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Adaptation of the fundamentals of laparoscopic surgery box for endoscopic simulation: performance evaluation of the first 100 participants

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Abstract

Background The paucity of readily accessible, cost-effective models for the simulation, practice, and evaluation of endoscopic skills present an ongoing barrier for resident training. We have previously described a system for conversion of the Fundamentals of Laparoscopic Surgery box (FLS) for flexible endoscopic simulation. Six endoscopic tasks focusing on scope manipulation, and other clinically relevant endoscopic skills are performed within a 5-min time limit per task. This study describes our experience and validation results with the first 100 participants.

Methods A total of 100 participants were evaluated on the simulator. Thirty individuals were classified as experts (having done over 200 endoscopic procedures), and 70 were classified as trainees (39 individuals reported having no prior endoscopy experience). Of the 100 participants, 55 individuals were retested on the simulator within a period of 4 months. These 55 individuals were also evaluated using the "Global Assessment of Gastrointestinal Endoscopic Skills" (GAGES). *T*-tests and Pearson correlations were used where appropriate, values less than 0.05 were considered significant.

Results Experts completed all six tasks significantly faster than trainees. For the 55 participants who were retested on the simulator, all tasks demonstrated evidence of test–retest reliability for both experts and trainees who did not practice in between tests. Moderate correlations between lower completion times and higher GAGES scores were observed for all tasks except the clipping task.

Conclusions The results from the first 100 participants provide evidence for the simulator's validity. Based on task completion times, we found that experts perform significantly better than trainees. Additionally, preliminary data demonstrate evidence of test–retest reliability, as well as GAGES score correlation. Additional studies to determine and validate a scoring system for this simulator are ongoing.

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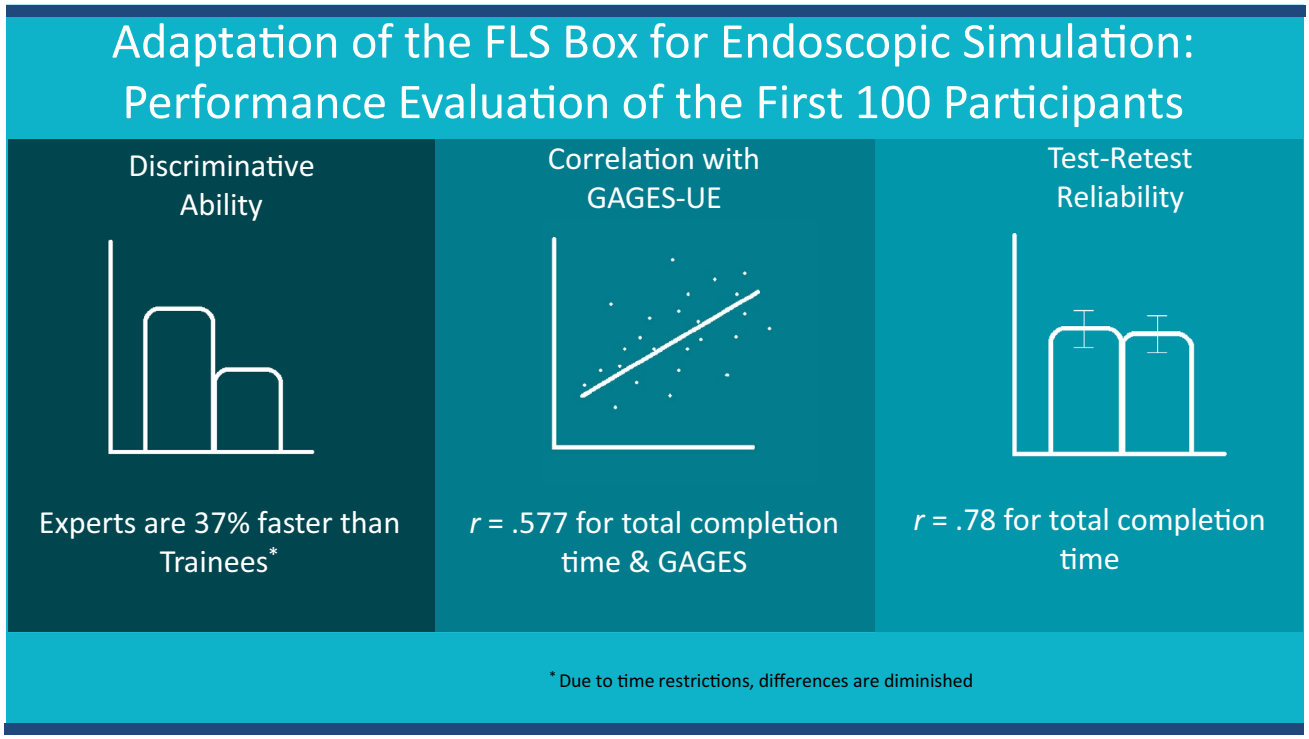
Graphical abstract



