Allowing New Opportunities in Advanced Laparoscopy Training Using a Full High-Definition Training Box

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Abstract

Introduction. Simulated laparoscopy training is limited by its low-quality image. A high-definition (HD) laparoscopic training box was developed under the present necessity of simulating advanced surgery. Objective. To describe and test a new HD laparoscopic training box for advanced simulation training. Methods. We describe the features and image quality of the new training box. The simulator was tested and then evaluated by a group of 76 expert surgeons using a 4-item questionnaire. To assess the effectiveness of training using this simulation box, 15 general surgery residents were trained to perform a laparoscopic jejuno-jejunostomy in a validated simulation program. They were assessed with objective rating scales before and after the training program, and their results were compared with that of experts. Results. The training box was assembled using high-density fiberglass shaped as an insufflated abdomen. It has an adapted full-HD camera with a LED-based illumination system. A manually self-regulated monopod attached to the camera enables training without assistance. Of the expert surgeons who answered the questionnaire, 91% said that the simulation box had a high-quality image and that it was very similar to real laparoscopy. All residents trained improved their rating scores significantly when comparing their initial versus final assessment (P < .001). Their performance after completing the training in the box was similar to that of experts (P > .2). Conclusions. This novel laparoscopic training box presents a high-resolution image and allows training different types of advanced laparoscopic procedures. The simulator box was positively assessed by experts and demonstrated to be effective for laparoscopy training in resident surgeons.

Keywords

surgical education, simulation, image-guided surgery

Introduction

Laparoscopic surgery has become the standard approach for the most common abdominal surgical procedures. It was initially described for simple procedures, such as appendectomy or cholecystectomy but later extended to much more advanced procedures such as colorectal, bariatric, and hepatobiliary surgery. Laparoscopic surgery is associated with less surgical trauma, faster recovery, shorter hospital stays, and better cosmetic results.⁵,⁶ All these advantages have led laparoscopic skills to become a minimal competence requisite for general surgery programs.⁵

Advanced laparoscopic surgery involves long learning curves, where residents and fellows must acquire technically demanding minimally invasive skills, such as intracorporeal suturing and knot tying.⁵,⁶ Restrictions in working hours, less exposure to patients, and ethical concerns make the optimal learning of these advanced surgical skills even more difficult.⁷-¹⁰ Surgical simulation has appeared to be the answer to these problems because technical aptitudes learnt in the training box transfer to real clinical settings.⁷,¹¹

Simulation in medical training has been demonstrated to reduce the learning curves, lower the costs of training, and decrease the complications associated with some medical procedures, such as central venous catheter insertion.¹²-¹⁶ In surgery, simulation-based training allows...
inexperienced residents to acquire skills through deliberate practice in a safe educational environment without risks for the patients.9,17

There are many different simulation settings, from cadavers to virtual reality trainers.18 Cadavers and animals are high-fidelity models (very similar to real procedures) but are of limited use because of high costs and ethical concerns. Virtual reality simulators are reusable and easy to use, but many lack haptic feedback and high-quality images, so they are especially convenient for basic laparoscopy training.8,18

Box trainers have gained great popularity because they are inexpensive, preserve haptic feedback, and present the opportunity to use standard endoscopic instruments. When compared with virtual reality trainers, no difference was found in skill acquisition, yet box trainers were much more cost-effective ($77,500 vs $120,000 [US dollars] in the first year of implementation).19,20 Box trainers can be used in simulation models to practice basic and advanced laparoscopic skills. For example, the fundamentals of laparoscopic surgery (FLS) course uses bench models to practice basic laparoscopic skills such as 2-dimensional vision, bimanual dexterity, and handling long instruments with an amplified tremor.21,22 The fidelity of the simulation depends on the model used, from low-fidelity rubber tube anastomosis to complex high-fidelity ex vivo models for hepatobiliary surgery.7,8,20 The problem is that most box trainers lack high-definition (HD) images comparable with the image in the operating room and cannot simulate entire operations.

The objective of this study is to present a new training box with a HD camera designed for practicing advanced laparoscopy. It allows practicing the performance of an anastomosis using up to 2- to 3-mm ducts without video delay.

