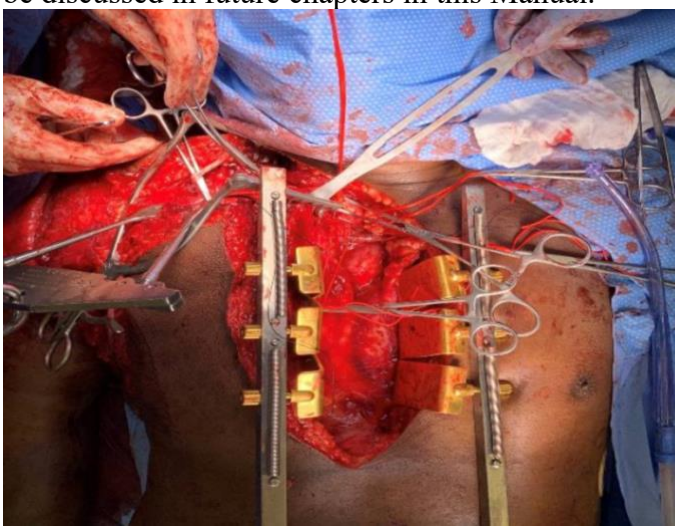
Sternotomy

Richard Davis, Elliot Bishop

Introduction:

A sternotomy provides excellent access to the anterior mediastinum, heart, and great vessels of the chest. It is used very frequently by cardiac surgeons for heart bypass and valve surgery, procedures that will likely never be done by the general surgeon in a resource-limited setting. However, this incision is very useful for resection of large tumors of the mediastinum such as thymoma, and on occasion for retrosternal thyroid tumors that cannot be delivered through the trans-cervical approach as described in the chapter Total Thyroidectomy for Substernal Goiter.

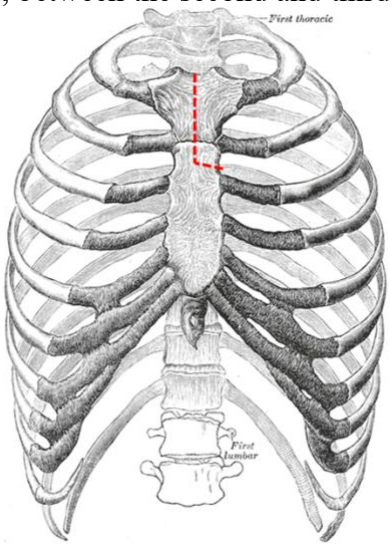
Surgeons who care for victims of penetrating chest or neck trauma also have reason to perform sternotomy, in patients with injuries to the heart, great vessels, or for proximal control of vascular injuries of Zone 1 of the neck. For more on this topic, see Approach to Penetrating Neck Trauma. Sternotomy can also be used to immediately apply a clamp to the proximal right or left subclavian vessels. In most circumstances, it is then extended as needed into an anterior sternocleidomastoid incision or a supraclavicular incision to expose the carotid, jugular or subclavian vessels. These approaches will be discussed in future chapters in this Manual.



Sternotomy extended into a right clavicular incision to expose a right subclavian artery injury.
Source: doi:10.1016/j.amsu.2020.03.012

The sternotomy should not be used in unstable patients, as it takes much more time to perform, and provides much poorer access to the lungs and hila, than a left or right anterolateral thoracotomy, which can be extended across to the contralateral chest in a maneuver known as the "clamshell" thoracotomy.

Here, we describe a complete sternotomy, dividing both the sternum and the manubrium. It is possible to perform only manubriotomy, or only partial sternotomy, by dividing the manubrium and sternum from the sternal notch downwards, then deviating the knife to one side into the second or third intercostal space. Recall that the second rib's medial end is at the sternal angle, where the sternum and the manubrium meet. The second intercostal space is caudal to it, between the second and third ribs.



