

Chapter 11

The No-nonsense Trauma Thoracotomy

*Life is pleasant. Death is peaceful.
It's the transition that's troublesome.*

~ Isaac Asimov

Imagine playing a new computer game. The plot takes place in one or more of five domains or territories. While you're exploring one domain, the real action may well be unfolding in another. Each domain has a separate portal, and choosing the wrong portal for a specific game lands you in deep trouble from the get-go. To make things even more interesting, the game has a different storyline in each territory. To top everything, your game is fast-paced and short - with no replays.

Beginning to think that you don't want to play? Sorry, it's not a game, and you have no choice. It's thoracotomy for trauma, an operation that often starts as a good case and quickly turns into an operative roller coaster, especially if you are a general surgeon who does not frequently visit the chest. The action can unfold in one or more of five separate visceral compartments (two pleural spaces, pericardial space, thoracic outlet, and posterior mediastinum), each accessible through a different incision. Several pathophysiological mechanisms may be at work simultaneously: bleeding, hypoxia, cardiac tamponade, tension pneumothorax, and air embolism, each evolving at a different pace. Get the picture?

Where to cut?

Choosing the correct incision may well be your most important strategic decision in a trauma thoracotomy. The wrong incision can turn a straightforward case into a technical nightmare.

For the hemodynamically unstable patient in need of a crash operation, the utility incision is an anterolateral thoracotomy through the 4th intercostal space on the injured side. This quick incision keeps your options open. You can easily extend it across the sternum to the other side of the chest or go into the abdomen without having to reposition the patient. However, flexibility comes at a price. While an anterolateral thoracotomy allows you to get to all parts of the ipsilateral lung, trying to reach a deep posterior chest wall bleeder or a posterior mediastinal structure may be virtually impossible.

For a penetrating wound to the right lower chest with hemothorax, consider going into the abdomen first. The liver dominates the right thoracoabdominal region and is, therefore, the most likely source of severe hemorrhage (Chapter 10).

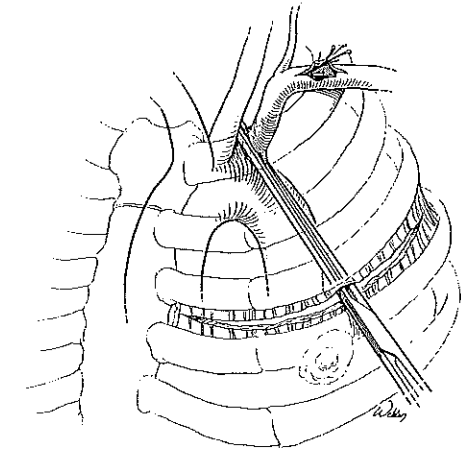
Begin with anterolateral thoracotomy in the unstable patient

Median sternotomy is a good incision for precordial stab wounds, since it gives you full access to the heart and great vessels of the upper mediastinum. Its biggest advantage is extensibility; you can easily carry it into the abdomen, neck, or along the clavicle. It also provides access to the hilum of each lung, but access to the periphery of the lung is restricted, and the posterior mediastinum is inaccessible.

In the patient actively bleeding from penetrating trauma to the thoracic outlet, you can stumble into a big trap if you choose the wrong incision. You must base your decision on an educated guess as to the source of hemorrhage. If the patient presents in shock with a large hemothorax, you typically begin with the utility anterolateral thoracotomy but may discover you cannot repair the injury through this incision. You must then rapidly extend it (or make a new one) to get to the bleeder.

If the patient is not actively bleeding into the pleural space, median sternotomy is a good incision for right-sided and midline thoracic outlet wounds, giving you access to the innominate artery and its branches. However, it is difficult to get to the left subclavian artery from the front because the vessel is intrapleural and posterior. So, in a patient with a

penetrating injury above or below the left clavicle, gain proximal control of the subclavian artery through a high left anterolateral thoracotomy in the 3rd intercostal space (above the nipple), recognizing that you cannot fix the vessel through this very limited incision. You will have to expose the injured subclavian artery through a separate incision (Chapter 13).