Keywords Endoscopy simulator · Simulation · FES · GAGES · FLS

Flexible endoscopy is seeing an ongoing shift from a solely diagnostic modality to increasingly more complex therapeutic procedures. Technological advancement and the proliferation of advanced endoscopic techniques such as per-oral endoscopic myotomy (POEM), endoscopic mucosal resection (EMR), and endoscopic submucosal dissection (ESD) are further fueling the increased demand and use of flexible endoscopy.

Recognizing the vital role of flexible endoscopic training the American Board of Surgery (ABS), in consultation with the Society of American Gastroenterologists and Endoscopic Surgeons (SAGES), announced that as of 2017–2018 graduating surgical residents must pass the Fundamentals of Endoscopic Surgery (FES) examination. The first component of FES is cognitive, aimed at testing basic knowledge. The second component designed to assess basic endoscopic skills is performed on a virtual reality simulator.

Unlike the Fundamentals of Laparoscopic Surgery (FLS) examination, access to the test modules on the virtual reality simulator is restricted to the FES examination itself. Although other training modules are accessible on the simulator, the sheer cost of the simulator platform results in a limited availability of the system outside of examination centers. Therefore, there is a significant need for a low-cost, widely available training simulator to help residents and other trainees acquire essential endoscopic skills and prepare for the high-stakes FES exam.

We previously described the development of the Basic Endoscopic Skills Training (BEST) box. This low-cost endoscopy simulator is designed to easily convert any existing FLS box for the practice and evaluation of flexible endoscopic skills consisting of six different tasks [1]. The FLS program is well recognized around the world, with most surgical training programs already in possession of one or more FLS training boxes. By modifying an existing FLS box for endoscopic simulation, costs can be significantly reduced, increasing the likelihood of widespread adoption. In this paper, we will describe our experience and preliminary validation based on the first 100 participants tested on the 'BEST' box.

Methods and procedures

Institutional ethics review board approval was obtained for this research study.

Participants

A total of 100 participants were tested at two sites. Table 1 presents the characteristics of the study participants. For the purposes of this study, an expert was defined as having performed over 200 endoscopic procedures.

Table 1 Participant characteristics

Characteristic	*N*	%
Gender		
Female	15	15
Male	85	85
Specialty		
General surgery	77	77
Gastroenterology	18	18
Other	5	5
Number of procedures		
None	39	39
1–10	13	13
11–50	5	5
51–100	9	9
101–200	4	4
> 200	30	30
Training level		
Other	6	6
PGY1	14	14
PGY2	0	0
PGY3	4	4
PGY4	6	6
PGY5	4	4
Fellow	11	11
Staff	55	55

The Simulator

The FLS adaptation called "BEST" (Basic Endoscopic Skills Training) consists of six tasks, with a 5-min time limit per task (Figs. 1, 2) [2]. A front panel is attached to the FLS box to allow for insertion of a flexible gastroscope. The user manipulates the endoscope and provides instructions to an assistant, such as to open or close a grasper. The six tasks are forward peg transfer, retroflex peg transfer, puncturing, snaring, clipping, and cannulating. User performance was recorded by video capture of the endoscopic view. The performance was subsequently scored for task completion times and user errors.