Partial sternotomy is useful for accessing upper mediastinal structures such as a retrosternal thyroid gland or some venous structures. It does not provide as much access to the great vessels or the pericardium as a complete sternotomy.

Sternotomy is performed in the following steps:

- Incision from above the suprasternal notch to below the xyphoid process
- Division of the interclavicular ligament and blunt dissection behind the sternum from above and below
- Division of the sternum
- Insertion of the retractor and gradual opening
- Intervention
- Passage of wires through or around the sternum
- Re-approximation of the sternum and closure of the wires

Sternotomy

Richard Davis, Elliot Bishop

- Layered closure of the subcutaneous tissue and skin

Steps:

1. After induction of general anesthesia, the patient is placed in supine position with arms tucked at the sides. A small roll placed vertically between the scapulae spreads the shoulders slightly and makes the head tilt back.
2. The neck, anterior chest, and upper abdomen are prepared and draped.
3. Make an incision from above the suprasternal notch to below the tip of the xyphoid, and extend it down to the sternal bone with diathermy. Make the incision on the bone clear and straight, you will follow this line when cutting the manubrium and sternum. The best way to make sure this incision is right in the middle of the bone is to make it right in between the origins of the pectoralis muscles. This line is clearly visible if you go slowly with excellent hemostasis and retraction.

The suprasternal notch and xiphoid process are the landmarks for a sternotomy incision. In this chapter, the procedure is shown on a cadaver.

Skin incision extends from just above the suprasternal notch to just below the xiphoid tip and is carried down to the periosteum of the sternum, right between the origin of both pectoral muscles. Make a straight line in the periosteum with the diathermy; you will follow this line when cutting the bone as described below.

4. Extend the incision with diathermy just above the suprasternal notch, through the interclavicular ligament. Use a hemostat to elevate the tissue. Be careful here because the innominate vein may be just below this incision.

The interclavicular ligament, above the suprasternal notch, needs special attention: elevate it with a forceps and divide it with diathermy, taking care not to injure the innominate vein, which may be directly underneath.

Sternotomy

Richard Davis, Elliot Bishop

5. Use diathermy to extend the incision around and below the xyphoid process.
6. Dissect bluntly with fingertips behind the sternum from above and below, as far as you can, clearing any adherent soft tissue in the space between the sternum and the structures behind it: the pericardium, thymus gland, and the great vessels.

Blunt finger dissection under the sternum clears the space underneath it.

7. Using retractors such as "Army-Navy" under both the upper and lower aspects of the sternum and manubrium, gently pull the sternum anteriorly, opening up more space between it and the structures behind it.

Putting the ends of two retractors underneath the sternum, pull it anteriorly in an additional maneuver to increase the space between the bone and structures underneath.

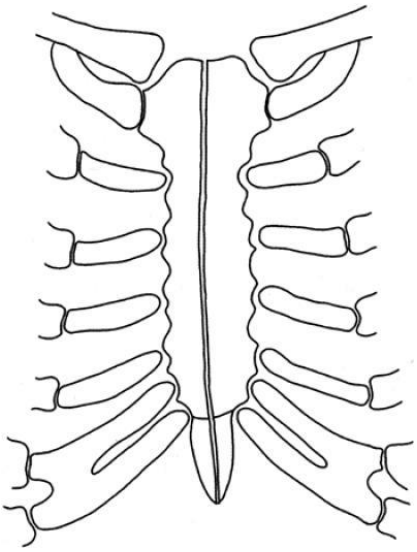
8. Remove the retractors and place the "guard" of the sternotomy knife (Lebschke) below the bone, either below the xiphoid or below the suprasternal notch. Pull the knife firmly upwards (anteriorly away from the patient). Strike the sternotomy knife in a controlled manner with the mallet held in the right hand. "Steer" the knife with the left hand to stay on the line that you created in step #3. The table will need to be lower during this step than the rest of the operation, to allow you to pull the knife upwards.