The classic trap door incision is a creative combination of a median sternotomy, left anterolateral thoracotomy, and a left clavicular incision. It requires forceful retraction to open the upper mediastinum and has a high incidence of postoperative causalgia-like pain due to stretching of the brachial plexus and other nerves. We never use it because you can achieve the same exposure using just two of the three elements of the trap door with much less morbidity.

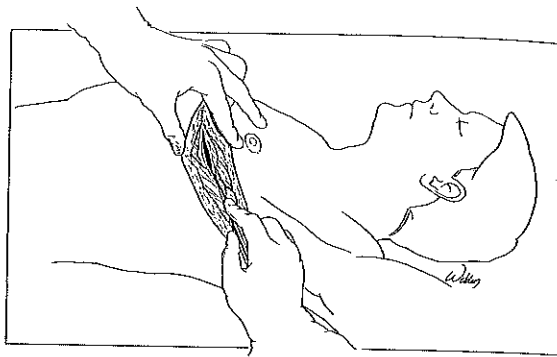
Stable patients hide fewer surprises. You know your surgical target from preoperative imaging, and this target dictates your choice of incision. Extensibility into another visceral compartment is usually not a consideration. Posterior mediastinal structures such as the aorta or esophagus are approached through a posterolateral thoracotomy at a level corresponding to the injury. In fact, posterolateral thoracotomy provides such outstanding exposure of the chest wall, lung, and mediastinum that one of us occasionally uses it in actively bleeding patients, especially if the penetrating wound is posterior and low.

Carefully select your incision for thoracic outlet injury

Anterolateral thoracotomy made easy

Place the patient supine with both arms extended, and shove a rolled sheet behind the scapula to slightly lift and medially rotate the operated side of the chest. A double-lumen endotracheal tube rapidly placed by a competent anesthesiologist gives you a huge technical advantage. Working around a collapsed lung is a walk in the park compared with the torture of trying to squeeze your way around a rhythmically inflating balloon.

Make a bold cut in the 4th intercostal space. In a male patient, this is below the nipple. In a female, retract the breast cranially and make the incision in the inframammary fold. Avoid the bulk of the pectoralis major by placing the incision immediately below it.

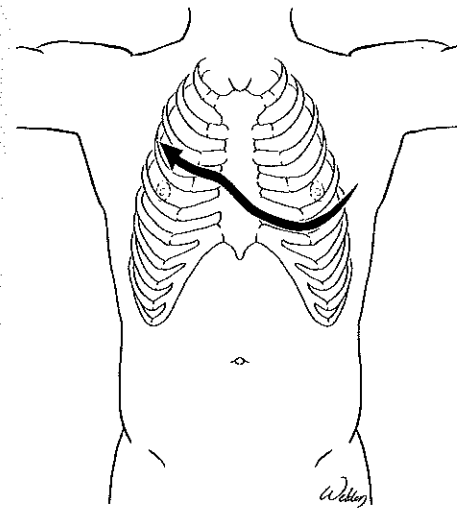
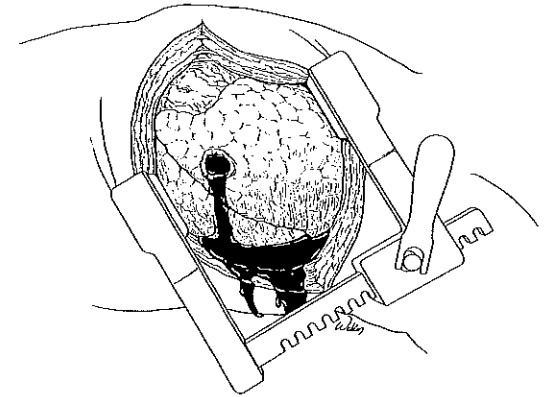


Think of this operation as the thoracic equivalent of a crash laparotomy. Work quickly and deliberately. This is not the time to be minimally invasive or go hunting for stray erythrocytes with your thunder stick. Just grab a knife and go into the chest. Carry your incision from the sternal border to the midaxillary line, following the intercostal space in a slight upward curve. Laterally, you soon encounter the law of diminishing returns: the further you extend your incision, the more muscle you have to cut with less exposure gained.

