

GENERAL & THORACIC SIMULATION SURGERY

for Developing Countries

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*Teaching
Manual*

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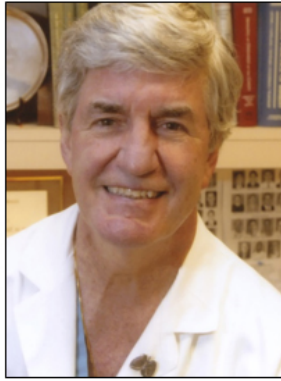
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Preface



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The purpose of this manual is to introduce general surgeons in developing countries to some of the general and thoracic procedures commonly encountered in their practices. The manual describes six trans-abdominal and four trans-thoracic simulation surgery exercises. These simulation exercises include the technique of patient positioning for a thoracotomy, and the technique of performing a posterolateral thoracotomy- the most common incision the surgeon needs to know in order to enter the chest cavity.

In developing the teaching exercises, every attempt has been made to:

- 1) Use inexpensive components to construct the exercises from instruments and material readily available in surgical operating theaters or available for ordering on the Internet.
- 2) Design models that can be reused for multiple teaching sessions.
- 3) Use inexpensive locally available animal tissue, such as the goat's mediastinal and proximal gastrointestinal organs.

This manual is based on the clinical and teaching experiences in Rwanda of Dr. Thomas Daniel, during 2013 and 2014. Dr. Daniel worked for five months as a surgeon, and as a teacher of simulation general and thoracic surgery, at the University Hospital in Kigali, Rwanda and the University Hospital in Butare, Rwanda.

Dr. Daniel is indebted to the contributions of:



Richard H. Feins, MD, Professor of Surgery at the University of North Carolina School of Medicine in Chapel Hill and a Director of the annual Cardiothoracic Simulation Surgery Boot Camp, Chapel Hill, North Carolina, USA.



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Kirk Barbieri, MS, Director of Specialty Care IT and Outcomes, Patient Care Services, University of Virginia Health System, Charlottesville, Virginia, USA. Mr. Barbieri played an integral role in planning the manual's text format, the layout of graphic illustrations and editing of the accompanying videos.

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Dr. Daniel would also like to acknowledge Dr. Byiringiro Fidele, Rwanda surgical resident and the Medical Editor of the Rwanda Medical Journal, who made substantial contributions to the development of the simulation surgery website; Mr. Charles Lewis, Telecommunications Network Analyst for the University of Virginia Office of Telemedicine, whose expertise was invaluable; Margery Daniel, PhD, videographer; and Mr. Alex Williams of the University of Virginia Operating Room Staff for sharing his technique for patient positioning for a thoracotomy using readily available and inexpensive supplies.

Lesson #1: Gastrojejunostomy

Equipment Needed:

- Goat stomach and at least 60 cm of attached small bowel. Note: The goat's stomach anatomy is quite different from human gastric anatomy. The goat is a ruminant and has four stomach compartments. The part just proximal to the pylorus - known as the abomasum or true stomach - is the best part to use for this exercise.
- 17-inch x 24-inch plastic cutting board.
- Scalpel with #10 blade.
- Metzenbaum scissors.
- Surgical forceps.
- Needle holder.
- 3-0 silk suture on an atraumatic curved needle.
- 2 curved small hemostats.
- Suture scissors.

Preparation of the Model:

- 1) Irrigate the goat stomach and the attached small intestine with copious amounts of water to clear of digestive contents.
- 2) Place the goat stomach on the cutting board.
- 3) Select a segment of jejunum to anastomose to the stomach just proximal to the pylorus along the greater gastric curvature.

Goals of the Exercise:

- 1) Learn the importance of initial stay sutures just proximal and distal to the intended gastrojejunal anastomosis.
- 2) Learn gentle handling of tissue edges to be anastomosed.
- 3) Learn the four layers of a side-to-side intestinal anastomosis.
- 4) Learn how to transition from the posterior interlocking (hemostatic) mucosal suture that approximates the stomach to the jejunum to the anterior inverting mucosal suture at the proximal and distal ends of the anastomosis by using a Connell suture technique. This is known as "turning the corner" and is a critical step in avoiding subsequent anastomotic leak.

Gastrojejunostomy:

- 1) Place 3-0 silk stay sutures 1 cm beyond the proximal and distal ends of the planned gastrojejunostomy (see next page).



Figure 1: Placement of Stay Sutures

- 2) Make an incision in the stomach that ends 1 cm from the two stay sutures (see below).
Note: In the human setting the cut edges will bleed. Do not use excessive cautery as this will risk necrosis of the bowel wall. Ligate large bleeders. Oozing bleeders will stop on their own.

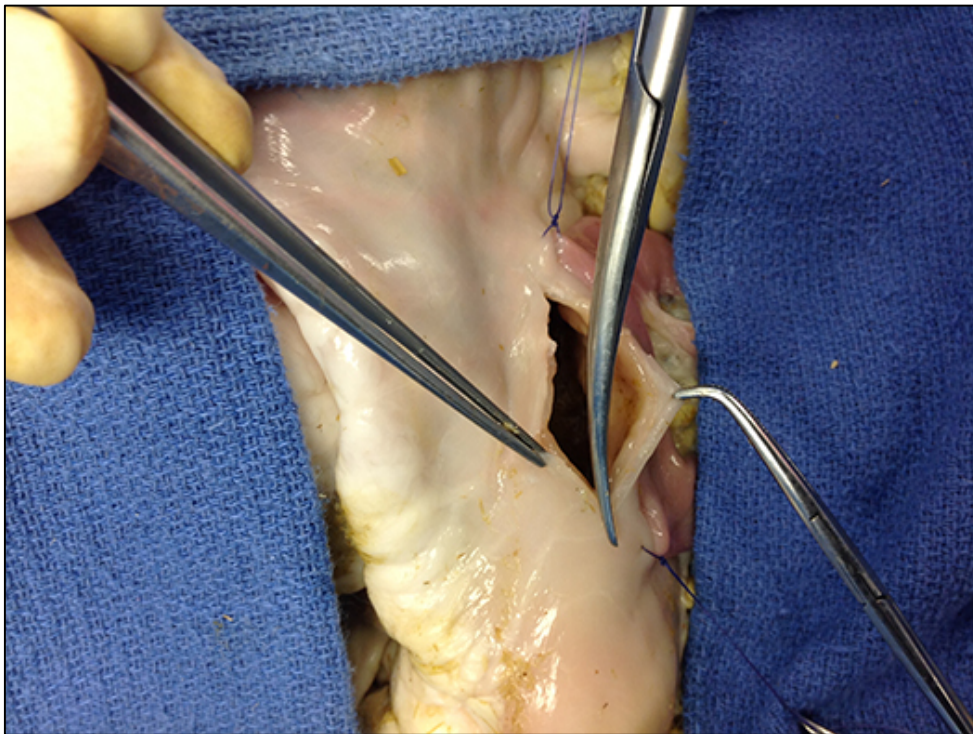


Figure 2: Gastric Incision

- 3) Make an incision in the jejunum parallel to the gastric incision (see below).



Figure 3: Jejunal Incision

- 4) Place seromuscular interrupted 3-0 silk sutures on an atraumatic needle between the posterior gastric wall and the adjacent posterior jejunal wall (see below). This is known as the posterior seromuscular layer of the anastomosis.

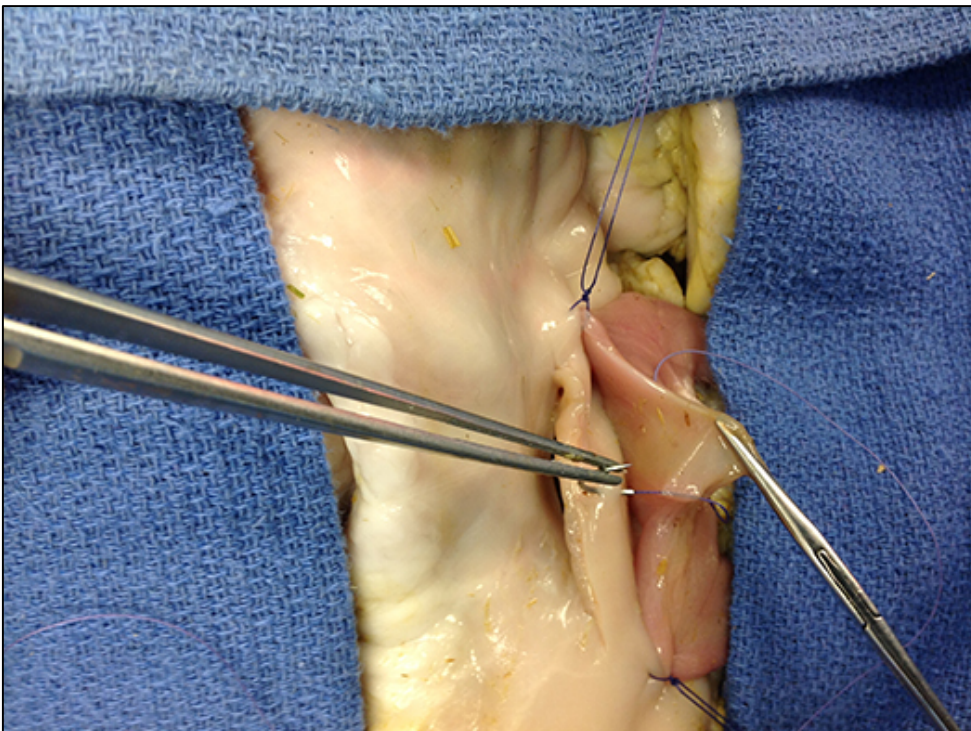


Figure 4: Initial Posterior Seromuscular Suture

- 5) Place two full-thickness sutures through the adjacent gastric and jejunal walls posteriorly (see below). Then run one suture proximally and one suture distally interlocking the sutures for hemostasis. This is the second posterior anastomotic layer.

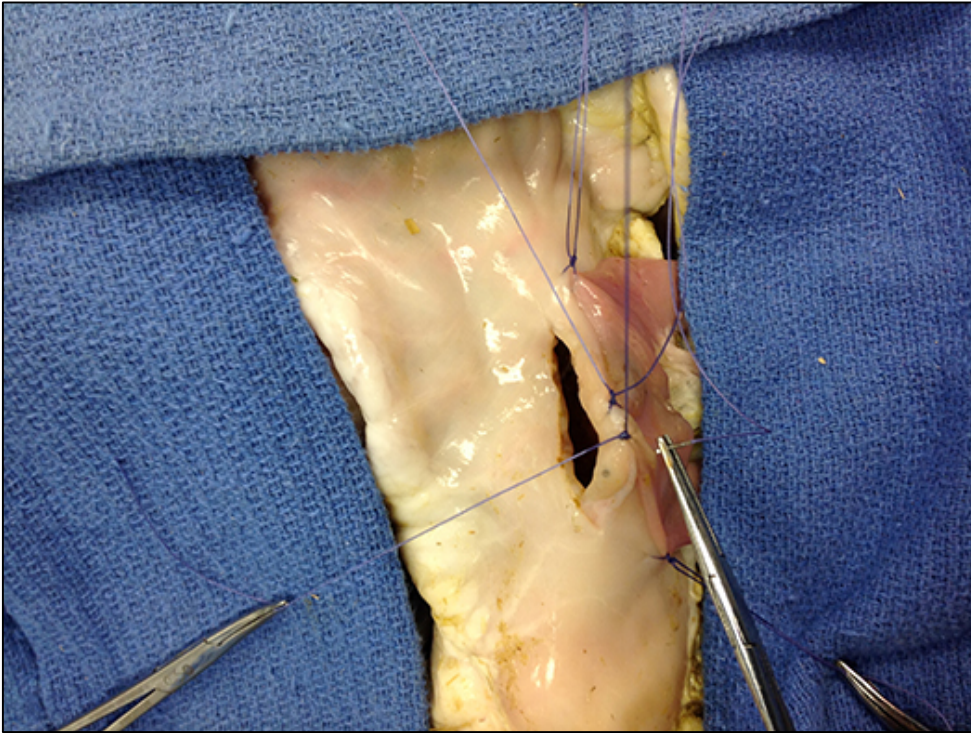


Figure 5: Jejunum Approximated to Stomach with Initial Proximal and Distal Sutures

- 6) Turning the anastomotic angle using Connell suture technique (see below). Using the distal interlocking posterior anastomotic suture, drive it starting through the mucosa and then full thickness through the distal gastric wall.