Sternotomy

Richard Davis, Elliot Bishop

The sternotomy (Lebschke) knife has a guard (Black circle) allowing its user to pull the sternum upwards with the handle on the opposite end. The cutting edge is to the right side of the knife in this photo.

Pulling upwards, the surgeon strikes the mallet and drives the blade through the bone.



The sternum and xiphoid are divided as evenly as possible, as shown here. Source: PMID: 11198322

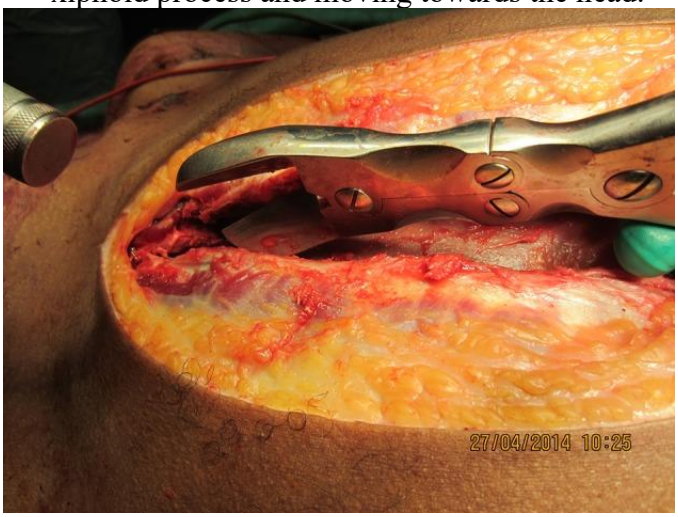
9. Alternatively, if you use an electrical saw, you must use the sternotomy attachment, which also has a "guard" that allows you to pull the sternum upwards as you cut it. A simple oscillating saw is dangerous, you cannot control the depth of the cut and you cannot pull the bone away from the innominate vein and other structures.

Electrical saw with sternotomy attachment. The "guard" in the Black circle is meant to sit under the sternum while the blade cuts the bone: the surgeon pulls the guard up against the bone by pulling upward on the handle, to prevent the blade from cutting anything deeper.
Source: doi:10.1016/j.xjtc.2020.03.007

Sternotomy

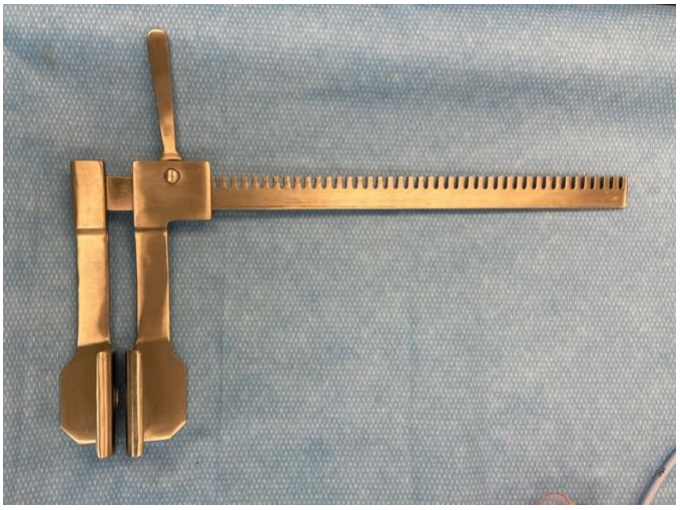
Richard Davis, Elliot Bishop

10. Alternatively, you may use a wire (Gigli) saw if you have a saw blade-passing tool, or a long narrow clamp to pass the blade from the xiphoid to the suprasternal notch. You may need to lengthen the caudal (upper abdominal) side of the incision to make enough room to pass the clamp or blade-passing tool.
11. Alternatively, a long straight bone cutter can be used to divide the sternum serially. The length of the cutter's handles requires starting at the xiphoid process and moving towards the head.