An experienced surgeon enters the chest with three bold strokes of the knife: the first divides the skin and subcutaneous tissue; the second cuts through the pectoralis fascia, the pectoralis muscle anteriorly and the serratus laterally; the third is a short incision in the intercostal muscles that brings you into the pleural space.

Grab a knife and dive into the chest

Once you have created a window into the pleural space, feel for any adhesions between the lung and the chest wall. If the way is clear, take a pair of heavy Mayo scissors and boldly cut the intercostal muscles along your line of incision. Insert a rib spreader into the incision with the handle toward the axilla; otherwise, the handle will be in your way when you try to extend the incision across the sternum. Open the rib spreader carefully to create your work space.



If necessary, extend your incision to the other side of the chest by cutting across the sternum cleanly using a Gigli saw, an oscillating saw, or bone cutters. When crossing the sternum from left to right, carry the incision upward to the 3rd intercostal space to stay above the right nipple, thus facilitating exposure of the upper mediastinal structures, especially the innominate bifurcation.

The classic pitfall in anterolateral thoracotomy is failure to identify and ligate the transected ends of the internal mammary artery. When the patient is hypotensive and vasoconstricted, this deceitful artery seldom

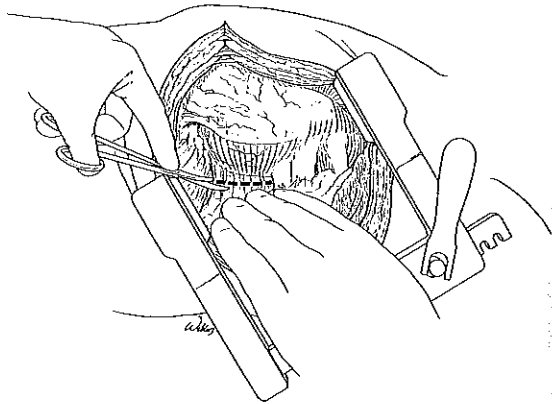
bleeds. After you close the chest, it soon makes its presence known. If you don't tie the transected ends, you guarantee your patient an early return to the OR.

Don't forget the internal mammary artery because it won't forget you

Once inside the chest

In most trauma thoracotomies you will not have the benefit of a double-lumen tube, and the anesthesiologist will not be able to drop the lung upon request. With the lung inflated, you initially see little except a rhythmically bulging balloon and blood around it. To explore the chest, you must mobilize the lung.

The key maneuver is cutting the inferior pulmonary ligament. Gently place your non-dominant hand below the lower lobe of the lung, pull it cranially to put the inferior pulmonary ligament on tension, and divide it with scissors. Remember that the ligament ends at the inferior pulmonary vein, and a lacerated pulmonary vein may bring your operation to a spectacular premature end. Now, you can retract the lung and work around it.



Mobilize the lung by cutting the inferior pulmonary ligament

Evacuate the blood, ask the anesthesiologist to stop inflating the lung for a moment, and rapidly assess the situation. Where is the bleeding coming from? Lung or chest wall? Do you suspect a pericardial

tamponade? Is there a mediastinal hematoma? Bright red blood pooling in the chest is frequently from chest wall bleeders, whereas a mixture of blood and bubbles usually comes from the lung. Gushes of dark blood are the hallmark of a pulmonary hilar injury. Mediastinal hematoma indicates potential large vessel injury. A bulging tense pericardium is a tamponade until proven otherwise. Obtain temporary control of bleeding by packing the chest wall, manually compressing the pulmonary hilum of a massively bleeding lung, or opening the pericardium to release a tamponade. Once you have temporary control of hemorrhage, decide whether you are dealing with BIG TROUBLE or a small problem (Chapter 2).

Are you worried about the other side of the chest? You certainly should be because you cannot see it. Any doubts about bleeding in the other pleural space (e.g. suspicious trajectory or unexplained hypotension) should prompt you to push your hand immediately anterior to the pericardium to create a window into the other hemithorax. Is blood pouring out of your window? Can you scoop up blood and clots when you push your hand into the lateral recesses of the pleural space? If so, you must explore the other side.