Figure 6: Initial Connell Suture Passing Inside Out Through the Distal Jejunal Wall

- 7) Then pass the same suture outside in through the full thickness of the adjacent distal gastric wall (see below).

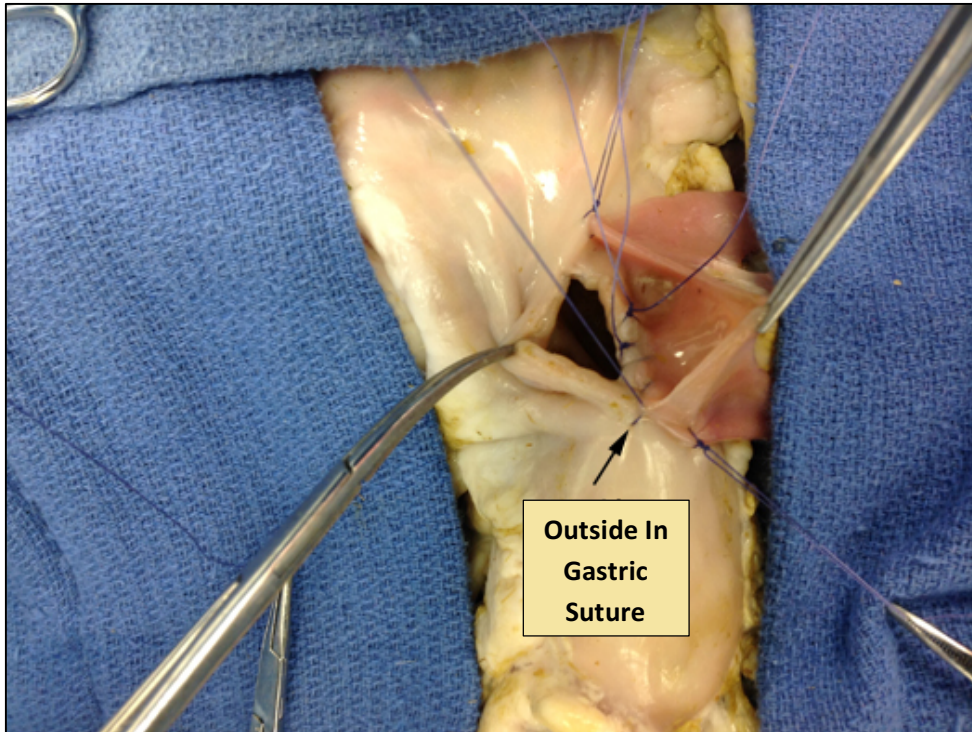


Figure 7: Outside In Gastric Suture

- 8) Next, turn the suture and pass it full thickness back inside out through the gastric wall (see below).

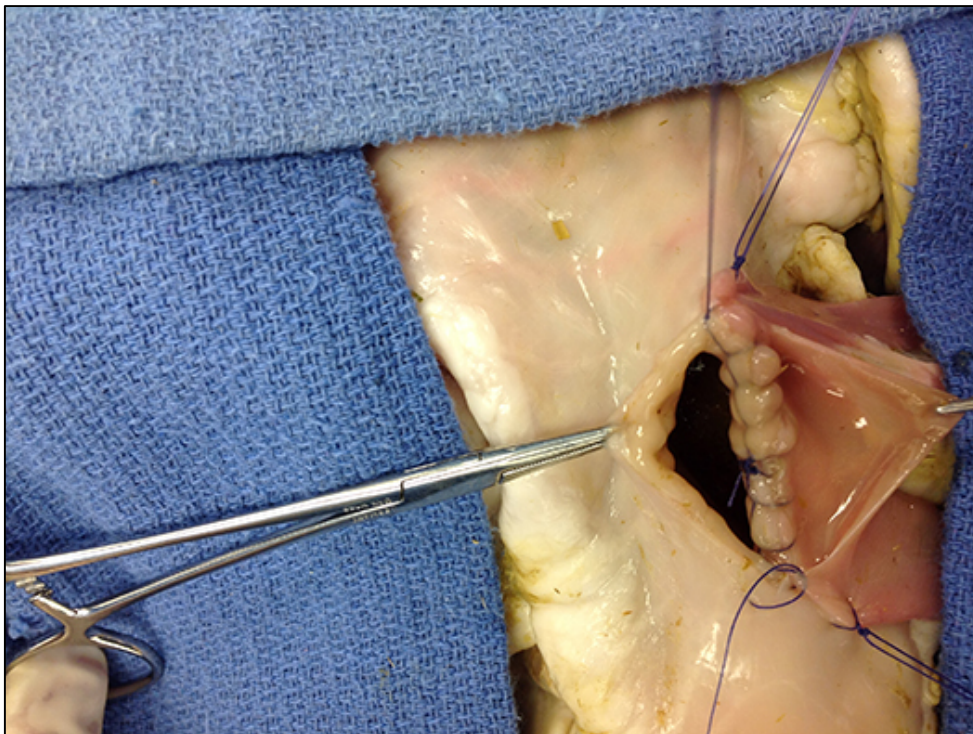


Figure 8: Inside Out Gastric Suture

- 9) Repeat the same process with the previously placed proximal suture after running it proximally with interlocking sutures to the angle of the anastomosis. Then use the Connell suture technique to turn the proximal anastomotic angle (see below). This maneuver inverts the mucosal layer.

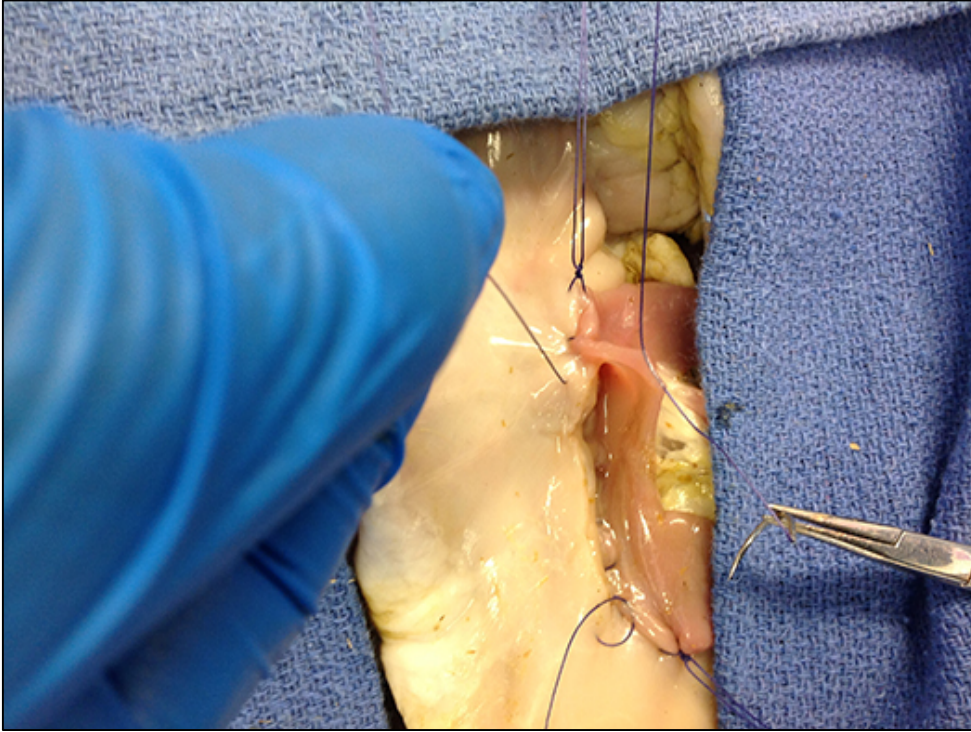


Figure 9: Closing Proximal Angle with Connell Sutures

- 10) Complete the anterior mucosal inverting layer by placing outside in and then inside out full thickness sutures through the stomach and adjacent jejunal walls (see below).

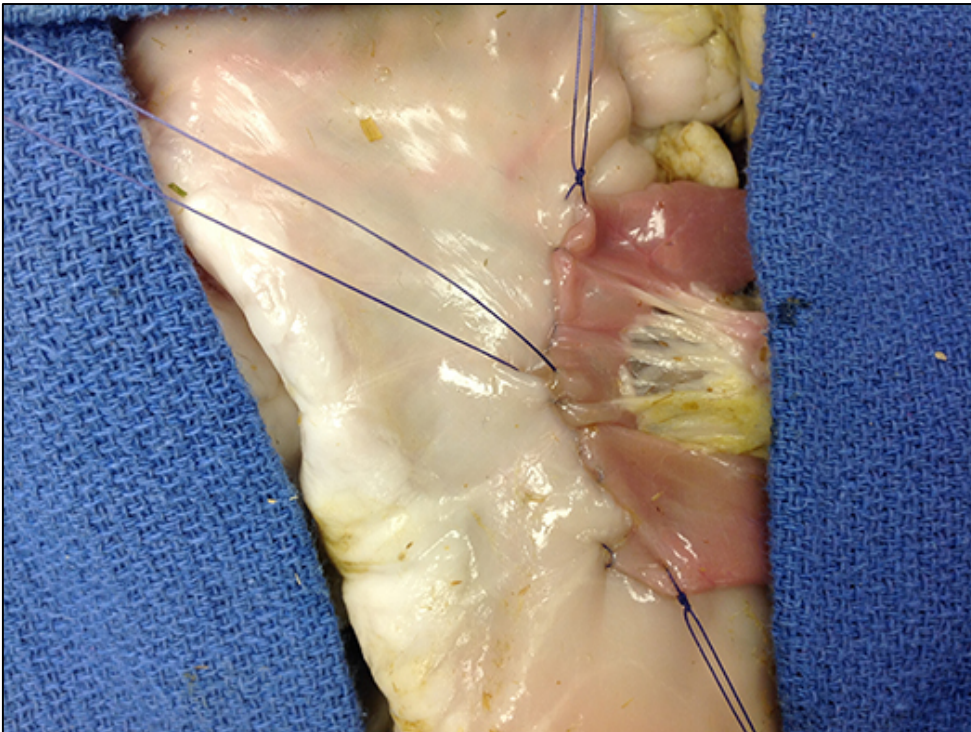


Figure 10: Anterior Inverted Gastrojejunal Anastomosis

- 11) The final step in the gastrojejunostomy is to place a second layer of interrupted seromuscular sutures anterior to the previously placed inverting mucosal layer.

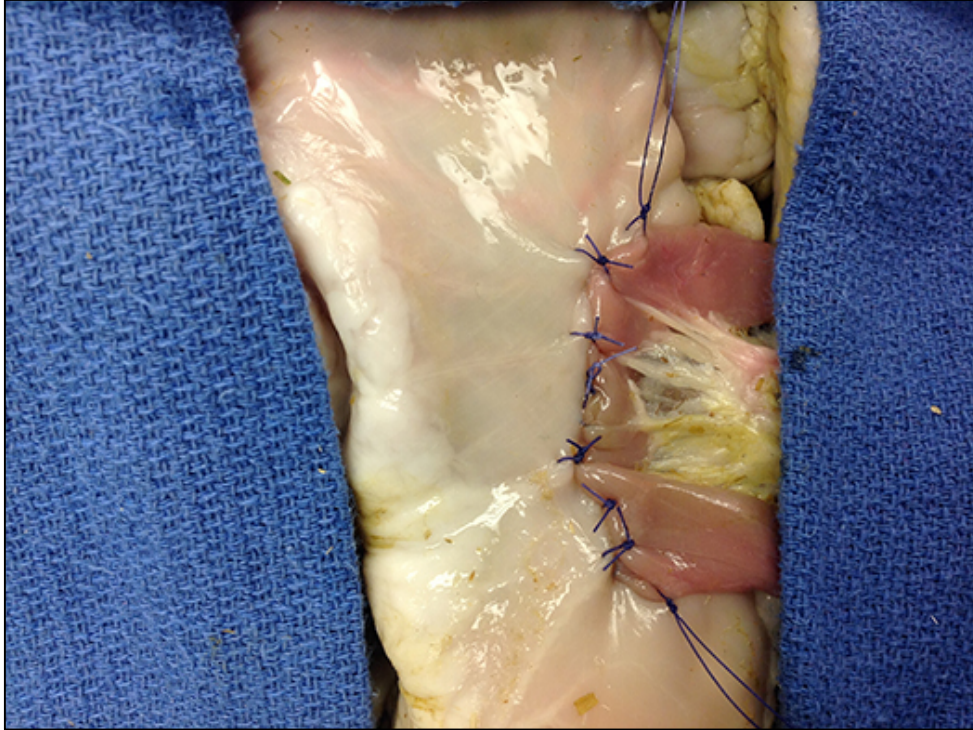


Figure 11: Interrupted Anterior Seromuscular Suture Layer

- 12) Cut the ends of the stay sutures leaving the knots in place. Place a seromuscular suture just beyond the anastomosis at each end to reinforce the angle.