If you have no other tools for sternotomy, a long straight cutter can be used, as shown here, starting at the xiphoid process and moving cranially. Source: doi: 10.1308/rcsann.2015.0005.5

12. After you have divided all of the sternum, insert retractors to gently pull it apart and insert the sternotomy (Finochietto) retractor. Turn the handle to spread it a bit, wait 30 seconds, then turn the handle a bit more. If you do not have a sternotomy retractor, you can use a self-retaining laparotomy (Balfour) retractor with shallow blades. Continue to slowly widen the retractor until the cut edges of the sternum are about 8-12cm apart.



The sternotomy (Finochietto) retractor, shown here with its blades facing toward the viewer.

The sternotomy retractor in place, opened a little bit at a time.

13. Remove the sternotomy retractor and use small retractors to pull up on both sides of the cut bone. Using diathermy, go around the cut edges of the bone and control any bleeding from the periosteum, especially on the posterior aspect.
14. Replace the sternotomy retractor, open it a bit more, and perform whatever operation you came to do.

Sternotomy

Richard Davis, Elliot Bishop

When you open the sternotomy at first, fat and thymus tissue will make it will make it look unlike the anatomy books would suggest. The pericardium will be at the inferior aspect of the incision, and the great vessels will be at the superior aspect. Dissecting through the fat and glandular tissue at the superior aspect, the left innominate vein will be the first structure you see: encircle it and continue dissection to locate the aortic arch and origin of the innominate, left common carotid, and left subclavian vessels.

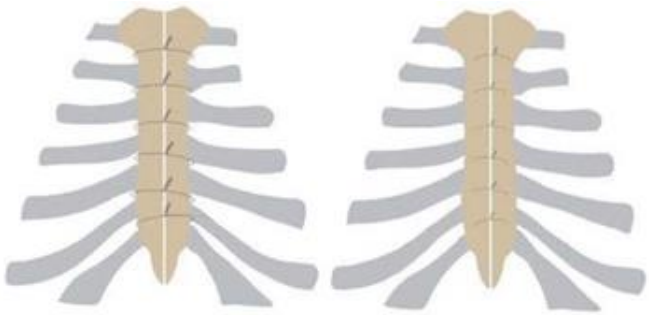
15. At the conclusion of the operation, be very careful to have excellent hemostasis. Areas that can bleed include the internal mammary arteries if they were injured, the thymus gland or any blood vessels feeding it, any small branches off the great vessels, and anywhere the pericardium was cut.
16. Place a closed suction drain in the anterior mediastinum and pass it outwards through the skin of the upper abdomen, below and to one side of the skin incision. If you have opened the pericardium, leave a chest tube inside it, directed posteriorly and inferiorly. If you have opened the pleura, leave a chest tube in the pleural cavity as well. Secure all these chest tubes to the skin before beginning closure so they cannot be dislodged.
17. Dedicated sternotomy wires are 1mm thick, swaged on to a heavy needle. Pass the needle directly through the sternum and manubrium; this takes some effort and practice. Grasp the bone directly with the thumb and index finger of your non-dominant hand, well away from where you will pass the needle through it. The needle will pass most easily when it meets the bone at an exact 90-degree angle. Pass two wires through the manubrium and four through the sternum. After you pass the wire, cut off the needle and grasp both ends with a heavy clamp, wrapping the wire around the tip of the clamp to protect yourself from its cut end.