Next, optimize your work space. Is your incision adequate or do you need better exposure? Using bone cutters, you can divide the costal cartilage of the 4th rib at the upper edge of your incision to allow the rib spreader to open wider. If time is critical, open the rib spreader as much as you have to, even if you feel a rib cracking. This is not an elective thoracotomy, and you must have adequate exposure, whatever it takes. If all this is still not enough, the ace up your sleeve is, of course, a clam-shell extension across the sternum that will expose everything. It is, however, an incision that carries significant morbidity.

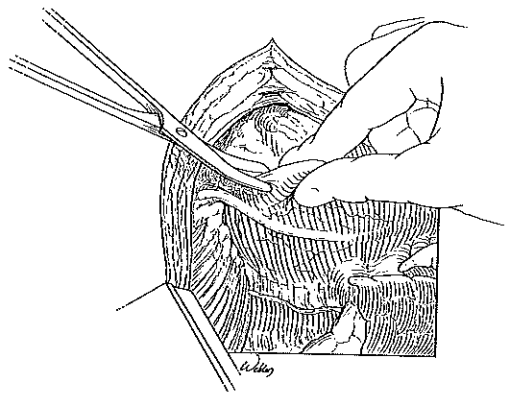
You may wish to do something about the lung that is rhythmically billowing in your face. You can ask the anesthesiologist to reduce the tidal volume to enable you to work around the lung, or you can help push the endotracheal tube into the contralateral bronchus. This "mainstemming" is much easier on the right, although the right upper lobe may remain non-ventilated. On the left side, it is difficult to blindly push the tube into the mainstem bronchus. Exchanging an endotracheal tube for a double-lumen

tube in mid-operation is difficult and dangerous. Consider it with much apprehension and only if nothing else works.

Optimize your work space and drop the lung if you can

Opening the pericardium

A classic error of inexperience is leaving the pericardium unopened because it looks okay from the outside. With the pericardium, what you see is not what you get, and a normal appearing sac can easily hide a tamponade. During a left anterolateral thoracotomy, retract the left lung



posteriorly to expose the left lateral aspect of the pericardium. Pinch it with your fingers to tent it up and make a nick with scissors anterior to the phrenic nerve. If you see blood draining through the hole, widely open the pericardium by sliding the slightly open scissors parallel to the phrenic nerve, and deliver the heart into the open chest.

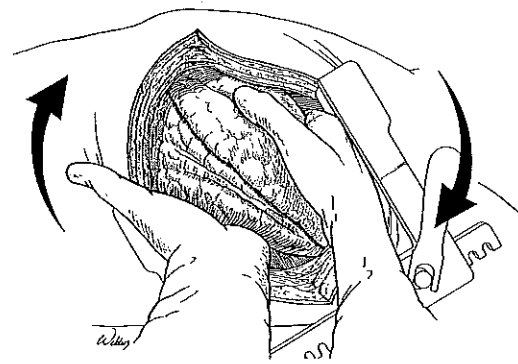
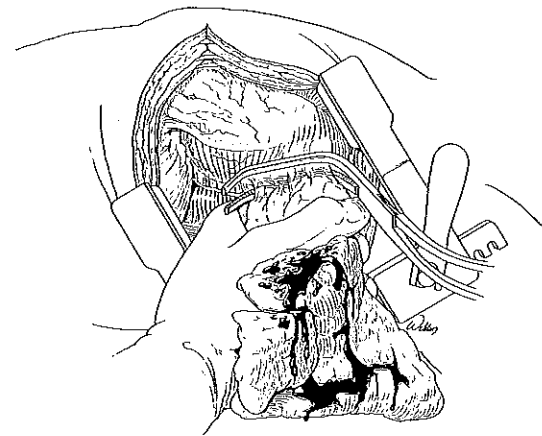
If you find blood in the pericardial sac during a right anterolateral thoracotomy, immediately extend into a clam-shell incision. You cannot properly examine or fix the injured heart from the right side.