Materials and Methods

The Laparoscopic Training Box

We describe the main specifications of the laparoscopic training box and HD image features.

Survey to Expert Bariatric Surgeons

A total of 76 expert surgeons attending an international minimally invasive course were asked to answer a 4-item questionnaire constructed using a 5-point Likert scale to measure their perception of this bench model when compared with the real operating room. All surgeons used the simulation box to create a side-to-side intestinal anastomosis in an ex vivo validated training model.23,24

Assessing Efficacy of the Simulation Box

To assess resident apprenticeship using the simulation box, 15 first-year residents (PGY1) from the postgraduate course in general surgery at our institution were trained in a validated training program.23 All trainees had completed the FLS course before the advanced training. The program consisted of 14 sessions of increasing difficulty for the completion of a 2-layer hand-sewn jejuno-jejunostomy. The details about the simulation program are described elsewhere.17,23 The PGY1 residents were evaluated before and after the program, and their performance was compared with that of 20 expert bariatric surgeons who completed the same model. The participants were evaluated using validated global and specific rating scales23-25; total procedure time was also recorded. Nonparametric tests were used for statistical analysis in the SPSS program (IBM software).

Results

The Laparoscopic Training Box

The box was assembled using high-density fiberglass shaped as an insufflated abdomen, and 4 laparoscopic ports were placed strategically to simulate different positions used in advanced procedures (Figure 1). The box was first designed as a clay model to get the shape and size of an adult man; then, 2 surgeons tested it for ergonomics and similarity to the operating room. A negative model was then made of acrylic to finally build the fiberglass box. A group of young engineers and designers assessed the manufacturing process.

The torso includes an intervened full-HD camera that is controlled through an integrated Arduino panel. The camera runs at 60 frames per second at 1920 × 1280 resolution, abolishing the possible delay in live streaming in HD screens when using the 2 incorporated High-Definition Multimedia Interface (HDMI) ports. The camera we chose is a Replay Prime X HD camera; because it combines light-weight, auto image processing and small size, it was electronically adapted to fit the simulator. A
manually self-regulated monopod was attached to the camera to enable training without assistance. High-resistant impe
dance touch buttons were created to control the camera’s main menu, and an analogue dimmer controls the illumination system based on LED lights.

The training box allows practice on a range of tasks, from basic FLS tasks to advanced 2-mm duct-to-mucosa anastomosis with excellent image resolution (Figure 2). The image quality is compared with that of other commercially available endotainers in Figure 3. The cost of this simulation box is US$3500, and it is designed to be portable and easy to carry. However, to take full advantage of the box trainer, it should be used in surgery departments and simulation centers where many students can practice.

Survey to Expert Bariatric Surgeons
A total of 76 expert bariatric surgeons answered the 4-item questionnaire. Most surgeons (91%) felt that the simulation box gives an image quality similar to or better than that of common laparoscopy in the operating room. Of the responders, 95% felt comfortable with instrument manipulation in the training box, and 75 (98%) considered that the simulation box had a high fidelity and was optimum for advanced laparoscopic simulation (Table 1).

Assessing Efficacy of the Simulation Box
A total of 15 first-year general surgery residents were trained in the simulation box. All of them improved their global and specific rating scores significantly when compared with their initial versus final assessment. When compared with expert laparoscopic surgeons, experts had significantly higher scores than trainees in their initial assessment, but no differences were seen when comparing experts with PGY1 residents in their final assessment (Figure 4 and Table 2). Average operative time decreased from 36.3 ± 8.9 to 22 ± 4.2 minutes (P < .001).

Discussion
Traditional surgical training was first described by Sir William Halsted in 1889.26 The “observe one, do one, teach one” approach is based on learning by watching an expert and practicing on real patients.12 The term learning curve is usually assessed as the explanation for higher morbidity and mortality in inexperienced surgeons.9,12,20,27

As an answer to advancing technologies, growing patient safety precautions, and working-hour restrictions, complex simulation settings have been created for surgical education. Based on airplane pilot experience, it has been demonstrated that surgical simulation shortens the learning curves, reduces learning costs, and decreases procedure-related...
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complications.\textsuperscript{28,29} Also, it has been proved that skills learned in the simulation lab transfer to the operating room.