Lesson #2: Nissen Total Fundoplication

Equipment Needed:

- Goat mediastinal tissue block. Fresh from local abattoir. Refrigerate. Consists of heart, lungs, esophagus, trachea, diaphragm, thoracic aorta and esophagogastric junction with attached proximal one third of the stomach.
- Maloney tapered bougie - Size 54 French for human adult. Size 45 French for goat model.
- 17-inch x 24-inch plastic cutting board with single screw placed in the center edge of each end of longest dimension.
- Lubricant- tube of K-Y jelly or Lubriderm.
- One pair of Metzenbaum scissors.
- Surgical forceps.
- 0 Ethibond sutures.
- 2-0 Ethibond sutures.
- Penrose drain.
- Kelly clamp.
- Suture scissors.
- Babcock clamp.
- Needle holder.
- Suture scissors.
- Spool of heavy twine.

Preparation of the Model:

- 1) Attach the mediastinal tissue block to the cutting board with heavy twine passed through the proximal esophagus and trachea. Do not obstruct the esophageal lumen. Tie this suture around the screw at the end of the cutting board. Place a second heavy twine through the distal diaphragmatic crura and tie around the screw at the distal end of the cutting board.
- 2) The goat stomach has four compartments. It is useful to separate one of these compartments, the reticulum, from the rumen, omasum and abomasum in order to more closely simulate the human gastric anatomy (see next page). The Kelly clamp is attached to the thick, muscular reticulum that has been surgically removed. The incision in the rumen near the esophagogastric junction is closed with inverting sutures. The proximal portion of the rumen then becomes anatomically similar to the fundus of the human stomach.

Note: this technique of separating the reticulum from the rumen is used in Exercises #3, #4, and #5 to prepare the goat stomach model.

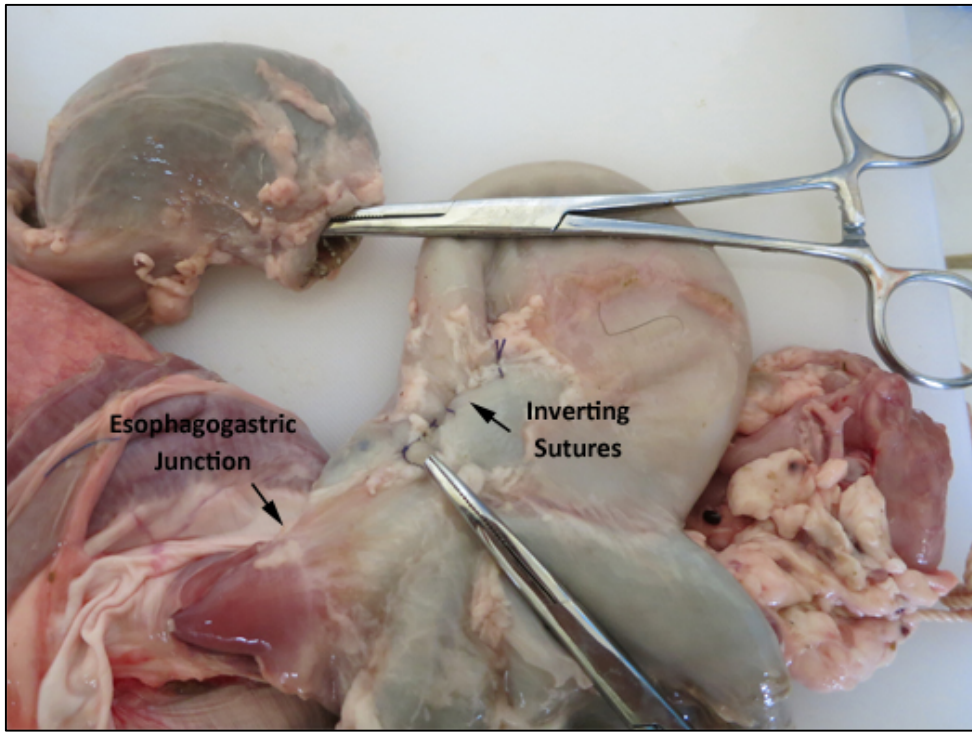


Figure 12: Preparation of the Goat Stomach to Simulate the Human Stomach

- 3) Pass a lubricated esophageal bougie the full length of the esophagus into the proximal stomach.

Goals of the Exercise:

- 1) Be able to identify the esophagogastric junction and the left and right crura of the diaphragm.
- 2) Understand how the total wrap of the gastric fundal tissue replicates the normal gastric anti-reflux mechanism. It holds the esophagogastric junction below the diaphragm and creates a high-pressure zone at the esophagogastric junction.
- 3) Understand the role of the bougie. It avoids too tight a wrap.

Nissen Total Fundoplication:

- 1) Pass an esophageal bougie by mouth through the esophagus and into the proximal stomach.
- 2) Describe the location and the rationale for dividing the vasa brevia between the gastric antrum and the spleen.
- 3) Identify the left and right crura of the diaphragm.
- 4) Create by blunt dissection a circumferential space around the intra-abdominal segment of the distal esophagus and then pass a Penrose drain to retract the esophagus while enlarging the space adequate to accommodate the gastric fundal wrap.
- 5) Grasp the gastric antral tissue and pass posterior to esophagogastric junction through the space created by Step #2.
- 6) Bring the end of "wrap" anterior to the esophagogastric junction by grasping it with a Babcock clamp and suture to the gastric antrum on the patient's left side with three 2-0 Ethibond sutures for a total wrap length of 1.5 cm (see next page).



Figure 13: Nissen Fundoplication

- 7) Retract the bougie into the thoracic esophagus and evaluate the crural space posterior to the wrap. If further closure of the crural space is indicated, place crural sutures of 2-0 Ethibond with the bougie retracted. Intermittently advance the bougie to “size” the space between the esophagus and the diaphragmatic crura. When appropriate crural sutures have been placed, the space should be just tight enough to admit one’s index finger with ease.
- 8) Place two “tacking” sutures of 2-0 Ethibond through the “wrap” into the adjacent crura of the diaphragm on each side of the wrap (see next page).

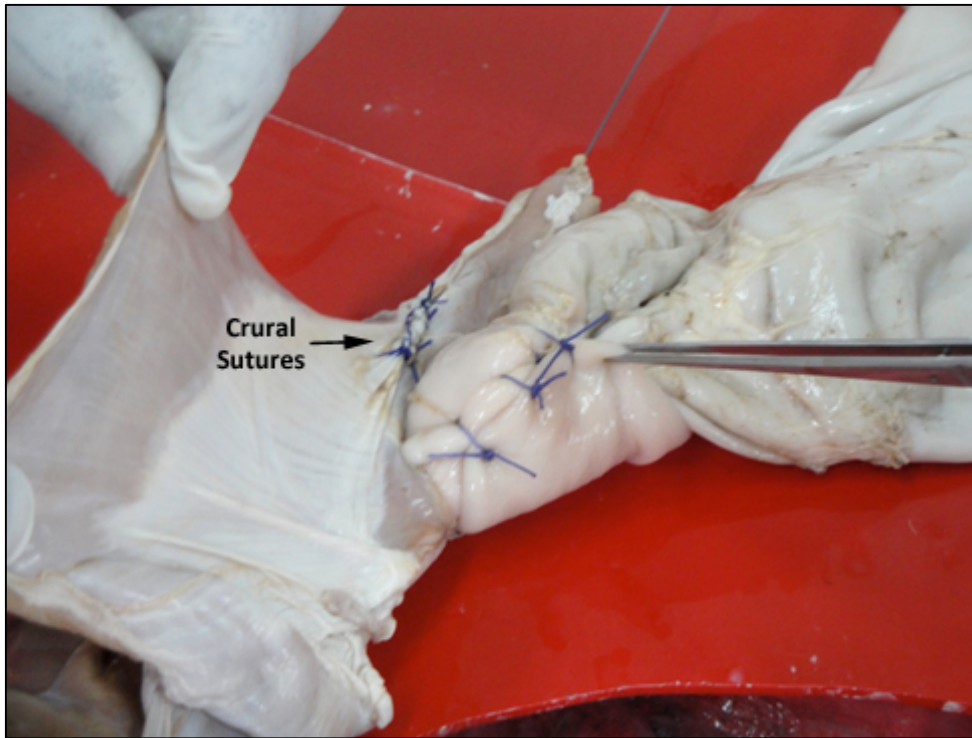


Figure 14: Nissen Fundoplication – Completed Total Wrap

Lesson #3: Esophageal Myotomy and Esophagogastric Myotomy

Equipment Needed:

- Goat mediastinal tissue block. Fresh from local abattoir. Refrigerate. Consists of heart, lungs, esophagus, trachea, diaphragm, thoracic aorta and esophagogastric junction with attached proximal one third of the stomach.
- Maloney tapered bougies - Size 45 French.
- 17-inch x 24-inch plastic cutting board with single screw placed in the center edge of each end of longest dimension.
- Lubricant- tube of K-Y jelly or Lubriderm.
- Scalpel with #10 blade.
- Curved small hemostat.
- Metzenbaum scissors.
- Surgical forceps.
- 3-0 absorbable suture.
- Needle holder.
- Heavy twine.

Preparation of the Model:

- 1) Attach mediastinal tissue block to the cutting board with heavy twine passed through the proximal esophagus and trachea. Do not obstruct the esophageal lumen. Tie this suture around the screw at the end of the cutting board. Place a second heavy twine through the distal diaphragmatic crura and tie around the screw at the distal end of the cutting board.
- 2) See Lesson #2, Step 2, for preparation of the goat stomach to simulate the human stomach.
- 3) Pass a lubricated esophageal bougie the full length of the esophagus.

Goals of the Exercise:

- 1) Learn to use the “belly” of the scalpel to make a longitudinal incision in the outer muscular layers of the bougie-distended esophagus. Recognize the underlying submucosal layer and avoid incising it.
- 2) Learn the technique of elevating the muscular layer for one third of the diameter of the esophagus at the site of the myotomy.
- 3) Learn the technique of recognizing and repairing an inadvertent entry into the esophageal lumen during the myotomy.

Esophageal Myotomy:

Note: this exercise is useful to teach as it demonstrates the basic surgical maneuver of myotomy which can be repeated multiple times on the same specimen.

- 1) Make a 2 centimeter longitudinal incision through the outer longitudinal muscle layer and the inner circular muscle layer of the bougie distended esophagus using the “belly” of a scalpel with a #10 blade. The depth of the myotomy can best be controlled by multiple light passes with the “belly” of the scalpel blade. It is much harder to control the depth of the myotomy using the “tip” of the scalpel blade.
- 2) Using a curved hemostat, Metzenbaum scissors and surgical forceps, elevate the esophageal muscular layers off of the submucosal layer for one third of the esophageal circumference (see next page).



Figure 15: Esophageal Myotomy

Esophagogastric Myotomy:

- 1) Make a 4 cm longitudinal incision through the two muscle layers of the bougie-distended distal esophagus.
- 2) Extend the myotomy for a distance of 1.5 cm onto the gastric cardia.
- 3) Using a curved hemostat, Metzenbaum scissors and surgical forceps, elevate the esophageal muscular layers off of the submucosal layer for one third of the esophageal circumference. Using the same instruments, elevate the gastric muscle layers adjacent to the myotomy just enough to assure a one centimeter separation of the muscle layers at the site of the gastric myotomy (see next page).

