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Porcine Abdominal Wall Simulator for Laparotomy Incision and Closure

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Abstract
We describe an economical and simple abdominal wall model that provides a realistic experience for trainees as they develop the skills of creating an abdominal incision through the midline, followed by closure of the fascia and skin.

Keywords
simulation, surgical education

Introduction

Two of the major components of any open abdominal surgical procedure are creating a midline laparotomy and closing the incision. These 2 steps of the operation are most often considered the domain of the junior trainee. As with almost all operative skills, inadequate competence can lead to both short and long-term complications that effect hospital stay, return to work, and need for further procedures.[1-3] Ideally, training programs should provide new trainees with an opportunity to learn and practice these skills in a low-stakes, low-stress environment before they are expected to perform the skill in the operating room.

Although there are numerous types of simulators available for the acquisition of laparoscopic skills, there is a dearth of open surgery simulators. The ACS/APDS (American College of Surgeons/Association of Program Directors in Surgery) Surgery Residents Curriculum uses a model developed at the Southern Illinois University School of Medicine by Janet Ketchum and Jenny Bartlett. This simulator uses synthetic materials, including fabrics, foam, bubble wrap, and adhesive wrap to create the layers of the abdominal wall.[4] Seagull et al[5] describe a simulator for laparoscopic hernia repair that uses synthetic materials to mimic the abdominal wall. Neither of these simulators use biologic materials that would provide a more realistic experience for the trainee.

Our goal was to create a model of the anterior abdominal wall that realistically simulated the anatomy, behavior, and feel of the abdominal wall and was logistically and financially feasible for any program. We have used this model as part of our "Interns Introductory Skills Workshop," conducted early in our residency training curriculum at University Hospitals Case Medical Center. Materials required, construction, utilization, and feedback from users is presented.

Materials

1. Sturdy plastic container measuring 14 × 11 × 3.25 inches
2. Water balloons (6)
3. Cable ties (8-10)
4. Electrocautery return pad
5. Surgical drape
6. Porcine abdominal wall: Anterior abdominal walls are harvested postmortem from animals used in our Animate Skills Lab for various courses offered by our department. These animals weigh between 30 and 40 kg. Animals that are used for laparoscopic courses are suitable, as the port sites are small and do not significantly alter the appearance or quality of the model.

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Figure 1. Anterior abdominal wall marked for harvest.

Figure 3. Water filled balloons placed in plastic container. Note holes along edges of container.

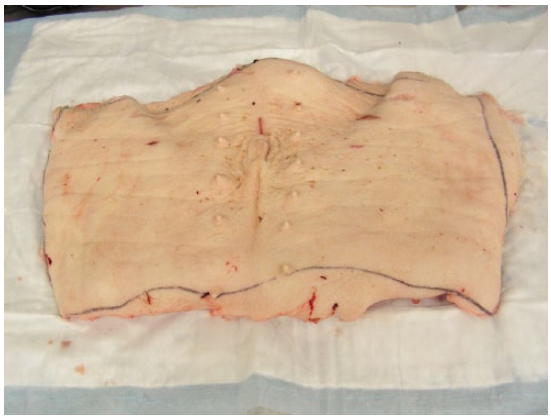

Figure 2. Harvested anterior abdominal wall.

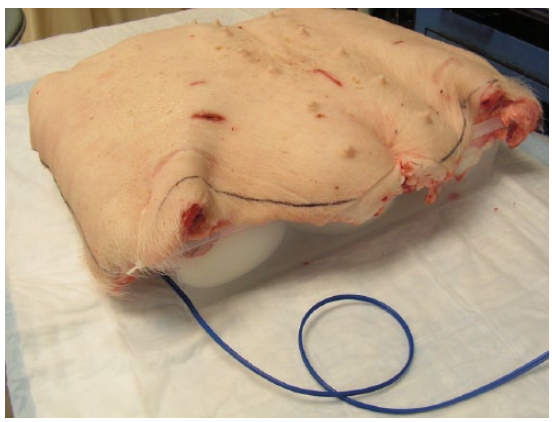

Figure 4. Abdominal wall secured to container with cable ties after securing electrocautery return pad.

Tissues can also be purchased at abattoirs/butchers etc. A large rectangular section of the abdominal wall extending between the lower ribs and the groin crease and the flanks bilaterally is harvested (Figure 1). All layers, including the peritoneum are removed en bloc (Figure 2). This tissue may be frozen till required, then defrosted by soaking in water at room temperature over 12 to 24 hours.