As you pass the wires, attach a clamp to each end and wrap the wire around the tip of the clamp so that the cut ends of the wire are protected. Pass 4-6 wires and lay the clamps to their corresponding sides as you pass the rest

18. If you do not have dedicated sternotomy wires, use stainless steel wire that is no thinner than 1mm thick. The medical grade of this is United States Pharmacopoeia (USP) 5 wire, which is sometimes called “5 Gauge” wire. This is confusing however, because non-medical grade wire is classified according to several different “Gauge” systems. If you are sourcing your wire from non-medical sources, be sure it is stainless steel and at least 1mm thick.
19. To pass wire that is not attached to a needle, palpate lateral to the sternum and manubrium to feel the intercostal spaces. If it is difficult to feel them, use diathermy to dissect the skin and

subcutaneous tissues off the sternum and ribs about 2-3cm laterally. Then use the needle driver to pass the wire through the intercostal space, around the manubrium and sternum. Be careful not to injure the internal mammary arteries on either side. After you pass the wire, grasp both ends with a heavy clamp such as a Kocher, wrapping the wire around the tip of the clamp to protect yourself from its cut end.

If you have stainless steel wire but no needle, you can pass the wire (Black arrow) around the sternum in the intercostal space, using the "peristernal" strategy as described in the figure below.



Two strategies for sternal closure. If you have wire alone ("peristernal," left) you must pass the wire around the sternum and manubrium, through the intercostal spaces. If you have wire with a swaged-on needle, you may pass the wire through the bone itself ("transsternal," right), or pass it through the intercostal spaces adjacent to the sternum and manubrium ("peristernal"). Source: doi: 10.1590/0100-3984.2024.0094

20. Cross each wire over itself so that all of one side's clamps are on the other side of the sternotomy. Then pull all the clamps first upwards and then apart, bringing the sternotomy together. As your assistant maintains traction on all the clamps, separate each one and twist it down on itself, Repeat until each wire is twisted on itself. Make sure that the sternotomy is relatively stable at this point, there should be minimal movement between the two cut pieces of bone, though you will tighten further as below.

Cross each wire over itself. Hold all the clamps on each side in one of your hands and pull upwards and apart to bring the sternal edges together.

While an assistant maintains upward and outward traction on the clamps, separate each one and twist it on itself until this is done with all the wires, as shown here.

21. Cut off the excess wire. Tighten each wire further by grasping it with a heavy needle holder and pulling it upward. Then twist the wire to close

down the space that you have created by pulling. Tighten the wire by pulling only, and then twist to close the space you have created; tightening by twisting will break the wire.

Tighten the wire further by pulling it upwards as shown here. Then twist the wire until the newly opened gap between it and the bone disappears.

22. Crimp the cut ends of the wire downwards so that they lie flush with the bone and have no chance of cutting outwards through the wound.

The cut and twisted ends of the wire are turned downwards.

23. Close the subcutaneous tissue with interrupted absorbable suture
24. Close the skin with running absorbable subcuticular suture or staples.

Pitfalls

- Bleeding into the mediastinum, especially the pericardium, can be life-threatening. Take a brief "time out" before closing to make sure hemostasis is excellent, especially from the periosteum at the place you cut the sternum. Remember that no tube or drain can prevent a hematoma, or even help you to make the diagnosis.
- If the patient becomes hypotensive after surgery, consider tamponade, especially if you have opened the pericardium. This can be confirmed with an ultrasound, similar to a FAST scan in trauma, though this study will be more difficult postoperatively. Do not hesitate to re-open the sternotomy to relieve the tamponade, even at the bedside if the patient is in extremis.
- Sternal nonunion is a dreaded complication of sternotomy, due to infection or inadequate (too loose) closure of the sternum. The wires must hold the sternum in tight alignment as it heals. In resource-rich countries, solutions such as metal bands or miniplates and screws have been used to fixate the sternum to avoid this complication.

Sternotomy

Richard Davis, Elliot Bishop

Coronal CT scan image of sternal non-union. This problem can present as simple non-union, or infected non-union. Source: doi: 10.1590/0100-3984.2024.0094

Other open-source resources:
https://www.ctsnet.org/article/ctsnet-step-step-series-midline-sternotomy

https://www.ctsnet.org/article/ctsnet-step-step-series-sternal-closure-using-stainless-steel-wires

https://www.youtube.com/watch?v=fFz_vJpt8tQ

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