Global Assessment of Gastrointestinal Endoscopic Skills (GAGES)

In addition to being tested on the BEST box, 55 participants (44 Trainees and 11 Experts) were also scored using GAGES while performing an upper endoscopy on an animal model. GAGES is a validated global rating scale which assesses basic endoscopic skills [3]. Vassilou et al. validated two forms for GAGES, upper endoscopy (GAGES-UE) and colonoscopy (GAGES-C). In this study, GAGES-UE was used. A trained observer who is an experienced endoscopist scored the participant from 1 to 5 on four domains and overall performance to arrive at total score out of 25. For the purposes of this analysis, the "ability to keep a clear endoscopic field" section from GAGES-UE was removed as the BEST adaptation does not simulate this skill, thus the correlated GAGES-UE scores were out of 20.

Fig. 1 **A** The front shaft on the FLS box. **B** Working environment with the endoscope tower

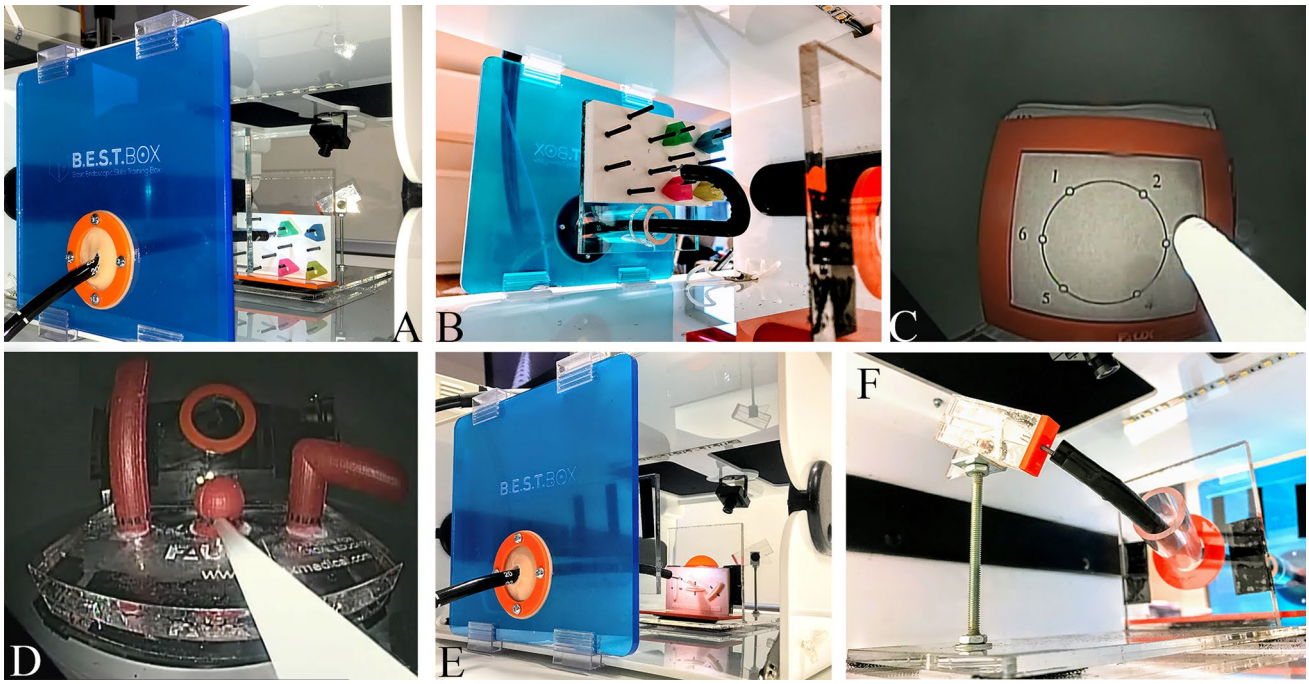


Fig. 2 **A** Task 1—forward peg transfer, **B** Task 2—retroflex peg transfer, **C** Task 3—puncturing, **D** Task 4—snaring, **E** Task 5—clipping, **F** Task 6—cannulation

Statistical analysis

Independent sample *t*-tests and Pearson correlational tests were preformed where appropriate. SPSS 24.0 (SPSS, Inc.) statistical software was used for analysis. *p*-values less than 0.05 were considered significant.