Simulator Construction

1. Small holes are drilled at equal distance around the edge of the plastic container on all 4 sides. A sharp object can be used if a drill is not available.
2. Balloons are filled with water to make them firm but not tense. The balloons are placed in the plastic container. Six balloons usually suffice for the container described (Figure 3).
3. A return pad is adhered to the peritoneal side of the abdominal wall, away from the midline.
4. Using cable ties, the abdominal wall is attached to the plastic container through the predrilled holes. A scalpel is used to make corresponding holes in the abdominal wall. The tissue is stretched till the abdominal wall feels taut. Excess tissue is trimmed if necessary. The slight bulge created by the presence of the water balloons nicely simulates the appearance and feel of an average human abdomen (Figure 4).
5. A hole is cut in the surgical drape to expose the center of the abdominal wall. The overhanging drape will conceal the sides of the simulator.

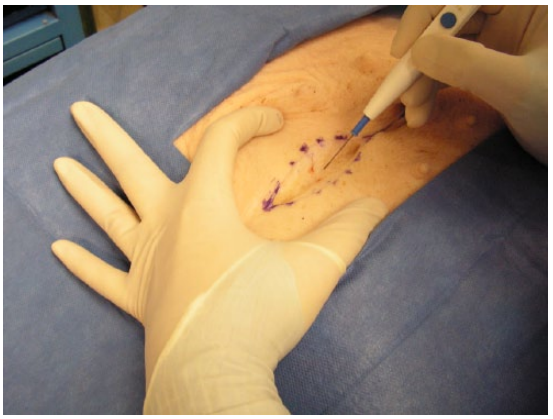

Figure 5. Midline incision being created.

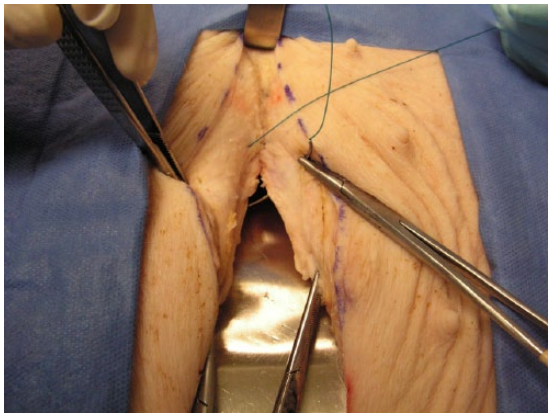

Figure 6. Closure of laparotomy incision.

Simulator Utilization

Prior to the simulation session, trainees are asked to review abdominal wall anatomy from an anatomic/surgical atlas of their choice. A short PowerPoint presentation is used to reiterate salient features of the abdominal wall and describe the basic steps of the skills to be learned.

Equipment for laparotomy incision simulation module:

a. Porcine anterior abdominal wall model
b. Basic instrument tray (including no. 10 scalpel, Adson forceps ×2, toothed forceps ×2, Kocher clamps ×2, Metzenbaum scissors, heavy needle driver, suture scissors, hemostats ×2, medium malleable retractor, small abdominal wall retractor).
c. 1/0 Monofilament suture
d. Marking pens
e. Electrocautery generator and electrocautery pencil
f. Wall suction (optional)

We prefer a ratio of 2 trainees per simulator. The model is placed on the 'operating table' to mimic the position of a supine patient. The trainees stand on either side and take turns opening the upper and lower halves of the incision. As beginners, they are instructed to mark the intended line of incision. The skin incision is made with a scalpel (Figure 5). The electrocautery pencil is used to incise the subcutaneous tissues to the level of the fascia. At the level of the umbilicus, the linea alba is identified and lifted between Kocher clamps and incised sharply. The peritoneum is identified, grasped with hemostats and entered using Metzenbaum scissors. Injury to the underlying water balloons with either electrocautery or scissors causes them to rupture, creating dramatic evidence of a simulated visceral injury. The incision is completed taking care to protect the underlying balloons, mimicking the skills necessary to protect the bowel.

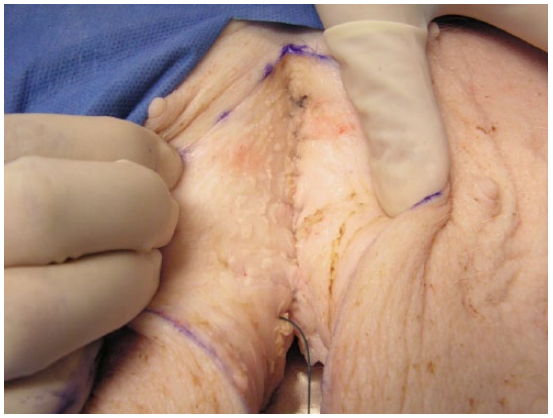

Figure 7. Closure of upper half of the incision.

