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Validation of a pediatric single-port laparoscopic surgery simulator☆

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ABSTRACT

Background: This study aims to adapt an existing multiport pediatric laparoscopic surgery simulator to be suitable for pediatric single-port laparoscopy and to investigate construct validity for its use as a resource for skills training and assessment. *Methods*: An existing pediatric-sized box trainer was modified to accommodate a commercially available port. A total of 41 participants (18 novices, 16 intermediates and 7 experts) were recruited to complete four curriculum tasks via a single-port access approach. Objective task performance scores were evaluated. *Results*: Task completion times and performance scores were significantly different between novices and experts for the peg transfer ($P = 0.02$, $P = 0.008$ respectively), pattern cut ($P < 0.001$, $P < 0.001$ respectively) and ligating loop ($P = 0.038$, $P = 0.035$ respectively). There were significant differences in outcomes between novices and intermediates for all tasks, including the intracorporeal suture task ($P \leq 0.001$). There were no significant differences in outcomes between intermediates and experts for all tasks. *Conclusions*: The Pediatric Laparoscopic Surgery (PLS) simulator can be easily adapted for single-port laparoscopic surgery to be construct valid for the peg transfer, ligating loop and pattern cut tasks. There is scope for additional tasks to be developed that focus on the unique technical challenges and skills associated with single-port techniques.

Single-port laparoscopic surgery (SPLS) has recently been introduced in an effort to further minimalize access trauma related morbidity and improve cosmesis compared to established multiport laparoscopy techniques. Following the earliest reported pediatric application in 1998 by Esposito, this technique has been applied to a diverse range of indications in children [1–3]. The dominant pediatric application for SPLS is appendectomy [1,2]. Other applications include inguinal hernia repair, varicocelectomy, cholecystectomy, splenectomy and pyloromyotomy [1,2].

There are unique technical challenges and skill requirements associated with SPLS and this creates a need for dedicated training [4,5]. Simulation is now a well-established component of modern surgical training. Simulation allows surgical skills to be acquired in a preclinical and safe environment, and has been shown to improve performance in the operating room [6]. The Pediatric Laparoscopic Surgery (PLS) simulator is the only construct validated box trainer for multiport pediatric laparoscopy that is commercially available [7]. This simulator is based on the well-established adult Fundamentals of Laparoscopic Surgery (FLS) simulator. The FLS box trainer has been demonstrated to be suitable for adult single-port laparoscopy simulation following simple modification [8]. This study aims to adapt the PLS simulator for pediatric SPLS and to evaluate its construct validity as a training and assessment tool.

1. Materials and methods

1.1. Hardware development

The PLS simulator was modified to accommodate a SILS™ Port (Covidien, Dublin, Ireland). To represent the usual umbilical location of the port in SPLS, the SILS™ port was positioned in a central location that was equidistant from the existing lateral instrument port sites. A wedge section of SILS™ port that usually accommodates the laparoscope channel was removed in order to accommodate the high-definition webcam that is standard with the PLS assembly (Fig. 1).

1.2. Participant testing

Participants with varying experience in pediatric single-port and multiport laparoscopic surgery were recruited from three university teaching hospitals in London. Participants were stratified according to their level of primary operator expertise. Criteria for allocation into novice, intermediate and expert categories were <10 multiport and <10 SPLS cases, ≥10 multiport and <10 SPLS cases, and ≥10 multiport and ≥10 SPLS cases respectively.

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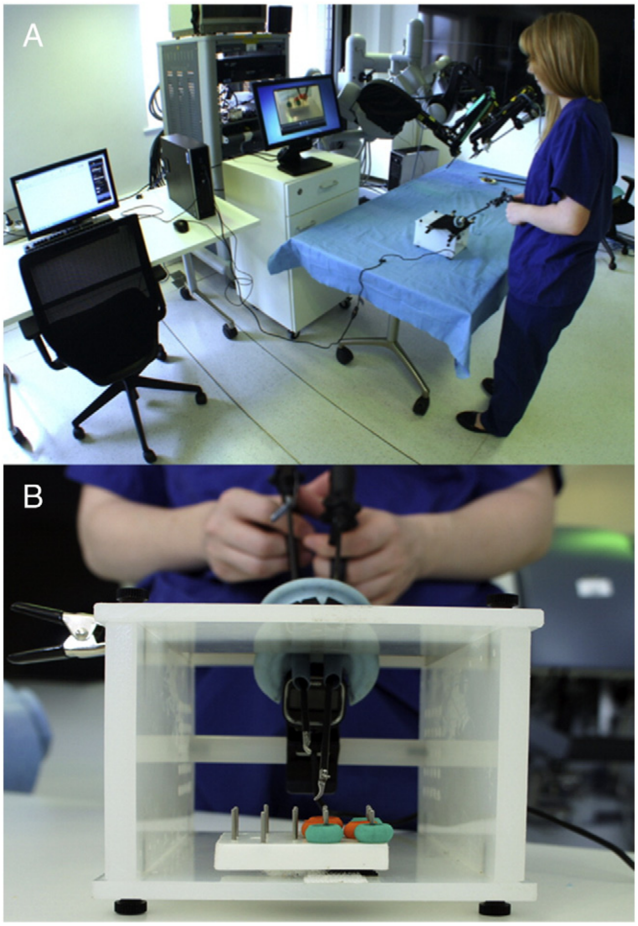

Fig. 1. Overview of (A) the experimental setup and (B) reverse angle view inside the modified PLS simulator demonstrating the arrangement of the SILS port, instruments and webcam.

