Published in final edited form as:

Surg Endosc. 2011 April ; 25(4): 1238–1244. doi:10.1007/s00464-010-1349-7.

ANALYSIS OF STANDARD MULTI-PORT VS. SINGLE SITE ACCESS FOR LAPAROSCOPIC SKILLS TRAINING

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Abstract

Introduction—Single site access (SSA) laparoscopy is more challenging to perform than multi-port(MP) laparoscopy. We examined MP versus SSA skills training on laparoscopic performance in surgically naive individuals.

Methods—Forty end-of-1st year medical students were randomized into two groups. Both were trained on 4 basic laparoscopic drills (peg, rope, bean drop, pattern cutting) using a standard MP setup (Group 1) or SSA approach (Group 2). Time to proficiency and number of repetitions (reps) were recorded. Each group then crossed over to the alternate approach where the sequence was repeated. Data are mean $\pm$ SD and statistical analysis was with two-tailed, unpaired t-test.

Results—Total times to proficiency for the SSA and MP approaches was not significantly different between groups (Group 1 M-P 234.0 ± 114.9 min vs Group 2 SSA 216.4 ± 106.5 min, $p=0.67$). The MP-trained group took less time to reach proficiency on the standard MP setup than the SSA group on the SSA approach (119.1 ± 69.7 min vs 178.0 ± 93.4 min, $p=0.058$) with significantly fewer repetitions (77.6 ± 42.6 vs. 118.8 ± 54.3 , $p=0.027$). The SSA-trained group took significantly less time to reach proficiency on the MP setup than the standard MP-trained group (38.4 ± 29.4 min vs. 119.1 ± 69.7 min; $p=0.0013$) requiring only a mean of 26.9 total repetitions. When the standard MP group crossed over to the SSA setup, they took significantly less time to reach proficiency with the SSA approach than the SSA-trained group (114.8 ± 50.5 min vs. 178.0 ± 93.4 min, $p=0.026$) but with more total repetitions than with the M-P approach (86.2 ± 35.2 vs 77.6 ± 42.6 , $p=NS$).

Conclusions—Laparoscopic single site access skills training results in longer times and more repetitions to achieve proficiency than multi-port training, but the skills acquired transfer well to the multi-port approach.

Introduction

Single incision or single site access (SSA) laparoscopic surgery is gaining interest as a potentially less invasive alternative to standard laparoscopic approaches. The first SSA

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Presented at the 2010 World Congress of Endoscopic Surgery/SAGES Meeting Washington, DC, April 16, 2010

Financial Disclosures:

Daniel Cox, Wenjing Zeng, and Margaret Frisella have no conflicts of interest or financial ties to disclose.

laparoscopic cholecystectomy was performed by Navarra in 1997¹, and already this approach has since been applied to most other laparoscopic surgical procedures.^{2, 3, 4, 5} In contrast to standard laparoscopic surgery which involves the use of multiple incision sites, SSA is performed with all ports and instruments placed closely together via a single incision access site at the umbilicus. The principal advantage of this approach appears to be less visible scarring. However, this approach can be more technically challenging than standard laparoscopy. Some of these challenges include loss of triangulation between the camera and working ports and restricted range of motion due to the close apposition of the ports, instruments, and camera.

Skills training is becoming an increasingly important component of surgical education⁶ and could potentially impact the learning curve for introducing SSA to residents and practicing surgeons. However, despite the increasing number of SSA laparoscopic cases being performed in clinical practice, no studies have to date evaluated methods of skills training from this perspective. Validated methods of laparoscopic skills training such as the SAGES Fundamentals of Laparoscopic Surgery (FLS) program⁷ and other methods such as Rosser drills⁸ should be easily adaptable to the SSA setting. The purpose of this study, therefore, was to investigate the SSA approach using some of these validated drills and to examine the learning curves for standard multi-port versus SSA laparoscopic skills training on laparoscopic skills acquisition and performance using surgically-naïve individuals.

