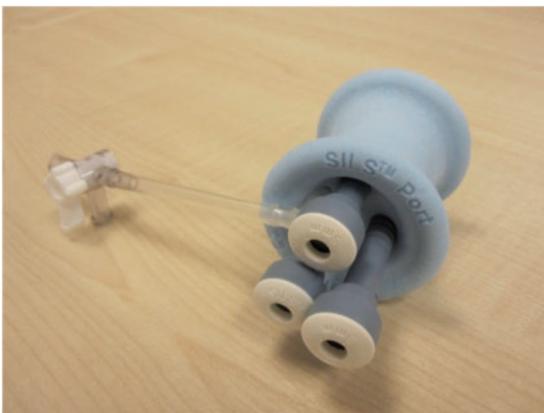**Figure 8** Multi-standard trocar port.

Figure 6 SILS port.

setup did not perform inferiorly to the commercially available ports. However, clinically, the facial holes can sometimes coalesce and cause gas leakage. Studying these ergonomic properties of the devices was beyond the scope of our study. A study from Xie et al.[11] demonstrated mechanical differences between ports, showing that the multi-port devices offer superior maneuverability.

When the instruments and telescope are inserted through the single-access device into the abdominal cavity, there is a natural tendency for clashing and loss of triangulation. This has become known as sword fighting or the chopsticks effect. Furthermore, the rigid core body of some single-access devices affects the movement of the ancillary instrument when the primary instrument is moving. As we have seen, the commercially available single-access devices differ in lumen size, the distance between lumens, the rigidity of their core material and fixation mechanisms (Table 1). We hypothesized that these differences might affect operative performance and attempted to demonstrate this with the peg transfer and pattern cut tasks.

Peg transfer is a bimanual task, which tests the movement of both the primary and ancillary instruments. Similar opposite direction bimanual skills are necessary when

Table 2 Performance times, errors and clashes of instruments

Parameter	Task	Tri-Port	SILS port	SSL port	GelPort	Multi-trocar	P value
Performance times (s ± SEM)	Peg transfer	141 ± 17	150 ± 4	132 ± 14	115 ± 9	130 ± 11	0.306
	Pattern cut	154 ± 12	155 ± 9	141 ± 8	146 ± 10	156 ± 13	0.819
Errors (mean number of errors ± SEM)	Peg transfer	0.4 ± 0.2	0.4 ± 0.2	0.1 ± 0.1	0.4 ± 0.2	0.1 ± 0.1	0.182
	Pattern cut	2.3 ± 0.6	1.2 ± 0.3	1.6 ± 0.5	1.2 ± 0.5	1.4 ± 0.5	0.478
Instrument clashes (mean number of clashes ± SEM)	Peg transfer	3.3 ± 0.9	2.2 ± 0.2	3.2 ± 0.6	2.7 ± 0.5	3.9 ± 0.8	0.947
	Pattern cut	2.1 ± 0.3	0.8 ± 0.2	2.3 ± 0.4	1.5 ± 0.5	1.6 ± 0.3	0.061

performing laparoscopic suturing and when trying to strengthen an intra-corporeal knot. Our results demonstrated no significant difference when comparing all five single-access devices.

The pattern cut task requires a different technique. It is best performed when the instruments are used in a combination of crossing and non-crossing movements (the chopstick technique), as described in robotic LESS by Rohan et al.[12] We observed some of the surgeons applying these simple principles in order to overcome the difficulties due to loss of triangulation. Our study again demonstrated that the type of single-access device does not affect performance of this task.

However, the technical aspects of ports have certain characteristics that make the decision making easier. The cost of each port is approximately the same in the region of £200; however, the cost can vary depending on the contract between the hospital and the manufacturing company. The GelPort allows extraction of large specimens through the incision due to the Alexis retractor used for its introduction. The SILS port's soft material and the GelPort cap allow the use of different sized instruments (larger than 5 mm) through the multi-trocar ports.

Our study has several limitations. First, the sample size was small, and that reflects the difficulty of recruiting busy laparoscopic surgeons to perform time-consuming simulation tasks. Second, the performance of the surgeons in advanced laparoscopic simulation tasks such as intra-corporeal suturing could have a major influence on our study but this was not explored due to time constraints. It is unclear if performance with simulated single-port laparoscopic tasks is reflected in clinical practice of single-incision laparoscopic surgery as already shown with basic laparoscopy. Studies to validate these aspects are required. Third, it would be interesting to assess the performance of surgeons with articulating or pre-bent instruments in combination with different single-access devices. These instruments allow for pseudo-triangulation to occur intra-corporeally and can be passed through some of the single-access devices, which have a very low profile inside and outside the abdominal wall.

Conclusion

Simulation room training is helpful in understanding the devices, each with its inherent advantages and disadvantages, and improving LESS skills. We have shown that surgeons perform similarly in basic and intermediate validated laparoscopic simulation tasks when using different single-access devices. Furthermore, we have shown that a home-made single-access multi-port setup is not inferior to the commercial devices currently available. Different ports maintain advantages according to their ergonomics, which affects the decision on which device is the best for which operation.

Further randomized evaluation of the devices in combination with smart instruments is required both in simulation and clinical environments. Currently, pre-operative variables, the surgeon's preference, as well as institutional guidelines are likely to determine device selection.

Note

Fundamentals of Laparoscopic Surgery (TM) (FLS) Program is owned by the Society of American Gastrointestinal and Endoscopic Surgeons (SAGES) and American College of Surgeons (ACS). This study is not connected to or approved by SAGES, ACS or FLS.

Conflict of interest

No conflicts of interest have been declared.

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