The PLS curriculum consists of 5 tasks that are each based on the McGill Inanimate System for Training and Evaluation of Laparoscopic Skills (MISTELS) [7]. Participants performed 4 of these tasks; the peg transfer, pattern cut, ligating loop and intracorporeal suturing. These tasks have previously been described extensively [7,9]. The differences in triangulation between multiport and single-port laparoscopy for each of the assessed tasks is displayed in Fig. 2. The extracorporeal suturing task was not included, as it is not routinely used by surgeons at our institutions and was not expected to demonstrate any differences between multiport and single-port laparoscopy as the knot is fashioned extracorporeally, independent of instrument configuration.

Following written informed consent, participants were shown a short prerecorded instructional video that demonstrated how each of the four tasks should be completed. Participants were then allowed 5 minutes to familiarize with the experimental setup (Fig. 1). A variety of 3 mm straight and 5 mm articulating instruments were provided during this preassessment period, and participants were informed that they could freely select any combination of these instruments for the assessed task repetitions. In all circumstances, paired straight instruments were ultimately selected.

Novices and intermediates were asked to perform two repetitions of each task in order to allow for failed attempts and therefore gain fairer results from these less experienced groups. An aggregate measure was used to calculate these results. Task completion times and task performance scores were assessed for each task repetition. Performance scores were calculated based on the validated PLS scoring method [6]. These scoring algorithms incorporate error penalties that are unique to each task. Raw scores were not normalized.

1.3. Statistical analysis

Median and interquartile range values were calculated for all task performance outcome measures. Kruskal–Wallis one-way analysis of variance was used to compare outcomes between groups. If significant differences were determined, then the Mann–Whitney test was used to further compare outcomes between 2 groups (i.e. novices versus intermediates) with the Bonferroni correction. Statistical analysis was performed using IBM SPSS Statistics 21.0 (SPSS, Chicago, IL, USA). Statistical significance was regarded as $P < 0.05$.

2. Results

A total of 41 participants were recruited, comprising 18 novices, 16 intermediates and 7 experts. Mean ($\pm$SD) participant age for the novice, intermediate and expert groups was 22.9 ($\pm$3.0), 33.9 ($\pm$6.4) and 43.4 ($\pm$9.4) years respectively.

Task completion time and performance score outcomes are summarized in Table 1. Outcomes were significantly different between groups in all 4 tasks evaluated ($P \leq 0.001$, Figs. 3 and 4).

When comparing novices and intermediates, there were significant differences between task completion times and performance scores for all 4 tasks ($P \leq 0.001$). When comparing novices and experts, there were significant differences between task completion times and performance scores for 3 tasks; the peg transfer ($P = 0.02$ and $P = 0.008$ respectively), pattern cut ($P < 0.001$ and $P < 0.001$ respectively) and ligating loop ($P = 0.038$ and $P = 0.035$ respectively). When comparing intermediates and experts there were no significant differences in task completion times and performance scores.

Performance in the intracorporeal suturing task was poor overall. Almost half of the participants (19/41) failed the task by exceeding the maximum allowable time of 10 minutes. Among the expert group, 1 completed the task in 3.5 minutes, 2 completed the task in more than 9 minutes and 4 failed to complete the task.

3. Discussion

The existing Pediatric Laparoscopic Surgery (PLS) simulator for multiport laparoscopy can be adapted in a low-cost and low-barrier manner in order to be suitable for pediatric single-port laparoscopic surgery. Our findings demonstrate construct validity for the peg transfer, pattern cut and ligating loop tasks.

Single-port laparoscopic surgery requires similar fundamental skills to multiport laparoscopic surgery but is associated with considerable increased technical challenges [2,10]. Reasons for the increased burden of difficulty are attributed to ergonomic factors associated with parallel configuration of instruments through a single access site. Surgeons lose much of the ability to triangulate instruments for optimally efficient handling of tissues and suture material. Coalignment of equipment results in crowding of instruments within the operative field and frequent clashing of surgeons' hands extracorporeally. The visual field is more obscured by the presence of instruments. The camera assistant is required to position themselves in close proximity to the operating surgeon, and this can restrict comfort and freedom of movement. A recent international multicenter survey study by Esposito *et al* revealed that pediatric surgeons experience more work-related musculoskeletal symptoms with single-port compared to multiport laparoscopic surgery [10].

Accommodating and overcoming each, some, or all these above unique aspects of SPLS requires advanced skill. The demands for increased technical skill undoubtedly account for the reasons that clinical applications of pediatric SPLS remain concentrated toward procedures that are relatively less complex and either ablative or extirpative. Developments in robotic and nonrobotic technology are anticipated to help make SPLS more achievable and more widely adopted in the future [11–13]. Irrespective of these exciting advances in surgical technology,