MATERIALS AND METHODS

Participants and Study Design

Forty surgically-naïve medical student volunteers were recruited to participate in this study. All participants were end-of-first year medical students at Washington University in St. Louis with no prior laparoscopic surgical experience. Students were invited to participate via class-wide email, and were selected on a first-come first-served basis. They were randomized to one of two groups under an IRB approved protocol as shown in Fig. 1: a standard multi-port group (Group 1) and a single site access group (Group 2). Each group underwent separate 1.5-hour training sessions taught by an experienced laparoscopic surgeon using either the multi-port or SSA set-up to which they were randomized. At the training session, students were given a brief overview of the laparoscopic equipment used in the study, the port set-ups, and a tutorial on the proper performance of four laparoscopic tasks which were used in the study as described below. They were then given the opportunity to perform each drill. The students also completed a survey questionnaire assessing their prior experience with basic surgical skills such as suturing and knot tying, as well as other activities that require hand-eye coordination such as athletics, musical instruments, and video gaming.

Students then trained using exclusively the setup to which they were randomized until a pre-determined proficiency standard was reached for each of the tasks. Training consisted of consecutive repetitions of each of the four tasks. Each repetition was timed and recorded, and students were considered proficient on a particular task when they were able to reach the time goal on three consecutive repetitions. Total time to proficiency was calculated as the sum of repetition times (actual task performance times). Number of repetitions to

proficiency was also recorded. Students signed up for practice time via an online schedule. No independent untimed practice was allowed, ie every single repetition of a task was timed and entered into an Excel database by one of the investigators (DC). After reaching proficiency in all four tasks, students crossed over to the alternate approach where the sequence was repeated. No additional instruction or training was given after the crossover. Training time and number of repetitions to proficiency was again recorded.

Training Setups and Equipment

Configurations for the standard multi-port and SSA training setups using conventional laparoscopic trainer boxes are illustrated in Fig 2. For the standard multi-port setup, the ports were placed in standard instrument port positions triangulated with the camera port. For the SSA setup, the camera port was placed in the central midline position, and instrument ports were placed at the same access site in an equilateral triangle configuration with each of the three ports 2.5 cm apart. Instrumentation was the same for each set-up except that the SSA approach utilized two low profile ports (Covidien, Norwalk, CT) for the dissecting and grasping instruments and a right-angle light cord adapter for the camera (Stryker Endoscopy). Disposable Maryland graspers and endoscopic scissors were used for the various tasks (Ethicon Endosurgery Cinicinnati, OH).

Drills

The training tasks used in this study were adapted from the ACS/APDS Surgical Skills Curriculum for Residents⁹. We used four tasks including peg transfer, cobra rope, bean drop, and pattern cut. The peg transfer and pattern cutting drills are from the SAGES FLS program⁷ and the cobra rope and bean drop as described by Rosser.⁸ Briefly, the peg transfer involved transferring the pegs from left to the right hand, placing them on the right sided pegs, and then transferring them back again using Maryland graspers. If a peg was dropped within the field of view, the student was allowed to re-grasp the peg and no penalty was assessed. If a peg was dropped outside the field of view, the proctor replaced it on the peg from which it was taken, and a 5 second penalty was assessed. For the cobra rope drill, 2.5 cm colored segments of nylon cord separated by white segments 10.5 cm in length were used. Students grasped the first colored segment using Maryland graspers and the rope was passed hand over hand until the last colored segment was reached. Only the colored segments could be grasped, and students were required to grasp each colored segment at least once. No time penalty was assessed for grasping a white segment, but students were required to release the rope and re-grasp within the colored segment before continuing. Bean Drop – The bean drop drill was designed to develop two-handed skills with one hand for camera navigation and the other for precise bean transfer similar to the coordinated movements that must occur during SSA surgery. Students grasped black-eyed peas with Maryland graspers using their dominant hand and dropped them into a 1.2 cm hole in the bottom of an inverted plastic cup without touching the top of the cup. If the top of the cup was touched, that bean was not counted. Ninety seconds were given to get as many beans as possible in the cup. Pattern Cut – two circles were stamped on two-layer thick pieces of synthetic gauze. The outside diameter of the small circle was 6 cm and the inside diameter of the large circle was 7 cm, leaving a 5 mm space between them circumferentially. Students were required to cut within the two lines, without cutting either line. If a line was cut, an

error was assessed and the task had to be performed again without error in order for proficiency to be reached.

