The Use of Models in Laparoscopic Education

STEPHEN J. SHAPIRO, M.D., F.A.C.S.
ASSISTANT CLINICAL PROFESSOR OF SURGERY, UCLA MEDICAL CENTER
DIRECTOR, ENDOCARE, LOS ANGELES, CALIFORNIA

MARGARET PAZ-PARTLOW, M.F.A., ASSOCIATE DIRECTOR, TECHNICAL SERVICES
MIDWAY HOSPITAL MEDICAL CENTER, LOS ANGELES, CALIFORNIA

LEON DAYKHOVSKY, M.D., ASSISTANT DIRECTOR, LASER LABORATORIES
CEDARS-SINAI MEDICAL CENTER, LOS ANGELES, CALIFORNIA

LEO A. GORDON, M.D., F.A.C.S., ATTENDING SURGEON
CEDARS-SINAI MEDICAL CENTER
ASSOCIATE DIRECTOR, ENDOCARE, LOS ANGELES, CALIFORNIA

From earliest times, visual aids–from crude diagrams to complex, beautiful wax anatomical models[1]–have been created to enhance the surgical learning process. Surgical educators realized early that suitable models could be used to develop the needed technical expertise essential to the safe performance of surgery. Practice on models also assisted in developing surgical judgment.

The reorientation of general surgery to a minimally invasive approach highlighted the need for teaching models in clinical surgery. Both the public and the surgical communities have begun to see the need for guidelines that can establish surgeons' credentials when performing these demanding laparoscopic procedures.[2-4] It would be to the benefit of all if reliable assessment of technical ability could be effected and the way in which surgeons master new approaches could be modernized. Additionally, changing healthcare systems will insist on increased cost-containment and efficiency both in surgical interventions and surgical education.[5] As priorities in surgical training are re-evaluated,[6] new approaches to postgraduate surgical education are needed.

Laparoscopic surgery requires superior technical ability and eye/hand coordination. These skills are needed to perform three-dimensional tasks in a two-dimensional field. Traditional surgery requires tactile sense, as well as visualization and unlimited access to an open three-dimensional visual field. Significant technical restructuring and adaptation must take place for the surgeon to make a successful transition.[7] How can these new laparoscopic skills be acquired and maintained? How can progress be assessed? One answer is to work with realistic inanimate models designed for specific surgical tasks that can be performed within a simple video module.

MODEL CONSTRUCTION

Frustrated with the lack of suitable surgical practice materials, one of the authors (SS) contacted a special-effects artist and discussed the possibility of building appropriate models. Each model's purpose was delineated and operations were described in detail. Tissue consistencies and textures had to be defined for each application. The artist then proceeded to create oil-

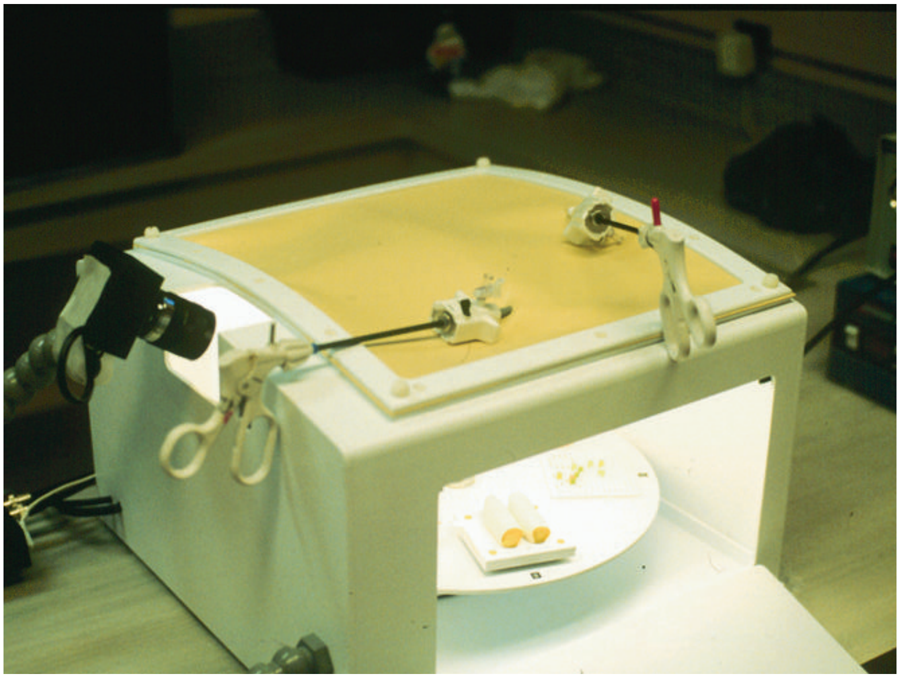

Figure 1. Self-contained training module with built-in camera and light source.

based clay sculptures that could be continuously manipulated until the desired shapes and proportions were achieved.

