Synthetic Torso for Training in and Evaluation of Urologic Laparoscopic Skills

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ABSTRACT

Background: The expanding use of advanced minimally invasive surgical techniques demands more advanced training methods, objective measures of resident performance, and more realistic and anatomically correct training models.

Materials and Methods: A new synthetic torso for urologic laparoscopy training was developed and assessed. The trainer, Lapman, was based on the Visible Human Model and has the exact shape of a human torso. The torso models the outer shape of the body and the abdominal and pulmonary cavities. Animal or synthetic models of the abdominal organs may be placed in the abdominal cavity. An abdominal wall provides access and seals the cavity and can be replaced after repeated punctures with laparoscopic instruments. The thoracic cavity connects to a pneumatic pump to simulate breathing. In order to render realistic mechanic properties, the torso is cast of materials with elastic properties similar to those of soft tissue and incorporates a synthetic skeleton. These similar mechanical properties and the thoracic insufflation create realistic ventilatory motion simulation.

Results: Twenty-five individuals—medical students, residents, and attending urologists—participated in a study comparing Lapman with a standard training box. Lapman presented several advantages over the traditional training box, specifically with regard to internal and external views and the incorporation of a realistically shaped abdominal wall. A significant and recurrent theme was the value of the synthetic wall as a tool to gain a greater appreciation of the importance of port placement. Study participants at all levels of training appreciated that Lapman gives a more realistic approximation of the operative procedure.

Conclusions: The novelty of the trainer consists in its anatomic shape, realistic mechanical properties, and ventilatory simulation. This paper reports on its design, construction, and preliminary tests.

INTRODUCTION

IN CONTRAST TO OPEN SURGICAL TECHNIQUES, laparoscopic surgery typically results in shorter hospitalization and reduced patient morbidity, lower analgesic dosages for pain control, and faster recovery.1–5 However, laparoscopic surgery requires significant surgeon training. The complexity of urologic applications and the low relative incidence of appropriate cases make it essential for the urologist to have access to training models.6–8 In an attempt to provide training, numerous urologic laparoscopy programs and short courses have been established.9–11

For most urologists, the short course is the only opportunity to acquire the skills necessary to initiate a laparoscopic practice. The difficulty for these individuals is translation of skills practiced in the laboratory to use at the operative table. Traditional laparoscopic trainers have focused on simple discrete tasks in an environment devoid of anatomic challenges. Although there is a role for such training, the importance of working within the abdominal cavity cannot be understated.

Similarly, residency programs are challenged to guide the development of these skills among their trainees.12 Accreditation boards will soon require objective assessment of surgical performance.13 The use of trainers and recording performance is one possible pathway to achieve this goal.

We developed Lapman to address deficiencies identified in standard laparoscopic trainers. Using the Visible Human Proj-
FIG. 1. Development of model. (A) Slice from Visual Human. (B) Three-dimensional reconstruction in ProEngineer.

ect of the National Library of Medicine, an exact synthetic replica of the human torso, including the thorax and abdominal cavity was created. Once it was manufactured, we conducted a preliminary randomized study to assess physician and medical student perceptions of this new device.*

MATERIALS AND METHODS

Trainer design, development, and description

Lapman was developed to mimic the anatomic and mechanical properties of the human torso and to provide means of incorporating synthetic or animal organs in situ for performing realistic surgical maneuvers.

The simulator is based on the three-dimensional (3D) model of a typical man created from segmented and reconstructed data available through the Visible Human Project of the National Library of Medicine. Transverse slices (Fig. 1) at an average of 5-mm intervals (from section no. 4155 at sagittal-coronal coordinate z = 463 voxel = 154 mm to section no. 2048 at z = 3190 voxel = 1063 mm) were obtained. This set spans the entire torso, including the thoracic, abdominal, and pelvic regions.

A manual segmentation method was used to define the outer body and pulmonary and abdominal cavities in these image slices (Fig. 1A). The volume created for the abdominal cavity includes all the peritoneal and retroperitoneal organs. A new aspect in creating the 3D model (Fig. 1B) was its construction using engineering design software, Pro/Engineer (PTC, Inc.), which was selected for manufacturing purposes. The model was used to design and fabricate negative molds for casting the trainer (Fig. 2). These were digitally manufactured of woodblocks using computer numerically controlled (CNC) equipment (Fig. 2A) in our laboratory.