The trainees are instructed on en bloc closure of the abdominal wall using a monofilament nonlooped suture, allowing the opportunity for knot tying with this type of suture. The incision is closed from above and below giving both participants an opportunity to practice (Figures 6 and 7). Trainees are coached and provided feedback during the entire process, allowing immediate recognition and correction of errors in technique. Following completion of the task, the proctor and trainee review the skills acquired, difficulties they may have encountered, and how to improve performance. Together they complete a 5-item assessment rubric that serves as a formative assessment (appendix).

Following the completion of this task, we use the simulator for skin suturing practice and instruction. Techniques of interrupted, running and subcuticular stiches can be practiced using skin rather than a synthetic substitute. The trainee is able to experience the realistic resistance and biomechanical properties of skin when using different suture sizes, materials, and needle shapes. The many nuances of proper knot tying are also better represented on real tissues.

Furthermore, this model can also be used as a laparoscopic simulator. The open (Hassan) technique for laparoscopic port placement can be practiced in similar fashion as the laparotomy described. The balloons can be removed or popped providing adequate working space within the plastic container with no need for insufflation. Synthetic materials or animal tissue can be placed in the container to practice a wide range of laparoscopic skills ranging from tissue manipulation to intracorporeal knot tying.

Discussion

Porcine abdominal wall has the basic muscular and fascial anatomy that is common to all mammals, with minor variations between species. The porcine rectus abdominis is extensive and thick with 7 to 10 inscriptions. Both muscles fuse in the midline along a very narrow linea alba. The tranversus abdominis is well developed. Overall, the midline muscular anatomy is almost identical to human anatomy, making it an ideal model on which to train.[6,7]

We have used this simulator over the past 2 years as part of our skills workshop for interns. A total of 33 interns attended 2 workshops. We collected feedback from trainees using a questionnaire administered after they had completed the task of creating and closing an anterior abdominal wall incision on the simulator. On a 5-point Likert-type scale, 32 of 33 interns strongly agreed that the simulator was ideal for the skill being taught. All trainees strongly agreed that the supervised practice strongly supported learning. No simulator design modifications were suggested by either participants or instructors (surgical faculty and midlevel residents).

Conclusion

The porcine abdominal wall simulator costs less and is easy to construct. It effectively mimics the human anterior abdominal wall in visual, tactile, and anatomic appearance. The realistic and economical features make this model instrumental to teach and practice many basic surgical skills, especially laparotomy incision and closure.

Appendix

Introductory Skills Workshop

Name: ____________________

Combined Assessment: Midline incision and closure

Midline incision					
Skin incision	Jagged incision with fits and starts	Crooked incision with beveling	Crooked incision with no beveling	Straight incision with beveling	Straight incision with no beveling
Incision of subcutaneous fascia	Oblique and off-midline	Vertically placed but off-midline	Some obliquity but mostly over midline	Minor obliquity but centered over linea alba	Vertically placed through subcutaneous tissue, overlying linea alba
Incision of muscular fascia	<25% through linea alba	50% to 25% through linea alba	75% to 50% through linea alba	≥75% through linea alba	Entire length through linea alba
Peritoneal incision	Injury to underlying structures	No identification, incision completed with cautery, inadequate protection of underlying structures	Identified, incised with cautery, incision completed with cautery, protection of underlying structures	Identified, incised with Metz, completion with cautery, incomplete protection of underlying structures	Identified, incised with Metz, completion with cautery, protecting underlying structures
Midline closure					
Fascial closure	Injury to underlying structures	Gaps in incision or fascia excluded from suture line or insecure knots	Fascia identified, structures protected, suture line with major irregularity but approximated	Fascia identified, structures protected, inconsequential suture line irregularity, secure knots	Fascia identified, structures protected, sutures placed evenly at appropriate intervals with appropriate tension, anchored with secure Surgeon's knots
NB: The peritoneal incision must be witnessed by an instructor					

Instructor: ______________________________ Date: ________________

Author Contributions

Design : Sadaf Khan, Steve J Schomisch, Cassie Cipriano. Manuscript writing: Sadaf Khan, Steve J Schomisch. Manuscript editing: Steve J Schomisch, Jeffrey M Marks, Cassie, Cipriano, Sadaf Khan

Declaration of Conflicting Interests

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