Once all agreed on the initial sculpture, a silicone mold was made from the piece. Since the molds are only a half inch thick and very pliable, they are mounted on a stiff plaster jacket. The mold is then filled with a self-skinning polyurethane foam of predetermined texture (an extensive range is possible). The finished structure is painted with urethane paint simulating the color of human tissue.

In order to create hollow tubular structures, such as the biliary system, *Y*-shaped wax constructions were coated with urethane, reinforced with fibers, and given a second coat. Once finished, the "biliary tree" was immersed in hot water. The softened wax was expressed from the tubular structures, leaving a hollow viscus. This process resulted in "tissue" with the color and consistency of human tissue.

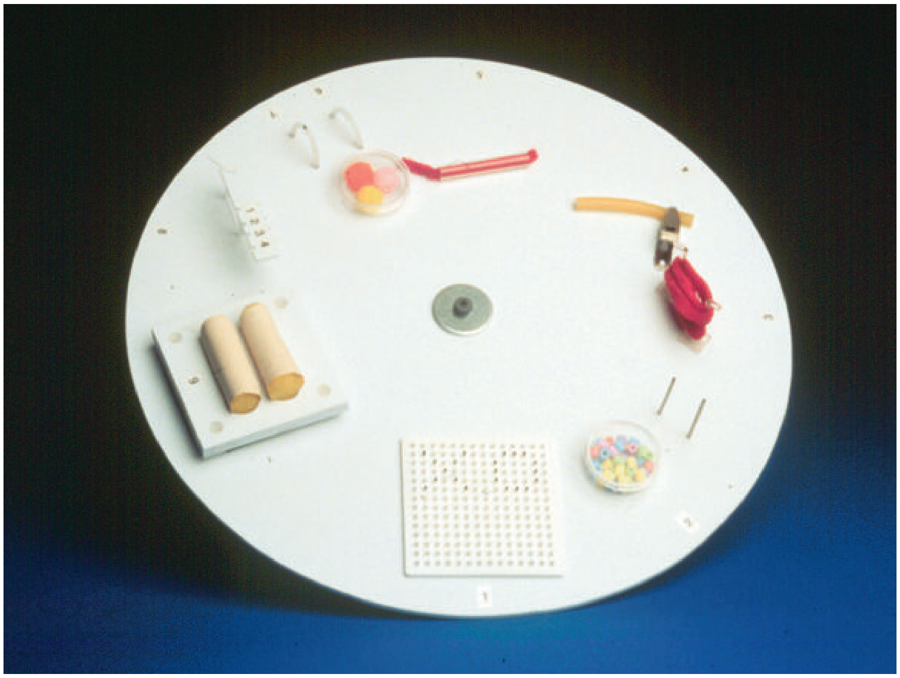

Figure 2. Basic skills board with nine exercises.

Camera Box

To facilitate the use of these models, a plastic box with built-in camera and general lighting is used (Fig. 1). The models are placed into this apparatus. The box is connected to a stop watch/character generator, television monitor, and videorecorder. Thus, a student can ID, time, and videotape his tutorial, creating a record that can be later analyzed and compared with his earlier performance.

We conducted a study with a group of 10 surgeons and gynecologists. They went through a five-session course of progressive suturing exercises. The same exercises were repeated and timed, and each session was proctored. When the data was analyzed, the participants' improvement was found to be statistically significant in four out of five exercises.[8]

Basic Wheel

The basic wheel contains a series of exercises designed in a stepwise manner to introduce the neophyte to the rigors of working remotely from a two-dimensional image (Fig. 2).