To facilitate comparisons, the same time goals were used for both the SSA and standard multi-port setups. The time goals for each task were determined using a combination of drill times from SSA experts (data not shown) as well as the standards outlined in the ACS/APDS Surgical Skills Curriculum for Residents⁸. Time goals for the various tasks were: peg transfer – 60 sec; Cobra rope – 32 sec; bean drop– 10 beans in 90 sec; and pattern cutting – 100 sec with no errors. The total number of errors that students made while performing each task was not recorded, and error rate was not evaluated separately as part of the data analysis.

Statistical Analysis

All data are mean $\pm$ SD. Two-tailed, unpaired t-tests were used to compare mean times and number repetitions to reach proficiency. A p value of < 0.05 was considered significant.

RESULTS

Of the 40 students who were recruited to participate, all but 4 completed the study (3 in Group 1 and 1 in Group 2). Two students were unable to complete the study due to scheduling conflicts and one due to a hand injury. Only one student was unable to complete the study due to inability to reach proficiency standards. Three other students were moved to the alternate group after randomization due to scheduling concerns (two from group 1 and one from group 2). Thirty-six of 40 students reached proficiency goals on all four tasks for both phases of the study. However, because incomplete data was recorded for some repetitions in 6 students, the total combined task times for Phases I & II were available for only 30 students (13 in Group 1 and 17 in Group 2). The mean age of the students was 23.1 ± 0.9 years and none of the students had significant experience with laparoscopic instruments or surgical techniques. Six had musical experience above the high school level and seven had athletic experience above the high school level. Seven reported video game use more than once a week. No attempt was made to correlate musical, athletic, or video game experience to laparoscopic performance.

Mean task times and numbers of repetitions to proficiency for each of the four tasks for both phase I and II of the study are shown in Fig's 3 and 4, respectively. On average, it took longer for the SSA group to reach proficiency in phase I for each task, although the difference was significant for the peg transfer and cobra rope drills only. After the crossover, however, the SSA group took substantially less time to reach proficiency than the MP group (significant for peg and rope drills only).

The total time and number of repetitions to proficiency for both Phases I and II combined are shown in Fig. 5. The SSA group required on average 18 minutes less time and 18 fewer repetitions to complete both phases of the study (Group 1 M-P 234.0 ± 114.9 min vs Group 2 SSA 216.4 ± 106.5 min, $p=0.67$; repetitions: Group 1 – 163.8 ± 73.6 reps vs Group 2 – 145.7 ± 63.6 reps) although the differences were not significant. Table 1 shows the sum of the time and numbers of repetitions to reach proficiency for the four tasks together on each

phase of the study. The MP-trained group took less time to reach proficiency on the standard MP setup than the SSA group did on the SSA approach (119.1 ± 69.7 min vs 178.0 ± 93.4 min, $p=0.058$) with significantly fewer repetitions (77.6 ± 42.6 vs. 118.8 ± 54.3 , $p=0.027$). When the SSA-trained group crossed over to the MP setup, they took significantly less time to reach proficiency on the MP setup than the standard MP-trained group (38.4 ± 29.4 min vs. 119.1 ± 69.7 min, $p=0.0013$), and reached proficiency in a mean of only 26.9 total repetitions (range 11–65 reps). Similarly, when the standard MP group crossed over to the SSA setup, they took significantly less time to reach proficiency on the SSA approach than the SSA-trained group (114.8 ± 50.5 min vs. 178.0 ± 93.4 min, $p=0.026$) but with more total repetitions than was needed to achieve proficiency on the MP approach (86.2 ± 35.2 vs 77.6 ± 42.6 , $p=NS$).

Discussion

Single incision approaches to laparoscopic surgery or single site access (SSA) laparoscopy, which was first developed as a novel approach to laparoscopic cholecystectomy, is now being applied to many different laparoscopic procedures.^{3–5, 10–12} While the advantages of this approach over standard multi-port laparoscopy through 5mm (or smaller) incisions is being debated, it is nonetheless gaining momentum among surgeons as a way of performing virtually “scarless”, less invasive surgery, with the goal of achieving better cosmetic outcomes. To date, surgical meetings and industry sponsored courses with didactic lectures and hands-on animate lab practice and/or live case observation have been the principal methods by which surgeons have been exposed to various SSA approaches. However, very little attention has been focused on ex vivo training methods to prepare surgeons for some of the differences and challenges in performing SSA clinically compared to standard laparoscopy. These challenges include the loss of triangulation, working with instruments in an in-line, near parallel configuration, and the close proximity of instruments and camera which can lead to sword fighting and restricted range of motion.