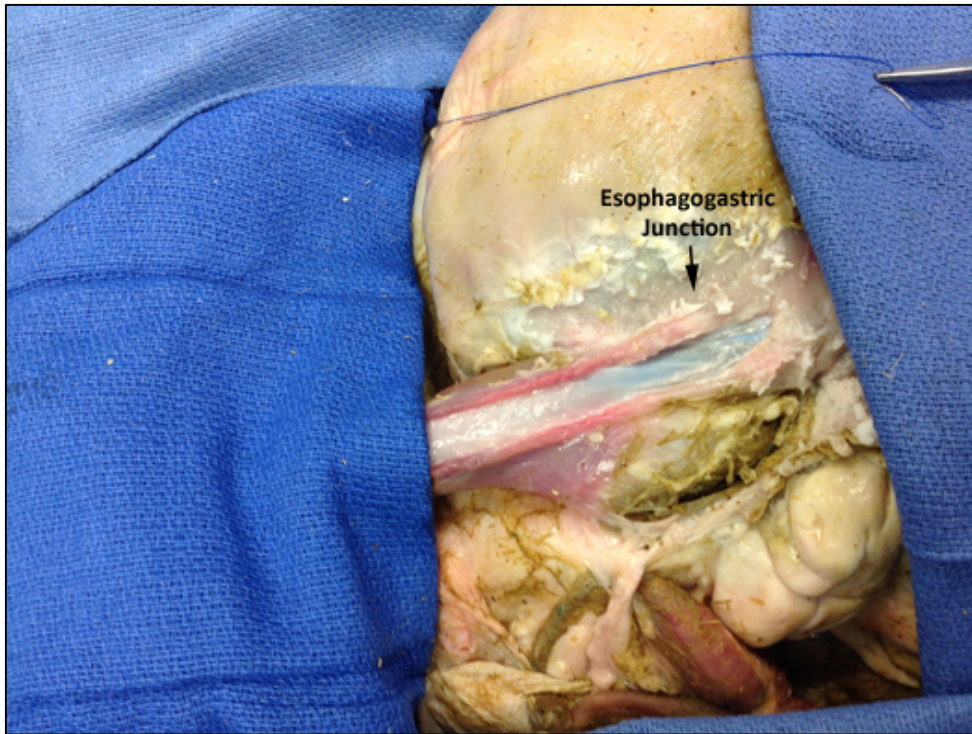


Figure 16: Completed Esophagogastric Myotomy (note the blue bougie lying in the esophagogastric lumen)

Closure of an Inadvertent Entry into the Esophageal Lumen while Doing a Myotomy:

- 1) Recognize the site of the lumen entry, grasp the tissue edges gently with forceps and close with absorbable 3-0 suture.

Lesson #4: Toupet Posterior Partial Fundoplication

Equipment Needed:

- Goat mediastinal and gastric tissue block. Consists of heart, lungs, esophagus, trachea, diaphragm, thoracic aorta and esophagogastric junction with attached proximal one third of stomach.
- Maloney tapered bougie -Size 54 French for human adult. Size 45 French for goat model.
- 17-inch x 24-inch plastic cutting board with single screw placed in center edge of each end of longest dimension.
- Lubricant- tube of K=Y jelly or Lubriderm.
- One pair of Metzenbaum scissors.
- Surgical forceps.
- 2-0 Ethibon or silk sutures.
- 3-0 silk sutures on an atraumatic needle.
- Suture scissors.
- Curved hemostat.
- Babcock clamp.
- Needle holder.

Preparation of the Model:

- 1) Attach the mediastinal and gastric tissue block to the cutting board with a heavy suture passed through the proximal esophagus and trachea. Do not obstruct the esophageal lumen with this suture. Tie this suture around the end of the cutting board. Place a second heavy suture through the distal diaphragmatic crura and tie around the screw at the distal end of the cutting board.
- 2) See Lesson #2, Step 2, for preparation of the goat stomach to simulate the human stomach.
- 3) Pass a lubricated esophageal bougie the full length of the esophagus.

Goals of the Exercise:

- 1) Know myotomy technique from Exercise #3.
- 2) Know why a partial wrap (fundoplication) is indicated in the setting of an esophagogastric myotomy for Achalasia.
- 3) Know the technique for posterior fundoplication (Toupet procedure).

Toupet Posterior Partial Fundoplication:

- 1) Pass an esophageal bougie through the esophagus from its proximal lumen through the esophagus into the lumen of the stomach segment.
- 2) Describe the location and the rationale for dividing the vasa brevia between the human gastric antrum and the spleen and for making an opening in the human gastrohepatic ligament. These anatomic structures are not available in this goat model.
- 3) Identify the left and right crura of the diaphragm.
- 4) Performance of an esophagogastric myotomy: make a 4 cm longitudinal incision through the muscular layers of the bougie distended distal esophagus using the “belly” of a scalpel with a #10 blade. Carefully carry this incision across the esophagogastric junction through the muscle layer of the stomach for a distance of 1.5 cm. Take care not to incise the underlying submucosal/mucosal layer of the stomach.
- 5) Using a curved hemostat, Metzenbaum scissors and surgical forceps, elevate the esophageal muscular layers off of the submucosal layer of the esophagus for 1 cm lateral and medial to the myotomy. This will reduce the likelihood of the myotomy closing again.

- 6) Toupet posterior fundoplication. Grasp the gastric antral tissue with a Babcock clamp and pass it posterior to the esophagus (see below).

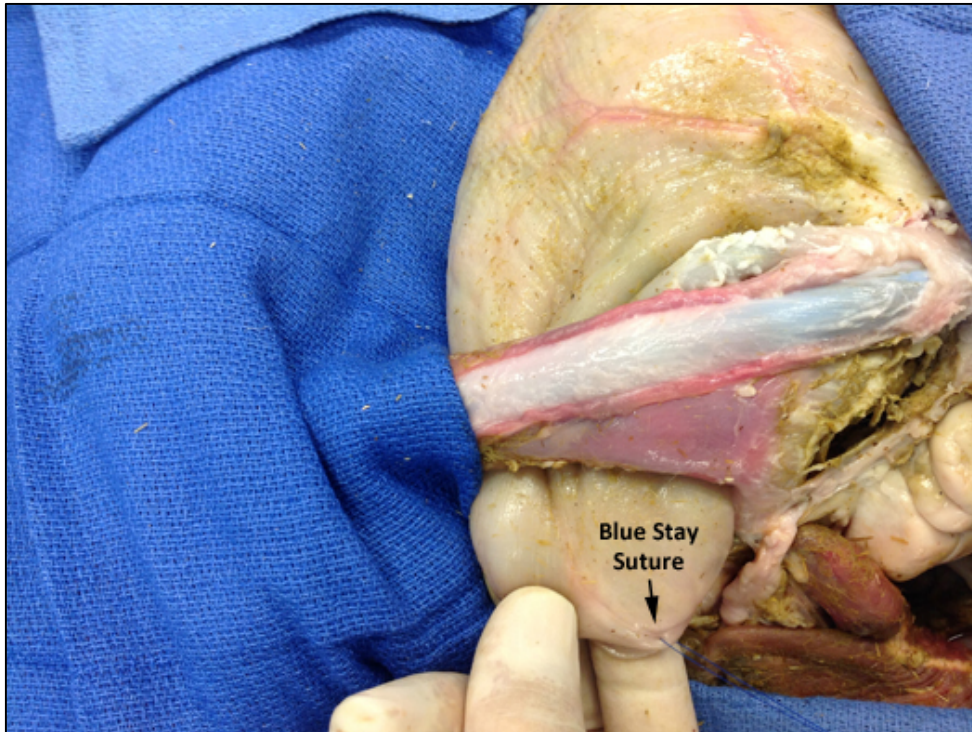


Figure 17: Blue Stay Suture Marks the Leading Edge of the Posterior Wrap

- 7) Place multiple 3-0 sutures attached to an atraumatic needle between the muscle layer of each side of the full length of the esophagogastric myotomy approximating each suture to the adjacent posterior fundic wrap (see below and next page). Tie in place.



Figure 18: Initial Sutures

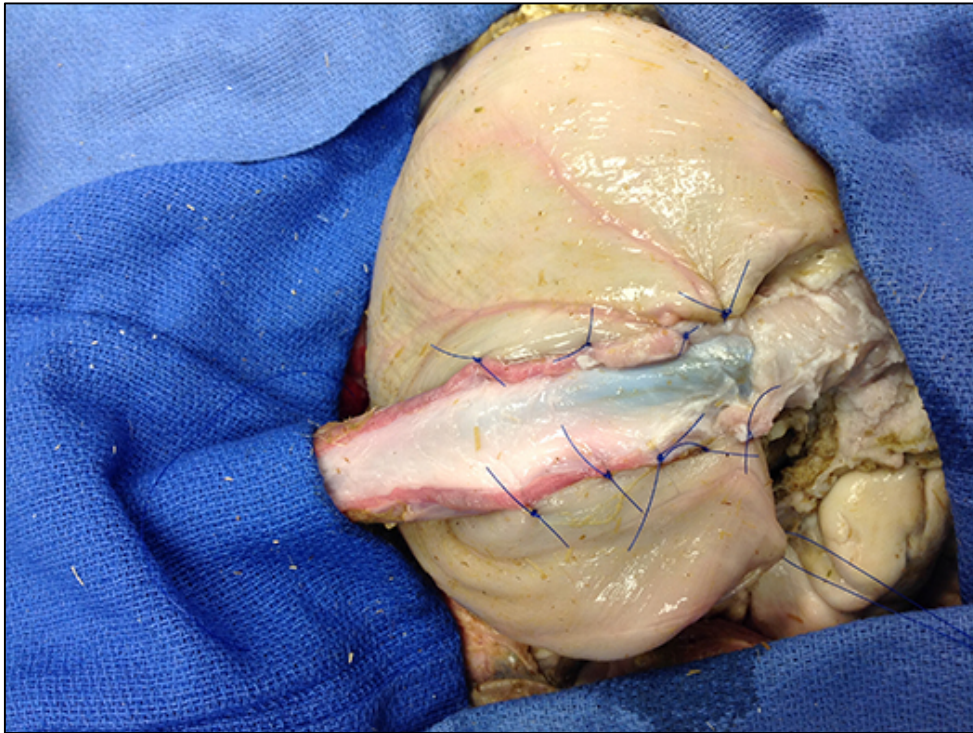


Figure 19: Completed Approximating Sutures

- 8) Final step. Place 2-0 sutures between the posterior gastric wrap and the adjacent underlying right crus of the diaphragm to anchor the wrap below the diaphragm (see below).

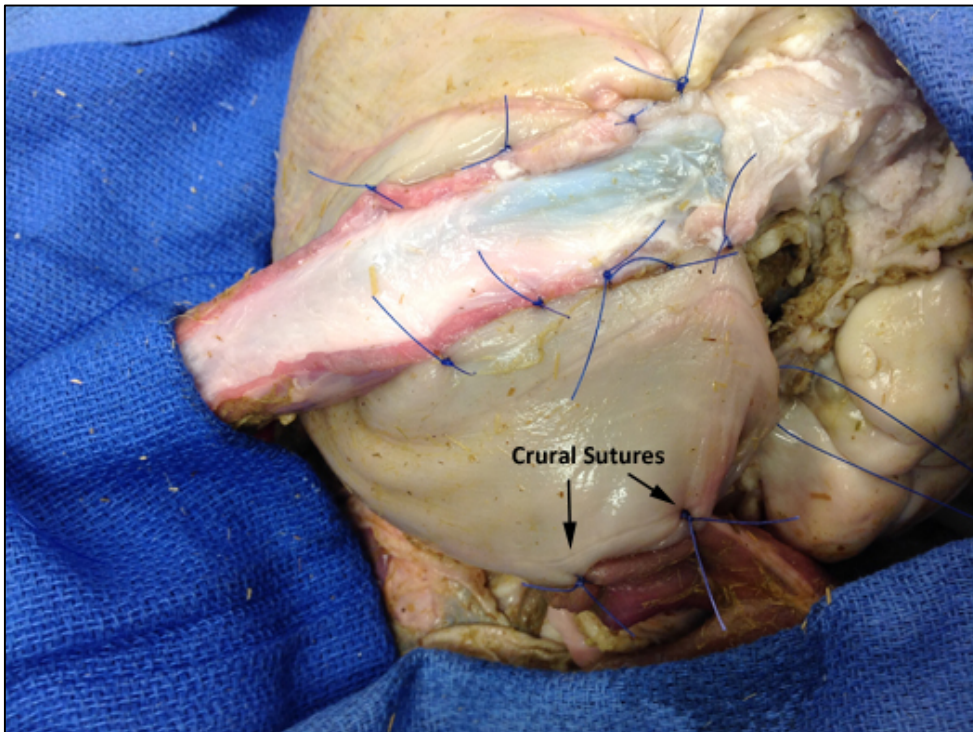


Figure 20: Sutures Anchoring Posterior Wrap to Right Crus of Diaphragm

Lesson #5: Dor Anterior Partial Fundoplication

Equipment Needed:

- Goat mediastinal tissue block. Fresh from local abattoir. Refrigerate. Consists of heart, lungs, esophagus, trachea, diaphragm, thoracic aorta and esophagogastric junction with attached proximal one third of the stomach.
- Maloney tapered bougie - Size 54 French for human adult. Size 45 French for goat model.
- 17-inch x 24-inch plastic cutting board with single screw placed in the center edge of each end of longest dimension.
- Lubricant- tube of K-Y jelly or Lubriderm.
- One pair of Metzenbaum scissors.
- Surgical forceps.
- 0 Ethibond sutures.
- 2-0 Ethibond sutures.
- Suture scissors.
- Curved hemostat.
- Babcock clamp.
- Needle holder.
- Spool of heavy twine.