Results

Discriminative ability

Experts consistently finished the tasks faster than Trainees (Fig. 3). Total mean time difference between Experts and Trainees was 514.8 s faster. Mean differences per task ranged from 99.5 to 73.6 s (time differences significant to $p < 0.0001$ were obtained for each task). Experts' completion rate was consistently higher than the Trainees' for all six tasks (Fig. 3).

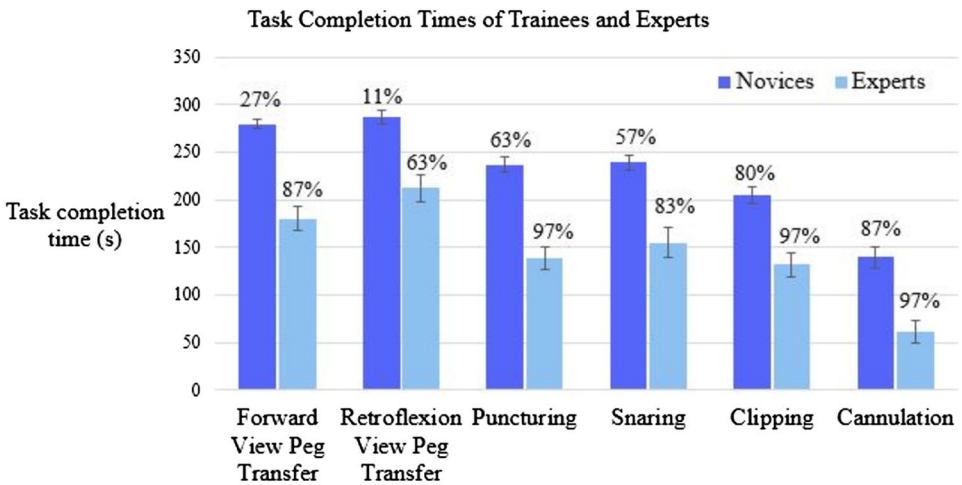


Fig. 3 Mean task completion time of the expert and trainee groups. Percentages indicate successful completion rate per group

Table 2 Test–retest reliability per task

Task	*r* coefficient	*p* (2-tailed)
Forward peg transfer	0.790	< 0.001
Retroflexion peg transfer	0.737	< 0.001
Puncturing	0.560	< 0.01
Snaring	0.478	< 0.05
Clipping	0.451	< 0.05
Cannulation	0.584	< 0.01
Total	0.783	< 0.001

Table 3 Task correlation with total GAGES-UE score

Task	*r* coefficient	*p* (2-tailed)
Forward peg transfer	− 0.584	< 0.0001
Retroflexion peg transfer	− 0.444	< 0.001
Puncturing	− 0.317	< 0.05
Snaring	− 0.295	< 0.05
Clipping	− 0.173	> 0.05
Cannulation	− 0.422	< 0.01
Total	− 0.577	< 0.001

Test–retest reliability

Eleven experts and 44 trainees were tested during an endoscopy course. The course occurred three times during the year, approximately 3–4 months between each meeting. This allowed for the repeat scoring of these same participants 4 months after the initial testing. Of these 55 individuals, only experts and trainees who did not practice on any simulator or performed any endoscopic procedures in between testing intervals were used to determine the simulator's test–retest reliability ($n = 24$). All six tasks demonstrated statistically significant test–retest reliability (Table 2).

Correlation with GAGES-UE

Table 3 shows the relationship between completion time for each BEST box task and GAGES-UE score. A significant relationship between faster completion times and higher GAGES-UE scores was observed for all tasks except the clipping task (Table 3).

Discussion

Endoscopy use in surgery has been increasing significantly and as a result, the need for residents in training to acquire endoscopy skills is greater than ever [4]. The demand for endoscopy training, in combination with the requirement to pass to the official FES exam, has stimulated the recent advancements in simulation-based learning (SBL) for flexible endoscopy.

This study provides preliminary validity evidence that the BEST trainer can differentiate between levels of expertise based on task completion times. Due to the logistics and practicality of administrating the evaluation on the simulator, the time permitted per task was capped at 5 min. Since a statistically higher number of trainees did not complete these tasks as compared to the expert group, the time difference between experts and novices for Tasks 1 and 2 are artificially diminished. Without this time limit, the time difference between the groups would be likely be considerably larger. Evidence of test–retest reliability was demonstrated for all the tasks based on time alone, when individuals were tested within a period of 4 months. Stronger test–retest coefficients were found for the more difficult tasks, however, weaker reliability was found for the tasks with lower mean completion times. Contributing to this may be the fact that even minor changes in completion times result in greater variability with these shorter tasks. Further investigation is underway to see if the incorporation of accuracy variables into a scoring system will increase test–retest reliability.