The torso was cast of Cine Skin Silicone A/B from Burman Industries Inc. (Van Nuys, CA). This material was selected by testing a number of skin-like materials (Moulage and Mold La-

FIG. 2. Development of model (continued). (A) Fabrication of mold by CNC machining. (B) Components for torso and abdominal wall.

*For more information on the work of the laboratory, visit http://urology.jhu.edu/urorobotics
tex material from Dick Art Materials Inc. [Galesburg, IL], Duralco from Cotronics Corporation [Brooklyn, NY], and Latex mold and mask materials from Douglas & Sturgess [San Francisco, CA]) with respect to the ease of the molding process, resulting mechanical properties, ability to vary these properties by changing the mixing components ratios, and by color and dye pigments available for proper color settings. The elastic properties of the selected material also allow for ventilatory-motion simulation. Because kidney position and other abdominal organs fluctuate with breathing, this was an important factor in designing and creating the model.

In order to provide realistic support and structure for the body and ventilatory motion, a synthetic skeleton was placed inside the molds prior to casting of the torso (Fig. 3). The lungs were initially cast of a low melting-temperature wax in a different mold. These were incorporated in situ before molding of the torso. After curing of the rubber compound, the wax was extracted by melting, to leave behind the cavities of the lungs.

The disposable abdominal wall was cast in a separate mold (Fig. 2B). It presents a two-layer structure of rubbers with different consistencies. The wall is attached to the body using a hook and loop fastener on its boundary and is hermetically sealed over the base with an elastic rim (Fig. 4A). This allows abdominal insufflation, as can be seen in Figure 4B.

Six connection hoses were included next to the spine from the left and right retroperitoneal fossas and out through the neck. These may be used to simulate blood and urine flow to animal organs placed within the torso.

**Evaluation methods**

We compared the self-evaluation and trainer scores of a group of subjects with either a standard box simulator or the anatomically correct simulator, Lapman (Fig. 5). Twenty-five medical students, residents, and attending urologists were enrolled in the study. A 15-minute instructional presentation given by an endourology fellow provided a basic overview of laparoscopic surgery and described and demonstrated the tasks to be practiced. The participants were then randomized and allowed to work for 2 hours, during which the fellow was present to provide assistance.

In the case of the laparoscopic training box case (Fig. 5A), a 10-mm port (U.S. Surgical Corp.) was placed in the middle for camera access. Ports of 5 mm and 10 mm (USSC) were placed for instrument access. A large plastic Petri dish was used to support and immobilize a porcine kidney within the box. With the Lapman (Fig. 5B), a 10-mm port was placed at the umbilicus for camera access. A second 10-mm trocar 4 cm lateral to the umbilicus at the midaxillary line and a 5-mm port 4 cm superior to the umbilicus were placed for instrument access. A porcine kidney was placed in the abdominal cavity in the left retroperitoneal fossa. The same type standard video cart was utilized for both simulators, and 10-mm 30° laparoscopes were connected to the camera and a light source (Stryker Instruments, Santa Barbara, CA). The laparoscope and camera were held and manipulated in both cases by another participant. The following tasks were performed: trocar placement, instrument selection and manipulation, needle and suture manipulation, suturing, and intracorporeal knot-tying.

After each session, the participants were asked to complete a questionnaire identifying the training model, the exercises performed, and the instructor. It also queried the level of education and surgical experience of the subject. The subjects ranked
their responses on a Likert 5 point scale, from “poor” to “excellent” and from “strongly disagree” to “strongly agree.” Participants also had the opportunity to provide written comments, suggestions, and critiques.

The questionnaires were then converted to an analog scale by assigning “strongly disagree” and “poor” a value of 1 and “strongly agree” and “excellent” a value of 5. The results were stratified by the simulator used. A mean and standard deviation were then calculated for each question. The means were compared and p values calculated using Student’s standard t-test. All statistical computations were performed using STATA. The level for statistical significance was 0.05.

RESULTS

Table 1 summarizes the statistical results for the questions asked in the survey. Users found Lapman significantly easier to use and a better approximation of real anatomy with a better internal view (p = 0.008, <0.001, and <0.001, respectively). The respondents felt that it was a better design (p = 0.002). Moreover, students in both groups agreed or strongly agreed that approximating real anatomy was important and that port placement was important for training (p = 0.064 and 0.500, respectively).

DISCUSSION

Training programs use a sequence of theoretical, simulator, and animal training followed by mentored surgery, whereas short courses address only the first three of these steps. Laparoscopy simulators can be classified as either physical devices or virtual reality (VR) simulators.