Preparation of the Model:

- 1) Attach the mediastinal tissue block to the cutting board with heavy twine passed through the proximal esophagus and trachea. Do not obstruct the esophageal lumen. Tie this suture around the screw at the end of the cutting board. Place a second heavy twine through the distal diaphragmatic crura and tie around the screw at the distal end of the cutting board.
- 2) See Lesson #2, Step 2, for preparation of the goat stomach to simulate the human stomach.
- 3) Pass a lubricated esophageal bougie the full length of the esophagus.

Goals of the Exercise:

- 1) Know myotomy technique from Exercise #3.
- 2) Know why a partial esophageal wrap (fundoplication) is indicated for an esophagogastric myotomy for Achalasia.
- 3) Know the technique for anterior fundoplication (Dor procedure).

Dor Anterior Partial Fundoplication:

- 1) Pass an esophageal bougie by mouth through the esophagus and into the proximal stomach.
- 2) Describe the location and the rationale for dividing the vasa brevia between the gastric antrum and the spleen.
- 3) Identify the left and right crura of the diaphragm.
- 4) Make a 4 cm longitudinal incision through the two muscular layers of the bougie distended distal esophagus using the “belly” of a scalpel with a #10 blade. Carry this incision across the esophagogastric junction through the muscle layer of the stomach for a distance of 1.5 cm. Do not incise the submucosal/mucosal layer of the stomach.
- 5) Using a curved hemostat, Metzenbaum scissors and surgical forceps, elevate the esophageal muscular layers off of the submucosal layer of the esophagus for 1 cm lateral and medial to the myotomy. This will reduce the likelihood of the myotomy closing again.
- 6) Grasp the gastric antral tissue with a Babcock clamp and bring it anterior to the esophagogastric myotomy.
- 7) Place three 2-0 Ethibond sutures between the muscle layer on the patient’s left side of the myotomy and through the adjacent anterior fundic wrap and tie in place.

- 8) Place three additional 2-0 Ethibond sutures between the muscle layer on the patient's right side of the myotomy and through the adjacent anterior fundic wrap (see below) and tie in place. Allow 1.5 cm distance between the left and right rows of suture on the anterior fundic flap. This will help hold the myotomy open.

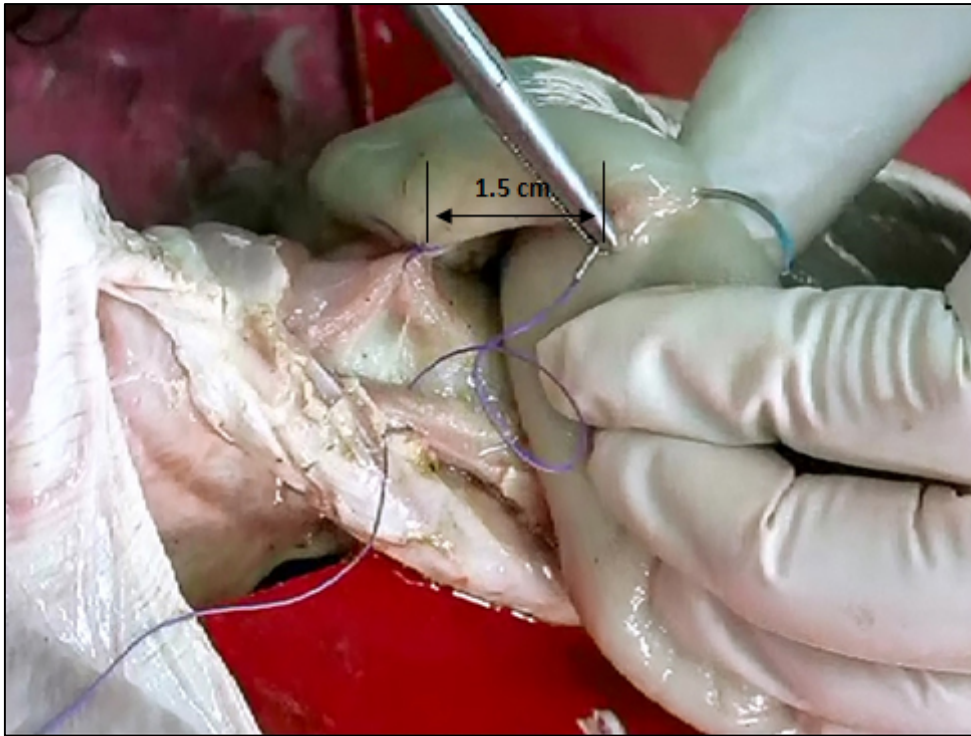


Figure 21: Dor Fundoplication

- 9) Place two 2-0 Ethibond sutures through the right crus, the posterior wall of the stomach and the adjacent anterior fundic wrap.
- 10) Place two 2-0 Ethibond sutures through the left crus and the adjacent fundus. These sutures will serve to hold the partial wrap below the diaphragm.

Lesson #6: Transabdominal Repair of an Acutely Ruptured Diaphragm

Equipment Needed:

- Goat mediastinal tissue block. Fresh from local abattoir. Refrigerate. Consists of heart, lungs, esophagus, trachea, diaphragm, thoracic aorta and esophagogastric junction with attached proximal one third of the stomach.
- Scalpel with #10 blade.
- Surgical forceps.
- 0-Ethibond or other size non-absorbable suture.
- Straight or curved hemostat.
- Two Kelly clamps.
- Suture scissors.
- Needle holder.
- Spool of heavy twine.

Preparation of the Model:

- 1) Attach the mediastinal tissue block to the cutting board with heavy twine passed through the proximal esophagus and trachea. Do not obstruct the esophageal lumen. Tie this suture around the screw at the end of the cutting board. Place a second heavy twine through the distal diaphragmatic crura and tie around the screw at the distal end of the cutting board.
- 2) Grasp the anterior edge of the diaphragm with two Kelly clamps and pull up to display the diaphragm surface.
- 3) Make a 3 cm incision in the diaphragm.

Goals of the Exercise:

- 1) Compare and contrast the management of the acute and chronic rupture of the diaphragm. In the acute setting, the transabdominal approach is best because of the high likelihood of associated injury to other abdominal organs. If there is a delayed recognition of diaphragmatic rupture, the transthoracic approach is often indicated because concurrent abdominal organ injury is unlikely and adhesions of the herniated abdominal viscera to intrathoracic structures are often present.
- 2) Demonstrate closure of a diaphragm laceration with an initial row of horizontal interrupted mattress sutures followed by a running interlocking suture over the first layer of interrupted sutures.
- 3) Learn how to do the repair with the assistant changing the plane of the diaphragm from a vertical plane to an oblique plane.

Transabdominal Repair of an Acutely Ruptured Diaphragm:

- 1) Grasp the edge of the diaphragm laceration and place a horizontal mattress suture of 0-Ethibond (see next page). Repeat with interrupted mattress sutures until the laceration is closed.

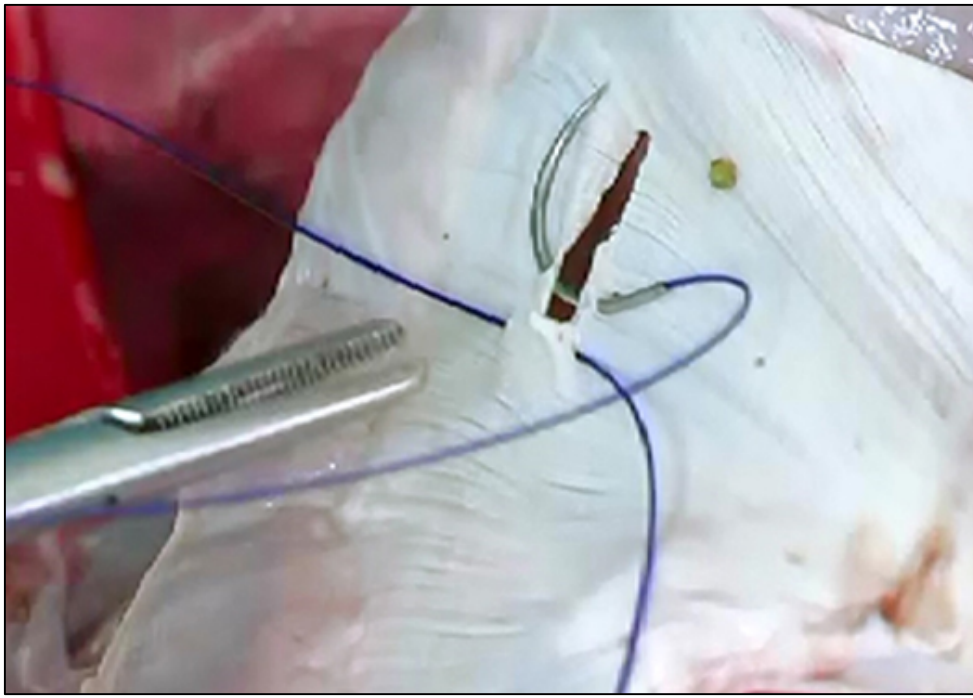


Figure 22: Ruptured Diaphragm Repair – Horizontal Mattress Suture

- 2) For the second layer, place a 0-Ethibond continuous interlocking suture along the entire length of the repair. This serves to reinforce the repair and enhance hemostasis.

Lesson #7: Patient Positioning for a Left Postero-Lateral Thoracotomy

Equipment Needed:

- Full body skeleton-3B Scientific Company.
- Flat table or-preferably-an Operating Room table with attachable padded flat arm board and a flexible upper arm support.
- 5 pillows.
- 3 sheets (2 for covering pillows and table, 1 as draw sheet for lifting thorax).
- One 4.5 inch x 3 yard Kerlix gauze bandage roll cut in 1 ½ yard lengths to encircle blanket rolls that stabilize thorax in the lateral position.
- One roll of 3-inch adhesive tape to adhere calf area foam padding to OR table and to adhere iliac crest folded blanket to OR table.
- Four foam rubber pads-12 inch x 4 inch - for padding calf, upper and lower arms.
- One rubber water bottle or plastic saline bag wrapped with a pillow case to create an axillary roll. The use of an axillary roll is not necessary if the anterior and posterior blanket rolls are positioned snugly against the patient's chest so that they elevate the chest cage with the right shoulder lightly touching the Operating Room table.
- 6 pillow cases (5 for pillows and 1 for axillary roll).
- 3 OR blankets (2 to make 15 inch long rolls secured with adhesive tape for thorax stabilization and 1 to fold lengthwise and tape for anterior hip padding and stabilization).
- Head rest pillow or a folded blanket to maintain the cervical spine horizontal to the Operating Room table.
- Cautery grounding pad.

Preparation of the Model:

- 1) Lay the full body skeleton on a flat surface or preferably an operating room table.