1. Beads are placed on pegs defining marked figures X and O. They are placed first with the right hand, then with the left hand. This drill can be made more challenging by alternating X/O, left/right bead placement.
2. The same beads are then threaded on two poles.
3. A knitted cotton ring is twisted over a top post. It is twisted in the middle to resemble the number "8." The ring's other end is placed over the bottom post.
4. An endoloop is placed on rubber tubing. The distal tip of the tubing is cut, leaving the endoloop in place.
5. A pipe cleaner is fed through a tube with the right hand, then the left.
6. A 2-0 suture is placed through a ring. An extracorporeal Roeder's knot is tied and positioned on the ring using a knot pusher.
7. Small pompoms are passed through both rings.
8. Pompoms are passed from instrument to instrument.
9. Using a suture, a needle is passed around the stick at the black indicator mark. The suture is tied extracorporeally, and the knot is slid down to an indicator using a knot pusher.

10. Using a 3-0 or 4-0 suture, three interrupted sutures are placed through the form; they are tied intracorporeally. This is repeated using continuous technique and ski needle.

Suturing Model

The suturing model was developed to provide greater facility with suturing and knot tying (Fig. 3). Laparoscopic suturing is the next logical progression after the skills board. This procedure-specific model includes three anatomical areas in which laparoscopic suturing and tying skills can be acquired and maintained. These consist of the following:

1. The esophageal hiatus.
2. The anterior wall of the stomach.
3. A gastroenterostomy.

In the first exercise, the hiatus is approached and closed under tension with an extracorporeal knot, nudged into position against the tissue with a knot pusher. The knot is secured and the suture cut. Next, the student turns to the stomach, where an anterior seromyotomy has been made. Intracorporeal knot-tying techniques can be practiced here. Several individual sutures can be placed in this part of the model. The third exercise involves the gastroenterostomy, where one may develop proficiency with intracorporeal knots and running stitches. Closing maneuvers such as the Aberdeen knot are practiced.

The suturing surfaces consist of removable inserts which can survive several sessions and are easily replaced. The acquisition and maintenance of suturing and tying techniques is mandatory for advanced laparoscopic procedures such as hiatal hernia repair and colon resections. This model provides a lifelike environment in which to practice these techniques.

Bilary Model

Because of the presence of common bile duct stones, laparoscopic transcystic bile duct exploration is the next skill to be acquired after laparoscopic cholecystectomy. The biliary model presents a lifelike simulator demonstrating the gallbladder, cystic duct, and common duct (Fig. 4). To practice common duct stone retrieval, small stones (8 mm or less) are loaded from the top back of the model, through the posterior common duct towards the ampulla. The model is then placed in the viewing box as described above. Trocars are placed in the usual positions for laparoscopic cholecystectomy. The student then assembles the necessary tools for exploration.

Transcystic common duct exploration requires additional instruments and accessories. A guidewire, a dilatation balloon, a 9-10 Fr. flexible choledochoscope, and a 3 Fr. Segura spring-loaded basket are required. The lubricated guidewire is placed through the balloon catheter. The catheter is then placed in a 3-mm reducer that is then introduced into the trainer though the uppermost 5-mm trocar on the assistant's side. This simulates the operative environment. The guidewire is then introduced into the biliary system through the opening provided in the cystic duct. The dilatation balloon is pushed over the wire into the cystic duct and is inflated with saline to 12 atmospheres of pressure. In a patient the cystic duct would then be dilated for three to five minutes. This process is simulated in the exercise. The balloon is then removed while the wire is advanced into the common duct. The choledochoscope


Figure 3. Suture model.

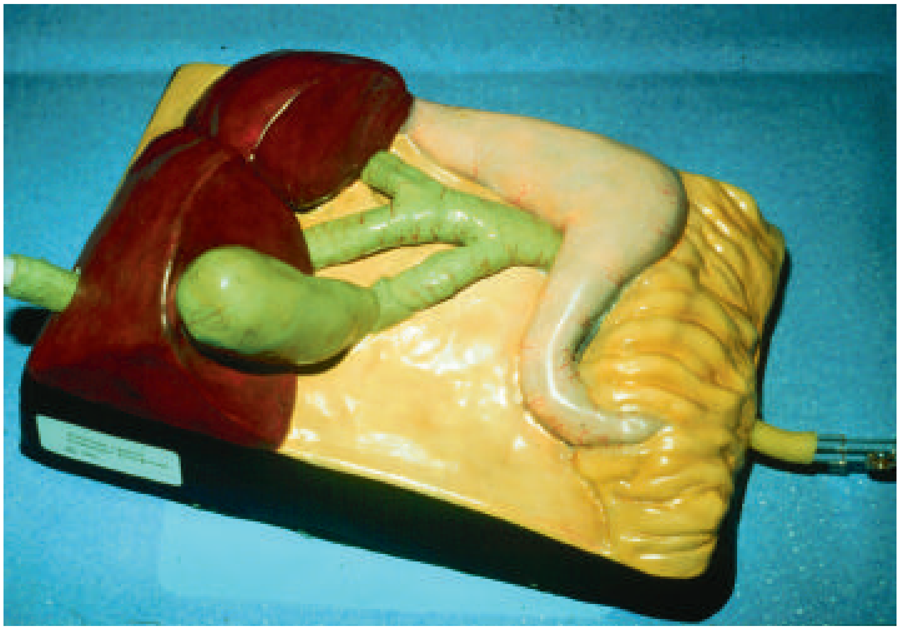
Figure 4. Biliary model for training in transcystic laparoscopic bile duct exploration.