The closed pericardium is an enigma - open it!

Controlling the pulmonary hilum

Massive bleeding from a central lung injury requires swift control of the hilum. Hilar clamping is a "doomsday weapon" because it is poorly tolerated by a patient in shock. If you can stop the bleeding by any other means, such as manual pressure, hemostatic suture, or rapid resection of the injured segment - don't clamp the hilum.

You can't even begin to encircle the hilum unless the lung is mobilized by cutting the inferior pulmonary ligament. Ask the anesthesiologist to stop ventilating the lungs momentarily, and gather the partially-inflated lung in your non-dominant hand like a bouquet of flowers. Negotiate a Satinsky clamp around the entire hilum, taking care to avoid injury to the phrenic nerve, which is alarmingly close. Pulmonary hilar clamping requires both hands; one hand holds the open clamp while the other guides the jaws around the hilum.



Clamping the hilum within the restricted work space provided by an anterolateral thoracotomy can be tricky because you often cannot see what you are doing. There is a simpler way to do it. You can twist the lung around the hilum - the pulmonary hilar twist. Instead of trying to negotiate an

open clamp around the hilum, simply grab the mobilized lung with both hands, holding the apex of the upper lobe and base of the lower. Now, twist the lung 180° so that the apex of the upper lobe abuts the diaphragm and the base of the lung is now where the apex resided until a few seconds ago. Bleeding stops immediately. You may need to place a laparotomy pad in the upper pleural space to keep the lung in the upside-down position. This quick and simple maneuver is particularly useful during ER thoracotomy, where exposure and working conditions are severely compromised.

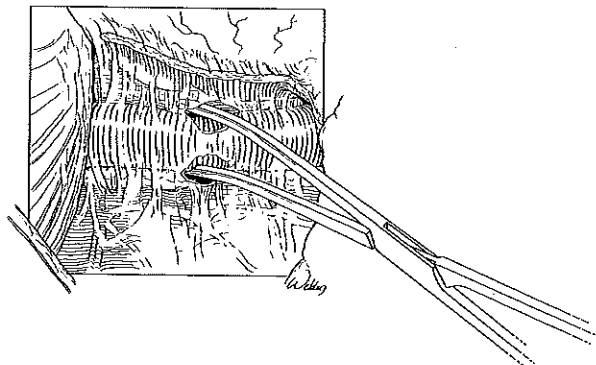
Twist the lung to rapidly control the hilum without a clamp

Aortic clamping

The descending thoracic aorta is flaccid and pulseless, easily mistaken for an adjacent flaccid pulseless tube, the esophagus. Clamping the esophagus does not improve the patient's hemodynamics one bit.

Placing a clamp on the descending thoracic aorta during an urgent anterolateral thoracotomy is guided mostly by palpation rather than direct vision. Retract the left lung anteriorly and slide your hand on the posterior chest wall from lateral to medial, feeling the concavity of the posterior ribs as they arch toward the spine. The first tubular structure you feel against the tip of your fingers is the aorta. You can either manually compress it against the spine or place an aortic clamp across it, freeing your hand for other useful work.

The key to successful clamping is to open the parietal pleura. If the mediastinal pleura overlying the aorta remains intact, your clamp will slide off and without obtaining a purchase on the vessel.



Make a hole in the parietal pleura on both sides of the aorta, either with your finger or Mayo scissors. All you need is a limited opening, just enough to accommodate a clamp, on each side of the flaccid tube. More extensive dissection may avulse an intercostal vessel or injure the aorta itself, making matters much worse.

You can't clamp the aorta over intact parietal pleura

The "turbo" version

The turbo version of a thoracotomy for trauma is the much-advertised ER (or resuscitative) thoracotomy, a heroic operation typically begun in the shock room but, if successful, always concluded in the OR. To begin a resuscitative thoracotomy, all you need is an endotracheal tube in place, a steady hand, a decent knife, and a brain in gear.