Our group first began a program of single incision laparoscopic cholecystectomy (SILC) in mid-2008, and have recently reported results with our first 54 cases through October 2009.¹³ It was apparent early on that there was a learning curve for even experienced laparoscopic surgeons and that this effect was magnified for most resident learners, including those at the most advanced levels of the training program. This perceived need for SSA-specific skills training led us to explore different laparoscopic skills tasks that would be potentially transferable to the single site environment.

The aims of this study were to investigate the SSA approach using well established laparoscopic drills, and to examine learning curves for standard multi-port (MP) vs SSA for laparoscopic skills training and performance. Our hypothesis was that there could be an advantage to exposing trainees to single site set-ups early in their training before they either had much experience with or had fully adapted to the conventional multi-port approaches. In order to test this concept, we selected end of first year medical students who were surgically naive in that they had no prior surgical technical experience and no operative or skills training exposure to laparoscopy. Forty students were randomized to either a standard multi-port laparoscopic approach or a single incision type set-up.

The study design chosen was structured to evaluate the learning curve required to achieve a pre-determined proficiency standard for each of 4 basic laparoscopic skills tasks – peg transfer, pattern cutting, cobra rope drill and pattern cutting. Two of these tasks are from the FLS program (peg transfer and pattern cut),¹⁴ and the other two (cobra rope and bean drop) are modified Rosser drills⁸ that were adapted from the ACS/APDS Surgical Skills Curriculum for Residents.⁹ The reasons we chose those four drills for this particular study are several -fold. First, we considered these drills to be relevant to laparoscopic cholecystectomy, which is the procedure to which the SSA approach is being most widely applied. Second, the materials required for these tasks are inexpensive and were readily available. Third, these tasks are less complicated than some of the other validated tasks. Suturing tasks were not included because of the increased complexity and unique challenges of conventional intra and extracorporeal suturing posed by the single site set-up. Since the study population was end of first year medical students, the study also had to be carried out over two months in the summer between the end of first year classes and the resumption of classes for the fall term. Therefore, the amount of training required for surgically-naïve individuals to become proficient at more complex skills such as suturing using two different approaches was not feasible given the time frame of this study.

Proficiency levels for each of the tasks were defined based on modifications of the ACS/APDS skills curriculum⁹ with some additional time added to compensate for the increased difficulty of the SSA set-up. The transferability of training on these two approaches was also evaluated by crossing these groups over to the alternate approach once they had achieved proficiency targets on the various tasks. An important component of the study design was that all total task times were recorded by one of the investigators (DC) for every repetition for every task, ie there was no independent practice or practice outside of timed performance. The times recorded, therefore, reflect precisely the actual hands-on time to reach the proficiency goals.

On average, for phase I of the study in which the two student groups practiced to proficiency on the set-up to which they trained, it took longer for the SSA group to reach proficiency for each of the four tasks (significant for peg transfer and cobra rope only). However, after the crossover to the alternate approaches (Phase II of the study), the SSA group took substantially less time and numbers of repetitions to reach proficiency than the MP group. In fact, many of the SSA-trained students were automatically proficient on the first three repetitions on the MP setup when they crossed over. The converse was not true for the multi-port trained students, however, as they still required 13–30 repetitions of each task to re-attain the same proficiency targets. When the total combined times and number of reps to proficiency for both phases of the study were compared, the SSA group reached proficiency 18 minutes faster with 18 fewer repetitions, although the differences were not significant. A crossover effect was also observed for the multi-port trained group in that they reached proficiency in significantly less time on the SSA set-up than did the SSA trained group.

Our results suggest, first of all, that adaptation of existing surgical skills curricula to the SSA approach is feasible. Almost all students were able to reach proficiency in a reasonable amount of time, and our proficiency standards were not substantively different from the

ACS/APDS Surgical Skills Curriculum⁸ standards. Also, the training setup we used closely approximates the intraoperative SSA setup, which would be necessary for an effective training setup. We have also shown that skills acquired while training on one modality transfer well to the other approach. These findings suggest that SSA training should be introduced early on in skills training curricula, in part because it may be easier for surgeons who acquire SSA skills to transfer those skills to the standard approach than the other way around.