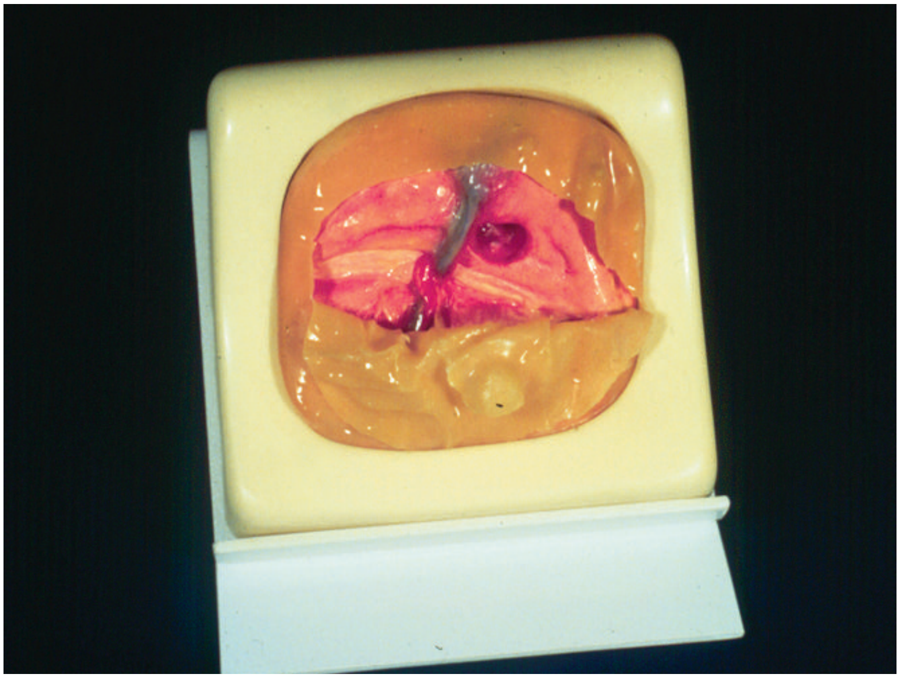

Figure 5. Hernia model with exposure of retroperitoneal anatomy.

(with camera attached) is advanced over the wire into the common duct. The endoscopic image is then seen on the television monitor. The wire is removed.

Once a stone has been located, a 3 Fr. Segura basket is advanced through the choledochoscope's instrument channel. It is advanced beyond the stone. The operator and assistant, by maneuvering both the basket and endoscope tip, grasp and retrieve the stone. Both basket and endoscope are removed simultaneously in the abdominal cavity with the stone. This exercise can be repeated multiple times. The biliary model can be filled with irrigation fluid, as it is self-draining. The fluid gives the stones a very lifelike appearance in the model ductal system.

Hernial Model

In no other area of laparoscopic education is there a greater need to relearn anatomy than in the area of laparoscopic herniorrhaphy. The retroperitoneal anatomy is well defined in the hernia model. The spermatic cords, Cooper's ligament, the spermatic vessels, and the so-called "triangle of doom" are represented (Fig. 5). A large direct hernia model has been created (Fig. 6). To assemble the model, a rubber peritoneal membrane is fitted over the retroperitoneum. The model is then placed into its holder. One can clearly identify the lateral umbilical ligament, the vas deferens, epigastric vessels, and the large, direct hernia. The repair is begun by incising the peritoneum approximately 1 cm above the hernia defect. The incision is carried from the lateral umbilical ligament to just beyond the internal ring. After adequate dissection of all anatomical structures, a Marlex patch is positioned in the preperitoneal space. The Marlex is then stapled to the appropriate structures–Cooper's ligament, the pubic tubercle, the anterior abdominal wall, and 1 cm anterior to the iliopubic tract. Once the repair is completed, the peritoneum is reconstituted, employing stapling or suturing techniques. The peritoneal repair is inspected, and the model is then taken out of the training box. The membrane is removed, and the preperitoneal repair is inspected and assessed.