Goals of the Exercise:

- 1) Demonstrate patient stability in the lateral position.
- 2) Demonstrate proper padding and positioning to prevent pressure and stretch injuries to nerves, skin and muscles and shoulder joint dislocation.
- 3) Discuss how to maximize left thoracic cage rib separation with table flexion.
- 4) Reliably identify the correct intercostal space for the incision.

Patient Positioning for Thoracotomy:

- 1) If using an Operating Room table, remove the head piece and insert at the foot of the table.
- 2) Tuck in two sheets to cover the table.
- 3) Place two folded strips of Kerlix across the table just above the "break" with the "open" end of Kerlix facing the future side of the skeleton's spine. Place "draw sheet" (a sheet folded in half) over the upper half of the table on top of the two Kerlix strips. This will keep the Kerlix from "burning" the patient's skin when the Kerlix is tightened around the blanket rolls. Fold 2 sheets into two rolls 2 feet long and encircle with 1 inch adhesive tape to form blanket rolls (see next page).

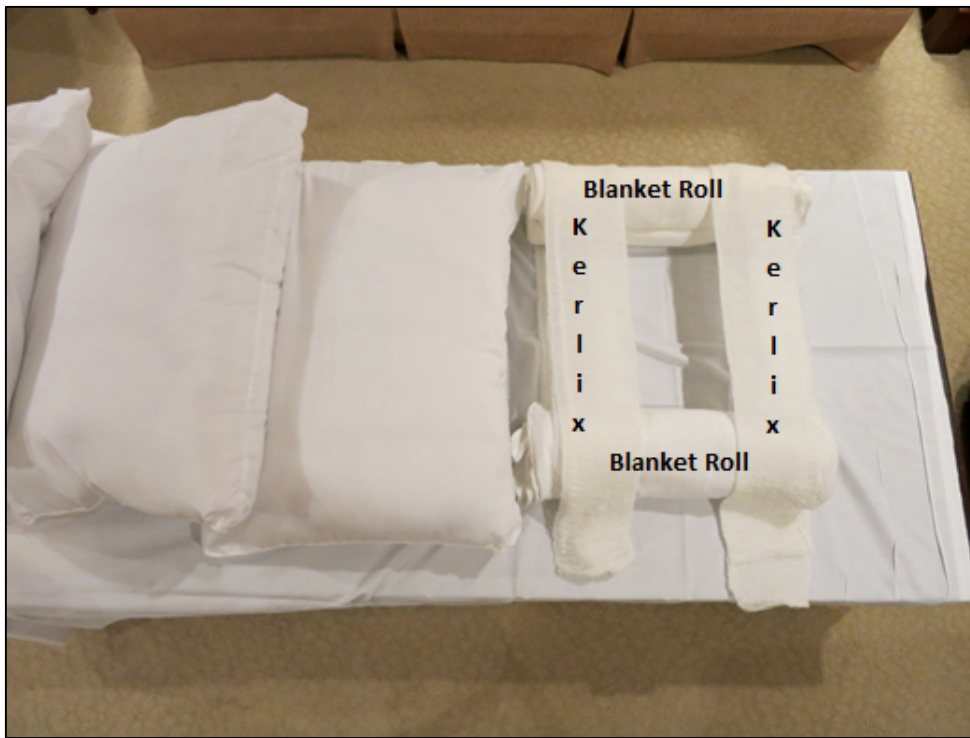


Figure 23: Patient Positioning

- 4) Insert one blanket roll within Kerlix loop at folded end of Kerlix and one blanket roll within the "open" end of the Kerlix.
- 5) Position the skeleton in the supine position with the tip of the xiphoid process over the "break" in the table.
- 6) Place two pillows covered with pillow cases side-by-side under the feet, knees and hips of the skeleton. Cover with a sheet and tuck in to hold pillows in place (see below).

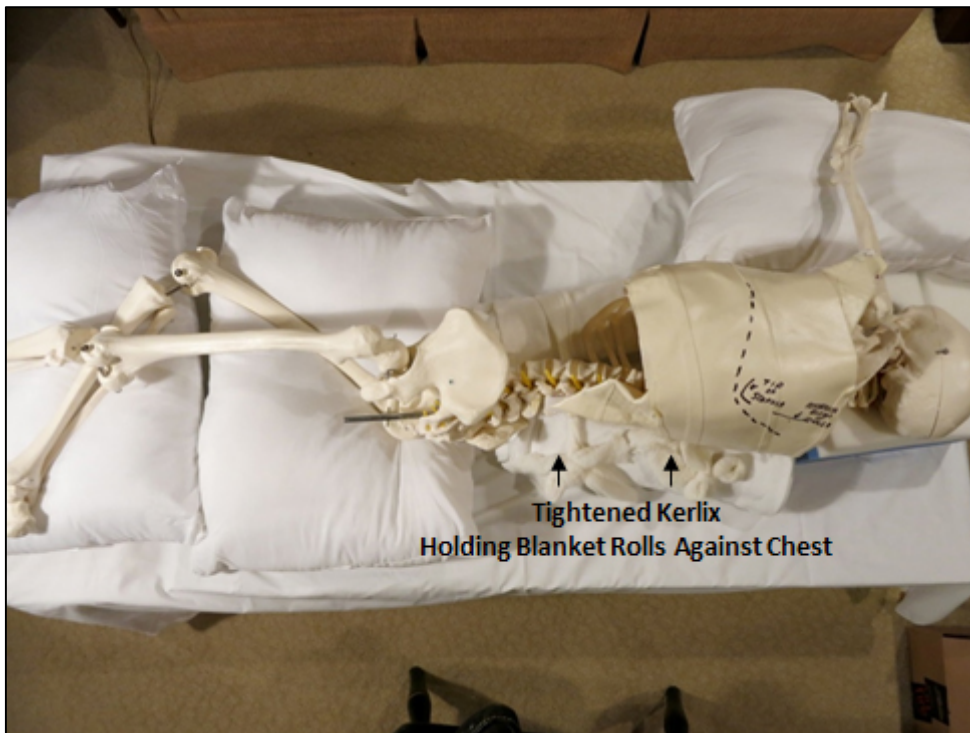


Figure 24: Lateral Thoracotomy Position

Patient Positioning for Thoracotomy (continued):

- 7) Place two pillows covered by pillow cases side-by-side between legs.
- 8) Attach padded flat arm board into right side of the table perpendicular to the right shoulder.
- 9) Attach padded flexible upper arm support to OR table. Lift skeleton with an assistant using the “draw” sheet and turn on its side facing to the right with right (lower) arm supported on the flat arm board and the left (upper) arm supported on the flexible upper arm board.
- 10) Pull the two Kerlix ends towards the skeleton’s spine and push the two blanket rolls snugly up against the sternum and the thoracic spine. Tighten the two open ends of Kerlix with a bow to hold in place.
- 11) Create an “axillary role” with an IV bag or water-filled rubber water bottle wrapped with a towel (or Chux pad) and secured in place with adhesive tape.
If an axillary role is chosen, ask the anesthetist or anesthesiologist to “flex” the table, then - while an assistant lifts the skeleton’s chest cage with their hands in the axilla - insert the axillary role just inferior to the assistant’s hands so that the roll lies just below the axilla. Do not place the role directly in the axilla as this will create pressure in the axillary plexus.
- 12) **Optional alternative to placement of an axillary role.** Tighten the two Kerlix strips against the anterior and posterior surfaces of the rib cage so that the patient’s chest cage is slightly elevated off of the surface of the O.R. table. This will reduced the pressure on the right shoulder and axilla and thus do without the need for an axillary “role”. Then ask the anesthesiologist or anesthetist to “flex” the table.
- 13) Place a foam pad under the head to keep the cervical spine parallel to the OR table and not flexed.
- 14) Reposition the two pillows between the legs with right “down” leg flexed at the hip and knee. The knee should be resting just at the right edge of the table. The foot should be just at the left edge of the table. The “upper” left leg is positioned straight.
- 15) Reposition the two pillows between the legs with right “down” leg flexed at the hip and knee. The knee should be resting just at the right edge of the table. The foot should be just at the left edge of the table. The “upper” left leg is positioned straight.
- 16) Place a foam cushion from the left calf to just below the knee and tape with three inch tape to the table to keep left leg from falling off the table. Make sure you can insert your hand easily between the foam cushion and the patient’s calf to avoid pressure injury to the calf.
- 17) Place grounding cautery pad on skeleton’s “thigh”.
- 18) Place foam padding under the skeleton’s right elbow lying on the flat arm board that has been placed perpendicular to the body.
- 19) Secure the upper arm in the flexible arm support at a right angle to the body. If the arm is positioned at a greater angle towards the head it will stretch the nerves in the brachial plexus.
- 20) Place foam padding under the entire left forearm on the arm board with the left elbow just proximal to the arm support.
- 21) Strap both arms in place with tape around the arm boards.
- 22) Place a folded blanket across the left hip at the top of the iliac crest and tape with three-inch tape to the table.

Note: It is suggested to perform the next steps after Exercise #8: Performance of a Left Postero-Lateral Thoracotomy.

Repositioning the Patient in the Supine Position after the Lateral Thoracotomy:

- 1) Untape the upper and lower arms from the arm boards to allow the arms to move when “unbreaking” (leveling) the OR table. If they are not released the change in position when the table is flattened may dislocate a shoulder.

Repositioning the Patient in the Supine Position after the Lateral Thoracotomy (continued):

- 2) Ask anesthesiologist or anesthetist to flatten (unflex) the table.
- 3) Remove the two pillows from between the legs and remove the blanket across the skeleton's hip.
- 4) Remove the axillary roll while an assistant lifts the chest cage with the draw sheet.
- 5) Untie the Kerlix and remove the blanket rolls from within the Kerlix.
- 6) Tuck both arms alongside the skeleton and, using the "draw" sheet with an assistant's help, turn the skeleton into the supine position.

Lesson #8: Performance of a Left Postero-Lateral Thoracotomy & Chest Tube Insertion

Equipment Needed:

- Full body skeleton- 3B Scientific Company.
- Spool of 22 gauge steel wire.
- Wire cutter.
- Microfoam 4-inch surgical tape-3M HealthCare- Sold by Vitality Medical, Salt Lake City, UT.
- Fine point black Sharpie felt pen to label anatomy.
- ¾ inch x 5 feet Velcro strips- Velcro Sticky Back, www.velcro.com.
- Gorilla Super Glue- The Gorilla Glue Company, Cincinnati, OH.
- Medium size right angle retractor.
- Rib spreader.
- Periosteal elevator.
- Rib cutter.
- Pigtail periosteal elevator (optional).
- Rib approximator.
- Sheet of small size bubble wrap.
- #1 Ethibond suture on a large needle.
- Needle holder.
- Suture scissors.
- Disposable scalpels with size 10 blades-Medi-Cut Sterile Disposable Scalpels with Safety Guard-Dynarex Corporation, Orangeburg, NY 10962.
- Chest tube.
- Kelly clamp.
- 0-silk suture on a curved needle.
- ¼ inch Vaseline gauze strips.
- 3-inch adhesive tape for chest tube attachment to chest wall.
- Waterseal drainage set.
- Plastic Y-connector for connecting two chest tubes to one waterseal drainage set.

Preparation of the Model:

- 1) Skeleton modifications: remove bolt holding left scapula in place. Cut off metal crossbar supporting left scapula at the vertebral body level. Cut the wire holding the 5th and 6th ribs together and replace with 22 gauge wire to hold the two ribs together for each exercise.
- 2) Create Left Latissimus Dorsi and Left Serratus Anterior muscle simulations with sandwiches made of Microfoam tape on the outside and small bubble wrap on the inside. Glue Velcro strips to muscle and bone origins and insertions.
- 3) Create left chest skin simulation with two layers of Microfoam tape stuck together. Glue Velcro strip to “skin” edges and anterior and posterior skeleton bony attachments.
- 4) Apply one layer of Microfoam tape to anterior segment of 6th rib for rib resection exercise.
- 5) Apply one layer of 4-inch Microfoam tape to the anterolateral rib cage between the sixth and ninth ribs for use in chest tube insertion demonstration.