There are many simulation settings, yet box trainers appear to be the most cost-effective ones and also devoid of animal ethics concerns. Box endotrainers can be used to complete basic and advanced procedures because their fidelity being high or low depends on the model used.\textsuperscript{14,18,21,27,30} These trainers also use standard laparoscopic instruments for deliberate practice.

Video quality is critical for an accurate simulation.\textsuperscript{31-33} This is especially important in advanced simulation, where HD cameras are needed.\textsuperscript{34} Most endotrainers have low-quality images; therefore, many simulation labs have to use high-cost, regular laparoscopy equipment for advanced simulations.\textsuperscript{35} We present a novel training box that allows us to perform basic and advanced laparoscopic procedures with an HD image, using regular

![Image](image1.png)

**Figure 3.** Image quality comparison between high-definition endotrainer (images on the left) and regular fundamentals of laparoscopic surgery (FLS) endotrainers (images on the right) in FLS block transfer and choledochojejunostomy ex vivo model.

<table>
<thead>
<tr>
<th>Question</th>
<th>Strongly Agrees/Agrees</th>
<th>Indifferent</th>
<th>Strongly Disagree/Disagree</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Simulator has similar image quality compared with the OR</td>
<td>91%</td>
<td>3%</td>
<td>5%</td>
</tr>
<tr>
<td>2. Manipulating instruments is easy and comfortable</td>
<td>95%</td>
<td>2%</td>
<td>4%</td>
</tr>
<tr>
<td>3. Simulator has high fidelity</td>
<td>91%</td>
<td>5%</td>
<td>3%</td>
</tr>
<tr>
<td>4. Simulation endotrainers should have high fidelity and image quality for optimum training</td>
<td>98%</td>
<td>1%</td>
<td>1%</td>
</tr>
</tbody>
</table>

Abbreviation: OR, operating room.

![Image](image2.png)

**Table 1.** Four-Item Questionnaire Results of 76 Expert Bariatric Surgeons.

**Figure 4.** Global rating scale scores obtained by residents before and after the advanced laparoscopic training program, compared to the score obtained by experts. Abbreviations: PGY1, postgraduate year 1.
endoscopic instruments. Its manually regulated camera enables training without the need for assistance. Many simulation settings can be used, from the basic FLS course to advanced 2-mm duct-to-mucosa anastomosis. Two HDMI ports are included for simultaneous display in different monitors or for HD recording purposes.

Image characteristics and instrument versatility were assessed by a group of 76 laparoscopy experts, and most surgeons (>90%) felt comfortable with the simulation characteristics and felt that they were similar to operating room characteristics. Also, a first-year resident group trained through deliberate practice in the simulation box significantly improved their surgical skills. The skills acquired at the end of the exercise were similar to that of surgical experts.

Conclusion

We present a new low-cost laparoscopic simulation box with high-quality images and minimal delay. The simulation created was very similar to the OR and allows one to perform tasks from basic FLS to very advanced procedures. The endotrainer was successfully evaluated by expert laparoscopic surgeons and was effective in training novice residents. HD box trainers may be the answer to shorten basic- and advanced-procedure learning curves in a safe and low-cost setting.

Acknowledgments

We thank Sergio Silva Miranda, Rodrigo Mejías, Emery Acuña, Eduardo Eade, and Ricardo Ramirez who helped with the design and development of the HD laparoscopy endotrainer.

Author Contributions

Study concept and design: Pablo Achurra, Julian Varas
Acquisition of data: Pablo Achurra, Julian Varas, Erwin Buckel
Analysis and interpretation: Pablo Achurra, Julian Varas, Antonia Lagos, Ruben Avila, Rodrigo Tejos, C. Boza, Juan Alvarado
Study supervision: Pablo Achurra, Julian Varas, Nicolas Jarufe

Declaration of Conflicting Interests

The author(s) declared the following potential conflicts of interest with respect to the research, authorship, and/or publication of this article: JV is the main developer and commercializes the HD laparoscopic simulator. CB commercializes the HD laparoscopic simulator. The rest of the authors have no conflicts of interest to declare.

Funding

The author(s) disclosed receipt of the following financial support for the research, authorship, and/or publication of this article: This study was supported by internal funding.

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