As stated above, we chose the proficiency standard for each drill based on SSA expert times using the ACS/APDS Surgical Skills Curriculum for Residents proficiency standards as guidelines.^{8, 15} These proficiency standards were developed by experts in the field and were modified slightly for this study to allow for the increased difficulty with the SSA approach. For example, the ACS/APDS curriculum utilized 48 seconds for peg transfer and 96 seconds for pattern cutting, versus 60 and 100 seconds respectively, for these two tasks in the current study. These proficiency targets were appropriately difficult for the students to attain, yet all but one was able to reach proficiency on each of the drills in a reasonable amount of time and number of repetitions. The standards were set high enough that there was a definite learning curve for the majority of individuals, but not so high as to make the standard unattainable. In order to widely apply the SSA approach to training programs, these proficiency standards would need to be validated in residents and surgeons with a range of laparoscopic expertise.

This study has a number of limitations. We have not determined if laparoscopic suturing tasks could be adapted to the SSA model reported herein and, therefore, cannot speculate as to whether the FLS program can be fully adapted to the SSA approach. Another potential limitation to this study is that we only used one SSA port setup. Several different port devices as well as flexible shaft instruments and flexible tip laparoscopes have been developed to facilitate single incision laparoscopic procedures, most of which have been constructed for more advanced applications. Whether any of these devices would impact the learning curve for skills training is uncertain but should be considered in future studies. Finally, it is unclear how SSA skills training might translate into improved operative performance as has been shown for the FLS training program.¹⁶ Further studies are needed to examine these variables and the interplay between conventional laparoscopic skills training and SSA approaches.

In summary, we have shown that laparoscopic single site access skills training initially results in longer times and more repetitions to achieve proficiency than standard multi-port training, but proficiency can still be reached by surgically naive individuals in a reasonable time frame. Moreover, the single site skills transfer well to the multi-port approach. Based on these results, we believe that the existing laparoscopic skills tasks can and should be adapted to the SSA approach. Through this study we have laid the groundwork for a basic SSA skills training program that could be applicable to junior and even senior residents and have begun to incorporate this into our surgical resident training program. If the SSA approach continues to gain traction in clinical practice, it will be important to incorporate these techniques not only into residency training, but also into training courses for practicing surgeons who wish to learn SSA techniques.

Acknowledgments

The authors wish to acknowledge the Washington University Institute for Minimally Invasive Surgery for support of this study. Daniel Cox was supported by T35 DK074375.

Dr. L. Michael Brunt has the following disclosures: Educational Grant Support from Ethicon Endosurgery, Inc.; Educational Grant Support and Equipment Support from Karl Storz Endoscopy and Stryker Endoscopy; Grant/Research Support from Lifecell Corp.; and Honorarium for speaking/teaching from Ethicon Endosurgery, Covidien, and Cook Medical. None of these disclosures are related to the content of this study which was conducted in a completely independent manner and free of industry funding.

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Fig. 1.
Study design

Fig. 2.
Skills trainer box set-up. A) Multi-port configuration. B) Single site access port configuration.

Fig. 3.

Mean times to reach proficiency for the four skills tasks for Phase I (left panel) and I (right panel) of the study. MP = multi=port, SSA = single site access. * p<0.001 between groups for a given task.

Fig. 4.

Mean number of repetitions to reach proficiency for the four skills tasks for Phase I (left panel) and II (right panel). MP = multi=port, SSA = single site access. * p<0.001 between groups for a given task.

Fig. 5.
Total combined time (left panel) and number of repetitions (right panel) to proficiency for both phases of the study for the multi-port (MP) and SSA (single site access) groups.

Table 1

Combined Task Times and Number of Repetitions for Phases I & II for Multi-port and SSA Trained Groups

Group	Study Phase	Set-up	Time (min)	Repetitions
1 (Multi-port trained)	I	Multi-port	119.1 ± 69.7	77.6 ± 42.6
1	II	SSA	114.8 ± 50.5	86.2 ± 35.2
2 (SSA trained)	I	SSA	178.0 ± 93.4	118.8 ± 54.3
2	II	Multi-port	38.4 ± 29.4	26.9 ± 21.1

SSA = single site access