Figure 6. Hernia model with peritoneal anatomy (direct hernia).

Gynecologic Model

This model allows the student to identify, dissect, and remove an intramural myoma, an ectopic pregnancy, and a large ovarian cyst (Fig. 7). The surgeon can then suture the various anatomic areas. The uterus has a different consistency from the tube or ovary. Each structure is constructed to mimic the consistency of the particular anatomic area. The dissected structure can then be replaced and the model reconstituted.

DISCUSSION

Laparoscopic surgery demands new skills for its safe performance. The rise in biliary injuries and complications following laparoscopic cholecystectomy has caused a re-evaluation of surgical educational techniques. This re-evaluation has led to a review of the concepts of training and credentialing for surgical procedures.[9]

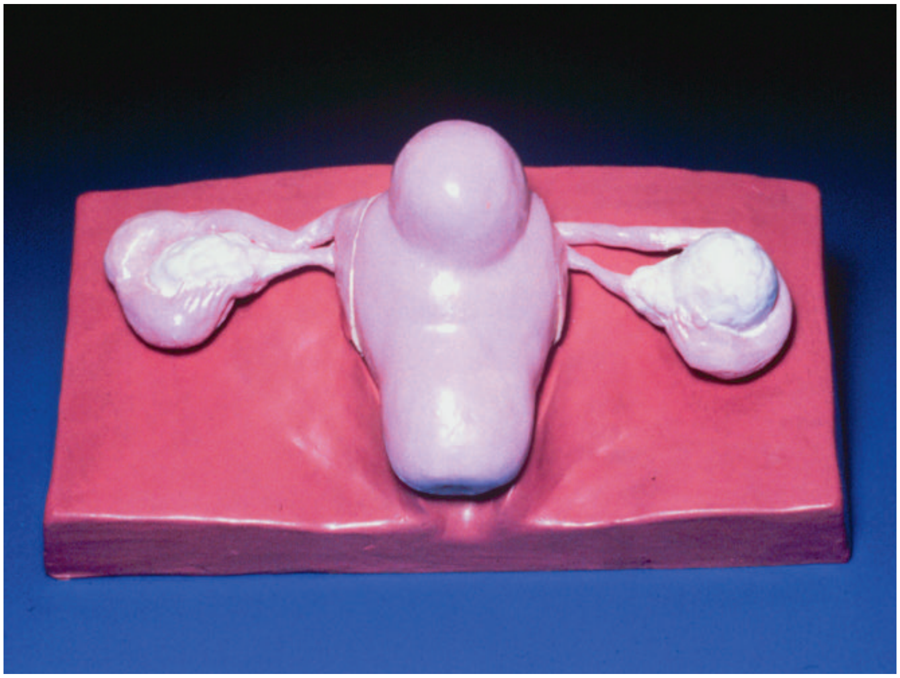

Figure 7. Gynecologic model.

Fluid eye/hand coordination and the ability to work from a two-dimensional perspective presently govern the performance of laparoscopic procedures. A graduated, progressive set of exercises can help the surgeon become comfortable with these initially disconcerting physical and intellectual demands. Repeated practice sessions at close intervals can improve and instill technical proficiency. Monocular depth cues can be identified and employed to ameliorate the disorientation inherent in working from a television monitor.

Learning these skills mandates a flexible approach to education. The practicing surgeon as well as residents should have access to functional, economical simulation aids conveniently located within their campus or office. Such availability can simplify the logistics of setting up tutorial sessions, which can be self-paced and self-monitored. After one-on-one tutorials, the student can continue to practice on his or her own, recording progress on videotape for later analysis and comparison.

Endoscopic models can simulate human operative experience in texture, anatomy, and strength. By videotaping student performance, measurable improvement in technique can be assessed. The reliability of such assessments depends in part on the model's realism.[10] Although research and development of computerized simulation software and virtual reality modules are progressing, these concepts are far from ready for everyday use and are prohibitively expensive.[11]

Models such as the ones described here provide a viable alternative to animal laboratories. They have the advantages of being portable, economical, and readily available. The use of endoscopic models teaches, refines, and maintains laparoscopic skills. STI

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