Goals of the Exercise:

- 1) Demonstrate palpation of the inferior tip of the scapula.
- 2) Demonstrate the site of skin incision.
- 3) Describe the origin and insertion of the Latissimus Dorsi muscle and the intended line of division.

- 4) Describe the origin and insertion of the Serratus Anterior muscle and the intended line of muscle division or inferior fascial attachment to the chest wall to allow retraction antero-superiorly.
- 5) Demonstrate the subscapular identification of the first rib and subsequent counting down to desired intercostal space. Fifth interspace for most operations. Seventh interspace for distal esophagus and diaphragm exposure.
- 6) Demonstrate the placement of rib retractor.
- 7) Demonstrate the intercostal incision to enter the chest cavity and describe the location of the intercostal neurovascular bundle.
- 8) Demonstrate subperiosteal rib resection and removal to enter chest cavity. Discuss indications.
- 9) Discuss chest tube placement and option of intercostal nerve blocks.
- 10) Demonstrate rib approximation and discuss closure of incision.
- 11) Discuss the indications for single lung ventilation and techniques for lung retraction during surgery.

Performance of a Left Postero-Lateral Thoracotomy:

- 1) Review the following left chest anatomic landmarks: nipple, inferior tip of scapula, posterior border of scapula, spinous processes of thoracic vertebrae (see below).

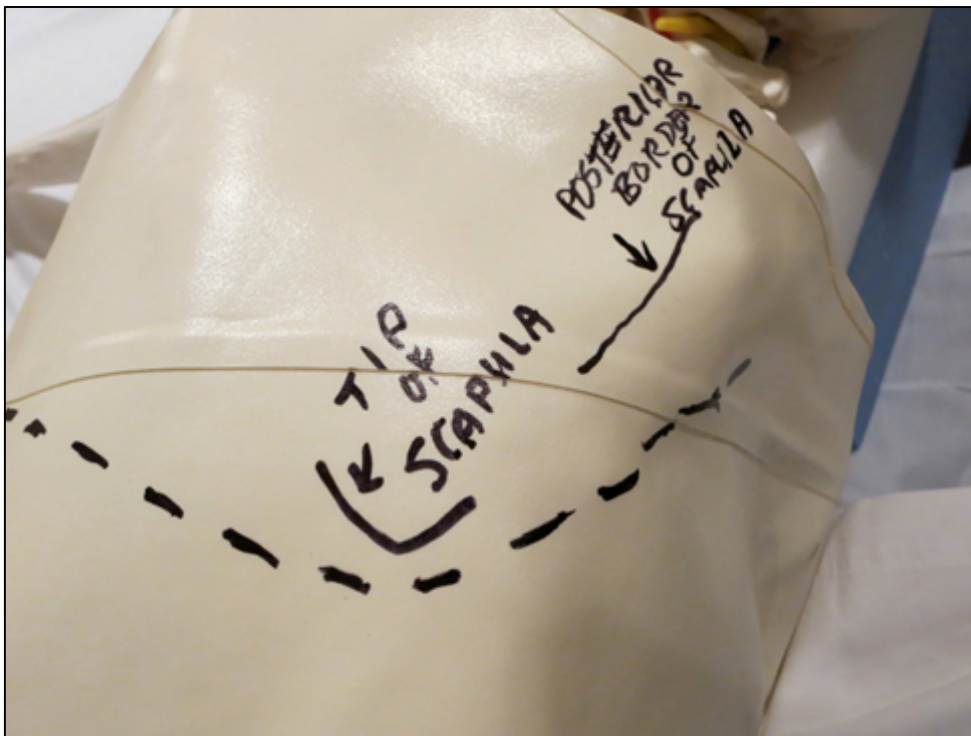


Figure 25: Left Chest Wall Landmarks

- 2) Outline incision.
- 3) Remove skin simulation by detaching from anterior Velcro strip. Keep attached to posterior Velcro strip.

- 4) Demonstrate origin and insertion of Latissimus Dorsi muscle (see below). Outline intended site of division. Remove from Velcro attachment to proximal humerus. Leave attached to posterior rib cage.

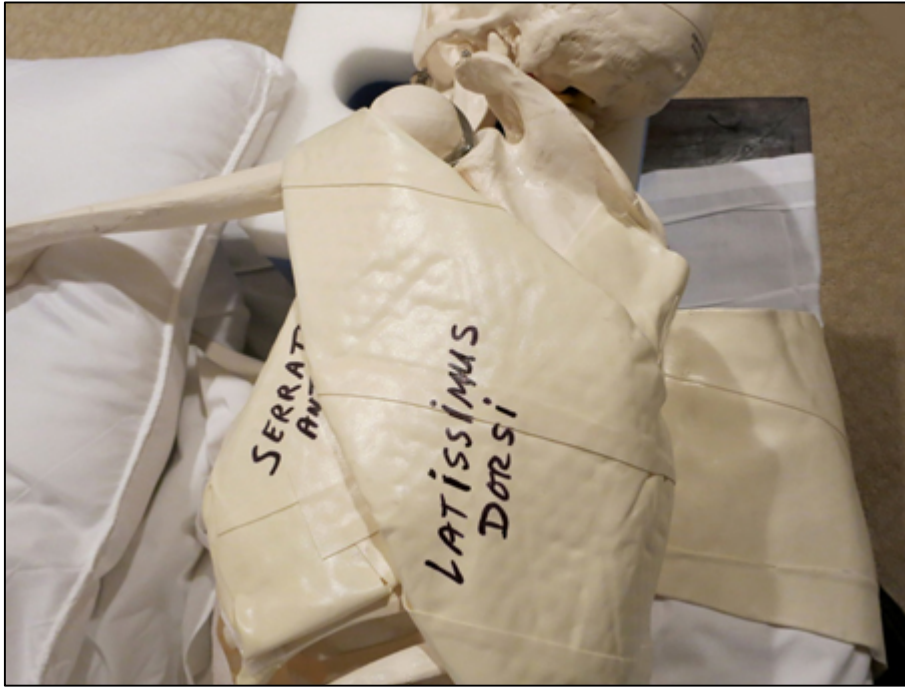


Figure 26: Latissimus Dorsi and Serratus Anterior Muscles

- 5) Demonstrate origin and insertion of Serratus Anterior muscle (see below).
- 6) Demonstrate site of fascial release from chest wall to permit antero-superior retraction of Serratus Anterior muscle.
- 7) Demonstrate subscapular identification of 1st rib and the technique of rib counting to 5th and 7th interspaces (see below).



Figure 27: Subscapular Palpation of 1st Rib

- 8) Release anterior Velcro attachment of Serratus Anterior to allow visualization of the 5th intercostal space.
- 9) Describe technique of intercostal space entry into the pleural cavity. Discuss the importance of communication at this step with the anesthesiologist or anesthetist. Describe the technique of Chest cavity entrance by rib resection using the Microfoam covered 9th rib.
- 10) Demonstrate the placement of rib retractor over gauze pads and reasons for long incision, slow rib separation and the limitation of separation width to the size of a fist (see below).



Figure 28: Thoracotomy with Rib Retractor

Closure of a Left Postero-Lateral Thoracotomy & Chest Tube Insertion:

- Chest tube placement. Describe making skin incision through the Microfoam “skin” just above the rib and the use of a Kelly clamp to create a “path” for the chest tube into the pleural cavity.
- Demonstrate Kelly clamp placement of the chest tube between the ribs with the tip of the clamp 1 cm beyond the end of the tube.
- Discuss anterior and posterior positioning of two chest tubes in the left thoracic cavity.
- Demonstrate securing of chest tube to chest wall with two 0-silk sutures.
- Demonstrate placement of circumferential “purse-string” 0-silk suture one cm. away from the base of the chest tube and then wrapping it untied after removing the needle around the base of the tube against the chest wall.
- Wrap a 10 cm length of the ¼ inch Vaseline gauze strip over the purse-string suture so that it will not adhere to the adhesive tape used to hold the tube to the chest wall.
- Apply a 20 cm length of 3-inch adhesive tape to the skin and chest tube to hold it in place. Repeat on the opposite side of the tube. Demonstrate the “elephant trunk” technique of creating three adjacent strips of the adhesive tape for 5 cm along one end of the tape so that the central strip can be wrapped around the chest tube and the two remaining outside strips can be secured to the skin beyond the chest tube.
- Demonstrate removal of the adhesive tape and underlying Vaseline gauze to expose the purse string suture when time comes for chest tube removal.

- Discuss the importance of removing the chest tube or tubes quickly with patient in maximum inspiration and manual compression of the tube sites to avoid pneumothorax.
- Demonstrate tying of the purse string suture at previous tube site.
- When closing the thoracotomy incision, discuss option of placing intercostal nerve blocks below each rib for postop analgesia.
- Discuss importance of communicating with anesthesiologist/anesthetist about releasing the left and right arm fixation to the arm boards and then “unbreaking” (flattening) the OR table at this point in the operation.
- Demonstrate the use of rib approximator and placement of pericostal sutures above the 5th rib and below the 6th rib.
- Discuss reattachment of inferior fascial border of Serratus Anterior and re-approximating the cut ends of Latissimus Dorsi muscle with placement of sutures through the surrounding muscle fascia and not just muscle tissue itself. Discuss the importance of anesthesiologist/anesthetist pushing the patient’s shoulder caudally and posteriorly to assist Latissimus re-approximation.
- **Optional.** Discuss and demonstrate principles of water seal drainage and how to “read” the drainage system for 1) air leaks 2) fluid drainage 3) fluctuation of water seal column as a guide to adequate post-op pain control and 4) tests to assure adequate chest wall suction.

Lesson #9: Chest Wall and Lung Decortication

Equipment Needed:

- Chest mannequin.
- Oil-based non-hardening clay- Plastalina by Van Aken International, Rancho Cucamonga, CA 01729.
- Polyethylene tubing - 3/4-inch x 18-inch (thoracic aorta simulation).
- Polyethylene tubing - 1-inch x 12-inch (thoracic spine simulation).
- Thirteen 1-inch bolts with nuts for attaching tubing to the mannequin and football half to mannequin.
- One 12-inch long rubber American football.
- One 10-inch long Styrofoam American football.
- One set of 10 disposal Size 10 scalpels - Dynarex Corporation, Orangeburg, NY 10962.
- One forceps.
- Two curved hemostats.
- One long Kelly clamp.
- Kittner dissector sponges - AMD-Ritmed Inc.-295 Firetower Drive, Tonawanda, NY 14150.
- One pair long Mayo scissors.
- Microfoam 4-inch surgical tape - 3M Healthcare- Vitality Medical, Salt Lake City, UT 84121.
- Drill set.
- Roll of 2-inch clear plastic packaging tape.

Preparation of the Chest Wall Decortication Model:

- 1) Saw the chest mannequin in half along its sagittal plane.
- 2) Cut an opening 5-inch x 8-inch on the lateral side of each mannequin half to simulate a thoracotomy incision.
- 3) Cut the rubber football in half along its short axis to simulate the diaphragm.
- 4) Drill three holes in the inferior portion of the mannequin to secure the football half with bolts. The point of the football is pointed cephalad.
- 5) Drill three holes in 3/4-inch tubing and the mannequin and attach to inside of left-sided chest mannequin to simulate the thoracic aorta.
- 6) Drill three holes in 1-inch tubing and mannequin and attach to the inside of the right-sided mannequin to simulate the thoracic spine.
- 7) Use 1/2-inch thick layer of Plastalina clay to line inside of left chest mannequin and “diaphragm” to simulate parietal thickening in third stage (organized) empyema. Begin at the level of the aortic arch and continue inferiorly to the end of the mannequin anteriorly and posteriorly. Cover the entire “pleural” surface of the football (the “diaphragm”).

Preparation of the Lung Decortication Model:

- 1) Wrap one layer of clear plastic tape around the football at the site of intended Microfoam tape wrapping.
- 2) Wrap three layers of Microfoam tape around styrofoam football on top of the plastic tape to simulate the hyalinized pleural thickening in third stage (organized) empyema. Decrease wrap to one layer towards one end of the football to simulate thinner apical peel over the lung (see next page).