Traditional training devices present box architecture with flexible trocar entry ports. These trainers are designed for gen-

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FIG. 5. Testing set-up on box (A) and Lapman simulators (B).
eral laparoscopy training in the initial phases for acquiring through-the-hole, inverted manipulation skills, depth perception under monitor vision, and hand–eye coordination but fail to give a realistic anatomic perspective. For example, Mughal16 developed a box trainer designed for basic inverted-motion laparoscopy training. Munro and associates17 and Kopchok et al18 reported more realistic box trainers that allow trocar placement and abdominal insufflation. Seattle’s Simulab Corporation,19 along with the University of Washington Center for Videoendoscopic Surgery, devised a simulator with the purpose of replacing live-animal training. This simulator consists of a synthetic body model and procedure-specific packs and allows trainees to introduce surgical instruments and practice laparoscopic skills on simulated latex organs with standard instruments and laparoscopes.

Recently, several VR surgical simulators have become available.20,21 These trainers use a computer-modeled human body and laparoscopic-like input devices (haptic interface) through which the trainee interacts with the model to perform specific surgical procedures. For example, MIST-VR,20,22 a laparoscopic trainer developed by Virtual Presence, allows the simulation of several laparoscopic procedures. Even though VR simulators are potentially the ideal training solution, providing a cost-effective and convenient setting, their application and utility are at present limited by the high complexity of realistically modeling human organs.21,23

The next training step, using live animals, is realistic with respect to tissue properties, but the use of animals is limited by cost. In addition, animals present different anatomy for port placement and dissection.

We report the development of a new laparoscopic trainer, Lapman, designed for laparoscopy on the upper urinary tract presenting exact human anatomy and mechanical properties similar to those of the human body. The simulator is intended to provide an additional training step, together with box simulators, live animal training, and mentored surgery, with the goal of improving the learning curve. In addition, Lapman could reduce or even eliminate the need for animal training. Lapman incorporates several characteristics of previous designs and adds other innovative features in a urologic laparoscopy trainer. Even though the development cost of the initial prototype was much higher, we believe that a commercial version of the Lapman simulator would not be significantly more expensive than classic box-type simulators.

The trainee participates in numerous steps, beginning with inserting the Veress needle, insufflating with CO2, determining the port sites, and placing the trocars. The trainee can then perform a variety of laparoscopic procedures in an anatomically consistent setting. The simulator allows the student to dissect and develop tissue planes, excise and reconstruct tissue, and learn suturing and electrocautery techniques. Moreover, the simulator is designed for the placement of an animal kidney in the retroperitoneum so that the trainee operates on realistic tissues, thus simulating various procedures such as renal biopsy, pyeloplasty, nephrectomy, and even partial nephrectomy.

The majority of participants in this study were medical students. It is not surprising that they would not identify port placement as a significant value of this model, as this is a relatively subtle skill that is developed as an individual’s laparoscopic experience expands. The experienced laparoscopists in this pilot study uniformly described this as a clear attribute of the synthetic torso. In order to measure the value of this particular aspect of the model adequately, one would need to evaluate longitudinal performance among a groups of individuals early in their training who were randomized to black box versus synthetic torso for laboratory training.

There were many limitations to the study performed. There was no objective evaluation of the participants, nor do we know if self-reported evaluations will translate to better surgical performance. The goal of the study was to collect the subjective impressions of how simulator design impacts training and to assess our Lapman design. A prospective study will be needed in order to assess objectively how the schedule impacts training: specifically, what is the most effective length of a training session and how many sessions are most effective. Future studies could also evaluate the ability of these training programs to decrease errors in the operating room, as well as what additional skills can be taught effectively through standardized lectures or video presentations.

CONCLUSION

The current paper presents a new laparoscopic simulator designed for urologic interventions. The natural human body configuration allowed the trainee to experience the correct spatial representation and distribution of trocars that are normally found in the human abdomen during laparoscopic surgery. The mixed synthetic/animal model with induced ventilatory motion of the organs rendered a most realistic model compared with existing box simulators. Lapman was tested in a limited comparative study and showed subjective superiority over the traditional box trainer.

ACKNOWLEDGMENT

The research presented in this paper was supported in part by grant No. PHD0103 from the American Foundation of Urologic Disease (AFUD). The contents of this paper are solely the responsibility of the authors and do not necessarily represent the official views of the AFUD.

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