We have also demonstrated some evidence of concurrent validity between completion times and GAGES scores. GAGES is a validated global rating tool for the assessment of basic endoscopic skills. While these correlations were moderate, it is possible that the incorporation of accuracy variables into a scoring system will also increase the concurrent validity with GAGES in the future.

Several endoscopic simulators have been developed and are currently available for training. These span the spectrum from high-end, resource-intensive virtual reality simulators such as the GI Mentor (3D Systems, Rock Hill, South Carolina) to less expensive benchtop box simulators. These high-fidelity simulators have been evaluated [5, 6] and shown to improve endoscopy training and performance on the official FES exam [7]. Several additional non-virtual reality benchtop simulators have been developed by Ritter et al. [8], Thompson et al. [2, 9, 10], and Berger-Richardson et al. [11].

Ritter et al. developed the Endoscopic Training System (ETS) (Limbs & Things, Savannah, USA), which aims to teach the user five basic endoscopic skills: scope manipulation, tool targeting, loop management, retroflexion, and mucosal inspection. Seventeen participants with minimal endoscopic experience were assessed before and after a training curriculum with ETS [8]. Passing rate improved from 17.6 to 100% by the end the course. Thompson et al. proposed a five part-task endoscopic training box [2] aiming to simulate retroflexion, knob control, torque, polypectomy, and navigation/loop reduction. Evidence accumulated thus far on sixty-two participants suggests that the simulator can differentiate between training levels, show improvement over time, and reduce mental demand [9, 10]. Finally, in their

pilot study Berger-Richardson et al. tested 12 users on their simulator [11]. They found that the simulator can differentiate between experienced and beginner users.

There are several aspects of the BEST trainer box that differentiate from these simulators. The proposed adaptation is a non-electronic, dry model designed to convert a pre-existing and widely available FLS trainer box. This greatly decreases the cost of acquiring the system thus removing one of the major barriers faced to obtaining the simulator. Furthermore, it provides for dual functionality to any training program's existing FLS box, allowing for both laparoscopic as well as flexible endoscopic skills training.

One of the potential disadvantages of our system includes the need for the use of a standard flexible endoscope. Although this may potentially be a barrier, this dry portable benchtop training system does not utilize explants and can be easily taken to the endoscopy unit to be used with any clinical endoscope. Furthermore, ongoing efforts by various groups to design an inexpensive training endoscope will eventually completely remove this barrier. The need to have an assistant for opening and closing some of the instruments does pose an additional barrier. At the same time, however, it increases the realism of the simulator through the use of real endoscopic tools as well as helps trainees develop communication skills essential to therapeutic procedures in endoscopy. In an evaluation setting, the assistant can also serve to evaluate the trainee.

Unlike some other simulators, this simulator was designed specifically with an emphasis on therapeutic rather than diagnostic skills and thus does not simulate mucosal inspection techniques. This was done with the view that these therapeutic skills, as opposed to mucosal inspection, are less likely to be encountered and practiced by trainees during live cases, and such were the main focus of this simulator [12, 13].

Conclusion

Our results thus far on the first 100 participants contribute to the validity evidence of the simulator including skill differentiation, test–retest reliability, and concurrent validity with the GAGES global rating scale. Further efforts are ongoing to develop a scoring system incorporating both task times and errors. This trainer has the potential to provide a low cost yet effective system for endoscopic skills training and evaluation.

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Compliance with ethical standards

Disclosures Ilay Habaz, Silvana Perretta, Allan Okrainec, Oscar M Crespin, Andrea V Kwong, Ethan Weiss, Else van der Velden, Ludovica Guerriero, Fabio Longo, Pietro Mascagni, Louis WC Liu, Timothy D Jackson, Lee L Swanstorm, and Eran Shlomovitz have no conflict of interest or financial ties to disclose.

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