Figure 29: Completed Models for Chest Wall and Lung Decortication

Goals of the Exercise:

- 1) Know the three stages of empyema and their recognition (Early Serous, Fibrinopurulent, and Late Organizing).
- 2) Know the intercostal and the rib removal techniques for entering the chest cavity.
- 3) Demonstrate removal of the parietal (chest wall) empyema peel.
- 4) Demonstrate removal of the visceral (lung) empyema peel.
- 5) Know the anatomic structures at risk during decortication (subclavian artery, intercostal arteries, thoracic aorta, phrenic nerve, esophagus, and diaphragm) and the techniques used to avoid them.

INITIAL PREPARATION FOR DECORTICATION:

Note: often in the setting of a late stage empyema, the volume of the lung will be reduced. This will cause the ribs to lie closer together and the diaphragm to lie much higher than usual. Removing a rib using the subperiosteal technique, described in the video from Exercise #8, will often allow room to begin the chest wall decortication by initial blunt finger dissection of the thickened parietal pleura off of the inside of the ribs.

Often finger dissection of the thickened chest wall pleura in a direction toward the apex of the chest cavity will demonstrate a thinner area of pleural thickening. One can then easily develop a plane between the lung pleura and the thickened tissue resulting from the empyema process. This plane can be extended inferiorly to initiate the lung decortication.

This will enhance the surgeon's ability to know how deep to incise the thickened pleura in order to orient himself or herself to the location of the underlying compressed lung, the actual empyema cavity (if present) and the location of the elevated diaphragm – three critical steps in performing a decortication.

Please note that the two exercises of chest wall and lung decortication are described as sequential events. In actual practice, the operation often requires moving back and forth between chest wall and lung decortication to achieve the best result.

Chest Wall Decortication:

- 1) Begin the chest wall decortication by blunt finger elevation of the layer of clay (the simulated layer of hyalinized thickened pleura) along the inferior border of the thoracotomy incision in the mannequin.
- 2) Continue medially towards the simulated descending thoracic aorta (see below). Discuss the importance of ending this dissection one centimeter lateral to the aorta in order to avoid injury to the intercostal arteries as they originate from the aorta.

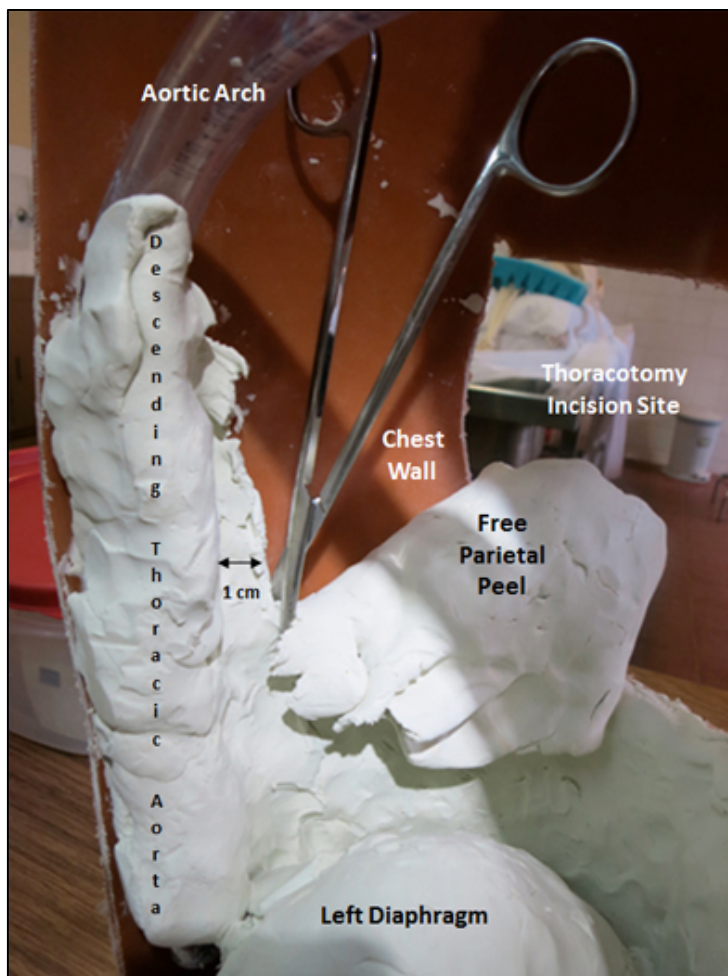


Figure 30: Chest Wall Decortication

- 3) Using heavy scissors, divide the “pleural peel” in a vertical fashion one centimeter lateral to the aorta and continue inferiorly down to the level of the inferior margins of the diaphragm anteriorly and posteriorly.
- 4) Discuss the importance of avoiding decortication of the apical pleura and the mediastinal pleura. Decorticating these surfaces does not contribute to any trapped lung expansion and

risks injury to the subclavian vessels, the major pulmonary vessels at the hilar area, the esophagus and the phrenic and vagus nerves.

- 5) Carefully dissect through the thickened “pleura” over the apex of the diaphragm in order to identify the diaphragm and develop a safe plane of dissection without perforation of the diaphragm.
- 6) Once this plane has been developed over the apex of the diaphragm, continue the decortication posteriorly and anteriorly until the entire diaphragmatic surface has been decorticated. Remove the thickened pleura that has been dissected free from the chest wall and diaphragm.

Lung Decortication:

- 1) Using the Microfoam tape covered American football, incise the “visceral peel” with the “belly” of the scalpel with shallow cuts.
- 2) Spread the pleural edges with a curved hemostat after each deepening incision to attempt recognition of the “pleural surface” of the lung (football) before cutting into it (see below).



Figure 31: Lung Decortication

- 3) Grasp edges of incised pleura with hemostats to assist the development of a plane just proximal to the underlying “pleura” (the layer of clear plastic tape). While assistant holds the hemostats, use Kittner dissectors to advance the plane of dissection. Also use scalpel edge to advance the edge of dissection.
- 4) Cut off pleural peel that has been freed up from the lung surface.
- 5) Deliberately incise the “pleural layer (plastic tape) into the underlying Nerf foam for a length of one centimeter and then demonstrate the strategy of avoiding further decortication in that area. Instead, decorticate the pleura in areas away from the pleural cut and thereby encircling the area of pleural entry. Only after completing the decortication circumferentially around the “pleural entry” does one complete the decortication directly over the pleural entry site. This maneuver avoids further damage to the underlying “lung” parenchyma that would happen if one continued decortication at the site of the entered lung tissue - thus worsening the damage to the underlying lung tissue.

Lesson #10: Transthoracic Repair of an Acute Esophageal Perforation

Equipment Needed:

- Goat mediastinal tissue block. Fresh from local abattoir. Refrigerate. Consists of heart, lungs, esophagus, trachea, diaphragm, thoracic aorta and esophagogastric junction with attached proximal one third of the stomach.
- Mannequin of human chest (from local department or Men's store) cut in half along the sagittal plane to create the simulation of a left hemi-thorax. Cut a wedge-shaped hole in lateral side of left chest mannequin to simulate a left postero-lateral thoracotomy incision.
- Two battery operated headlights (from local bike or sports store).
- Maloney tapered bougie- Size 45 French.
- 17-inch x 24-inch plastic cutting board with single screw placed in the center edge of each end of longest dimension.
- Lubricant- tube of K-Y jelly or Lubriderm.
- One pair of Metzenbaum scissors.
- Disposable scalpel with #10 blade.
- 3-0 vicryl sutures.
- 3-0 silk sutures.
- Long needle holder.
- One pair long surgical pickups.
- Two lung clamps.
- Endotracheal tube.
- Ambu bag for ventilating the lung using the endotracheal tube.
- Small Luer lock syringe to inflate endotracheal tube balloon.
- Two curved hemostats to "tag" sutures placed in esophageal muscle layer for exposure of submucosal layer.
- One lung retractor (eggbeater retractor).

Preparation of the Model:

- 1) Attach the mediastinal tissue block to the cutting board with #1 Prolene suture passed through the proximal esophagus and trachea. Do not obstruct the esophageal lumen. Tie this suture around the screw at the end of the cutting board. Place a second #1 Prolene suture through the distal diaphragmatic crura and tie around the screw at the distal end of the cutting board.
- 2) Pass a lubricated esophageal bougie the full length of the esophagus.
- 3) Using a scalpel, cut 1-inch longitudinal "laceration" through the esophageal wall down to the bougie.
- 4) Remove the bougie.
- 5) Gently grasp with a forceps the proximal and distal ends of the "laceration" and extend the submucosal/mucosal "laceration" with Metzenbaum scissors 1 cm proximally and distally.
- 6) Insert the endotracheal tube in the trachea, expand the balloon cuff and attach the tube to the Ambu bag.
- 7) Place the chest mannequin over the mediastinal tissue block and put on headlight.

Goals of the Exercise:

- 1) Observe the phenomenon of the submucosal/mucosal layer laceration extending for a greater distance proximally and distally than the muscular "laceration" and discuss why this is important to know.
- 2) Learn the gentle handling of esophageal tissue.
- 3) Experience working through a low postero-lateral thoracotomy incision while repairing a distal esophageal perforation in a patient whose lung is being ventilated on the operative side.

Transthoracic Repair of an Acute Esophageal Perforation:

- 1) Identify the site of the esophageal perforation (see below).

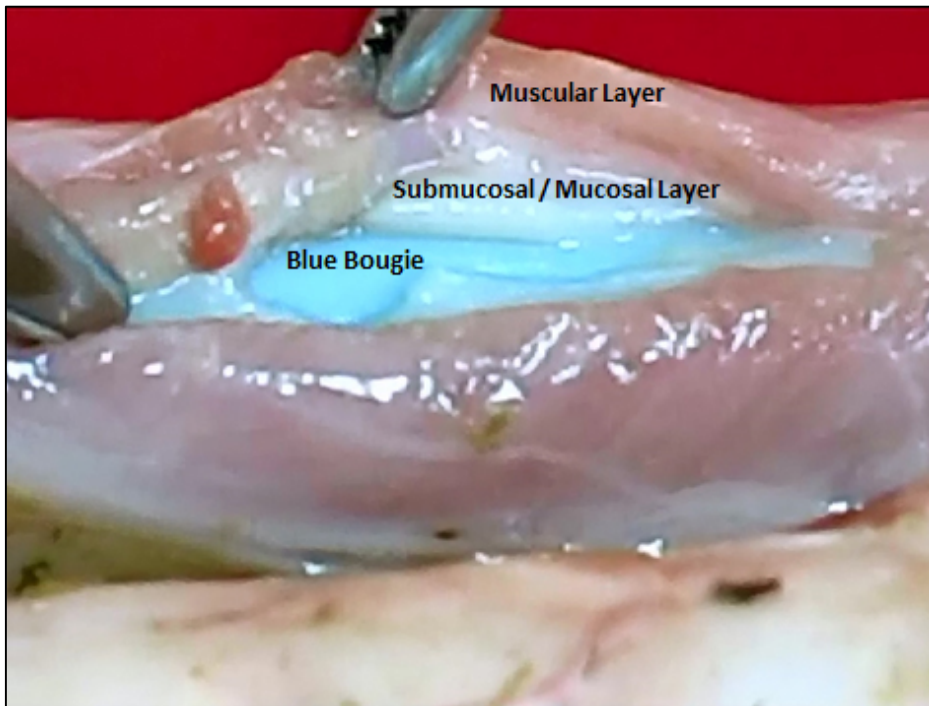


Figure 32: Esophageal Perforation with Bougie in Esophageal Lumen

- 2) Gently grasp the muscular layer of the esophagus at the proximal and distal ends of the laceration to assess the extent of the underlying submucosal/mucosal laceration. Extend the muscular layer laceration to expose the ends of the submucosal/mucosal laceration.
- 3) Close the submucosal/mucosal laceration with interrupted 3-0 absorbable sutures.



Figure 33: Tying Sutures to Close the Esophageal Perforation

- 4) Close the muscular layer laceration with interrupted 3-0 black silk sutures taking care to avoid narrowing the esophageal lumen.
- 5) Discuss the importance of placing a chest tube in a very dependent position in the chest cavity.
- 6) Discuss the harvesting of an intercostal muscle pedicle graft for reinforcement of the esophageal tear closure site. Note the importance of suturing the graft to the esophagus in a longitudinal manner. Discuss how wrapping the graft circumferentially around the esophagus will produce a calcified obstructing band around the esophagus due to the fact that the rib periosteal tissue will lay down new calcium.

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