Fully abduct the patient's left arm to get it out of your way, have someone squirt iodine on the left chest, and start cutting. While sterility is not a central issue here, your safety is. Sharp instruments and needles are prominently in play during resuscitative thoracotomy. A cardinal rule, therefore, is to have only one pair of hands in the operative field - yours. Accidental sticks and cuts are a clear and present danger in the organized chaos of a resuscitative thoracotomy, and patients with penetrating trauma often carry transmissible diseases. Don't kill yourself or injure a colleague while trying to save your patient.

Resuscitative thoracotomy is a classic damage control procedure. After you open the chest, only five maneuvers are done in the ER.

The Five Moves of ER Thoracotomy

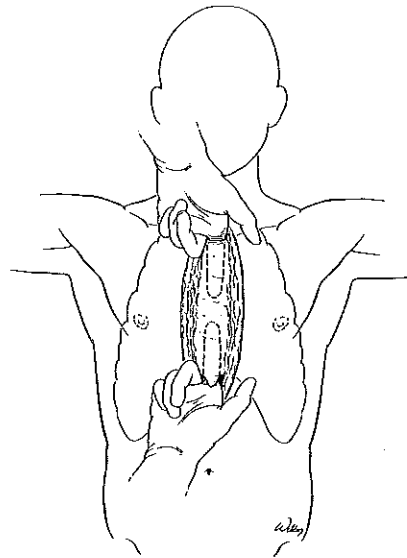
- Incise the inferior pulmonary ligament to mobilize the lung
- Open the pericardium and staple (or suture) a cardiac laceration
- Perform open cardiac massage
- Clamp the pulmonary hilum or twist a massively bleeding lung
- Clamp the thoracic aorta

If the patient survives, do everything else in the OR. If organized electrical activity does not return within a reasonable period of time, recognize failure and stop. Don't endanger your team in futile situations. Regardless of your surgical talents and experience, you will not have many survivors of resuscitative thoracotomy.

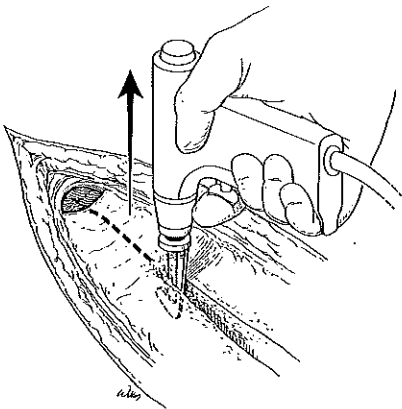
Worry about personal and team safety in a resuscitative thoracotomy

Median sternotomy

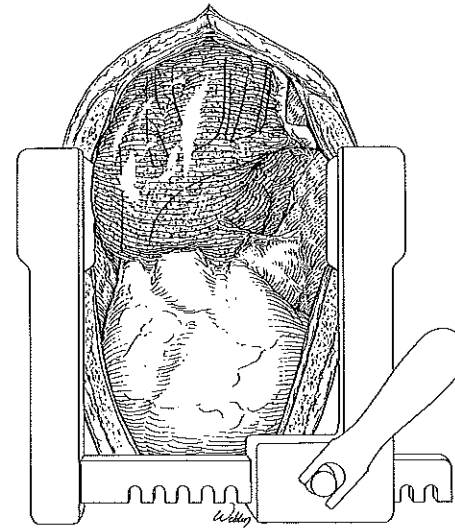
Make a vertical incision in the sternal midline extending from 2cm above the sternal notch to 3-4cm below the xiphoid. Deepen your incision to the anterior table of the sternum, keeping to the midline. Define the superior border of the manubrium and bluntly develop the retrosternal plane from above with your finger. Then, go to the inferior part of your incision and open the linea alba immediately caudal to the xiphoid to bluntly develop the same plane from below.



Ask the anesthesiologist to stop ventilating momentarily, divide the sternum in the midline using a vertical sternal saw. Hook the toe of the saw beneath the sternum and pull on it to elevate the bone as it is being cut to reduce the risk of iatrogenic injury to substernal structures. Use the cautery to control oozing from the cut edges of the bone. Insert a sternal



retractor and gradually open it without cracking the sternum.



What you are looking for is the left innominate vein, the gatekeeper of the thoracic outlet. Extending across the anterior aspect of the upper mediastinum, it is the first structure you have to deal with when dissecting in the thoracic outlet. In the trauma situation, identify, clamp, divide, and ligate the vein.

The left innominate vein is the gatekeeper of the upper mediastinum

Closing the chest

Much like trauma laparotomy, you have to choose between definitive and temporary closure of the chest. In either case, place chest tubes in the operated pleural space or in the mediastinum and inspect the chest wall carefully for intercostal, muscular, and internal mammary bleeders.

When should you consider temporary closure? It is a valid option when you are racing against the patient's rapidly deteriorating physiology or when you intend to return to the chest to remove packs or perform definitive repairs. Temporary closure of the chest means approximating only the skin to achieve airtight closure, leaving the ribs and chest wall muscles unapproximated. You can rapidly close the skin edges with either a continuous heavy monofilament suture or a series of towel clips. Rarely, when the heart is swollen and edematous and will not allow even skin closure of a median sternotomy incision, we temporarily suture an empty intravenous fluid bag to the skin edges while the underlying sternum remains open. This is the thoracic equivalent of the plastic bag closure described in Chapter 4.

Skin-only closure of an anterolateral thoracotomy has one big drawback: it bleeds. While making the incision, you typically divide a substantial mass of chest wall muscles in the lateral part of the incision. If you don't approximate this muscle mass, you will have continuous oozing that may translate into significant ongoing blood loss, especially if the patient is coagulopathic.

Formal closure of an anterolateral thoracotomy is straightforward. Approximate the ribs using heavy pericostal sutures followed by layered closure of the chest wall muscles, fascia and skin. In closing a clam-shell incision, take special care to precisely reapproximate the divided sternum using sternal wires.

THE KEY POINTS

- ▶ Begin with anterolateral thoracotomy in the unstable patient.
- ▶ Carefully select your incision for thoracic outlet injury.
- ▶ Grab a knife and dive into the chest.
- ▶ Don't forget the internal mammary artery because it won't forget you.
- ▶ Mobilize the lung by cutting the inferior pulmonary ligament.
- ▶ Optimize your work space and drop the lung if you can.
- ▶ The closed pericardium is an enigma - open it!
- ▶ Twist the lung to rapidly control the hilum without a clamp.
- ▶ You can't clamp the aorta over intact parietal pleura.
- ▶ Worry about personal and team safety in a resuscitative thoracotomy.
- ▶ The left innominate vein is the gatekeeper of the upper mediastinum.

Chapter 12

The Chest: Inside and Out

*Good judgment comes from experience.
Experience comes from poor judgment.*

~ Arthur C. Beall, Jr., MD

You are inside the right chest doing a thoracotomy for a gunshot injury to the low posterior back. You are relieved to see the lung is not bleeding. Bright red blood is coming from the bullet hole in the chest wall, probably from an intercostal artery. It looks like a simple problem that just needs a hemostatic stitch. Then, as you try to get to the bleeder, deep down in the inaccessible recesses behind the diaphragm, it gradually dawns on you - things are far from simple.

With the lung rhythmically billowing in your face, you can barely see the bleeder. Even if you do, getting to it through an anterolateral thoracotomy is tough, sometimes impossible. When you finally get to it and try to insert a figure of 8 stitch, you discover you cannot take a good bite with the needle because you keep bumping into ribs. The intercostal space is just not wide enough to accommodate a full swing of the needle. Welcome to the big leagues!

You have just come across a notoriously underrated injury - one of the "hidden monsters" of trauma surgery. It is certainly not the only one around. There is, in fact, an entire zoo. An injury around the EG junction (Chapter 5), a bleeding hole in the psoas muscle (Chapter 9), and blunt trauma to the lower extremity vessels below the knee (Chapter 15) are good examples. They are not as dramatic as a shattered liver or a gunshot to the surgical soul and may seem straightforward at first glance. But when you take them on, you discover you are in deeper waters than you thought, sometimes well over your head. The hidden monsters of trauma tax your operative creativity and imagination, forcing you to come up with unorthodox solutions.