

# Supraclavicular First Rib Resection

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Thoracic outlet syndrome (TOS) is arguably one of the most controversial conditions that a thoracic surgeon faces. The clinical condition has been known about for almost 200 years, yet a consensus on diagnostic and treatment strategies does not exist. The most common form of TOS, neurogenic TOS (NTOS), results from compression of the brachial plexus within the anatomic boundaries of the thoracic outlet.

The majority of patients presenting for an evaluation of presumed NTOS have pain of the neck, upper chest wall, and upper extremity. Altered sensation of the upper extremity is also reported by most patients. Symptoms of cervicobrachial pain have a long differential diagnosis, and a thorough evaluation of these patients is required to exclude other potential causes.

The author favors the use of imaging studies, including 3-dimensional reconstructions of a computed tomographic scan with a specific thoracic outlet protocol. A similar magnetic resonance imaging protocol has been developed and is complementary to the computed tomographic scan. However, imaging studies can only identify anatomic abnormalities. These abnormalities may correlate with patient's symptoms, but proving they are causal can be difficult. Given this, the author has adopted a conservative approach in applying surgical intervention to the treatment of NTOS.

The surgical treatment of NTOS typically involves decompression of the thoracic outlet by resecting the first thoracic rib. Bone abnormalities of the C7 vertebrae, such as cervical ribs or an elongated transverse process, may also need to be resected. This may be performed through a transaxillary or supraclavicular approach. There have been no direct comparisons of first rib resection with these 2 techniques, and both have their proponents and detractors. Both provide dif-

ficult but adequate exposure to the first rib. In the author's opinion, the supraclavicular approach is favored because of its improved exposure to the scalene muscles and brachial plexus.

The technique of supraclavicular first rib resection is presented in detail, but a few general considerations must be mentioned. Both the surgeon and the assistant would benefit from using surgical telescopes, and the surgeon should wear a headlight to improve visualization. The author's preference is to wear either  $\times 2.5$  or  $\times 3.5$  loupe magnification glasses.

The amount of retraction on the spinal nerves, phrenic nerve, and brachial plexus trunks must be kept to a minimum. There is no accurate way to characterize the appropriate "minimal" traction, but compromised exposure must sometimes be tolerated to avoid these potentially devastating nerve injuries. The occasionally limited exposure increases the difficulty and length of the operation, but this needs to be accepted. This occasionally compromised exposure must result in proceeding with great caution at certain points of the operation.

Bone regrowth in the bed of the resected first rib has been seen as a potential cause of recurrent symptoms. This is prevented by resecting the periosteum along with the first rib. Using periosteal elevators to remove scalene muscle and other soft tissue attachments to the first rib may create a subperiosteal plane, which would remain attached to residual muscle in the bed of the rib. This is avoided by the use of bipolar cautery to divide this tissue, typically keeping some soft tissue on the rib.

The patient is induced with general anesthesia and intubated, preferably without the use of neuromuscular blocking agents. If these agents are required, then a short-term medication is used for paralysis during the intubation only. Avoiding these medications allows for the use of an electrical nerve stimulator during the case. This assists in identifying nerve structures, but also confirms their function at the end of the case. The endotracheal tube is taped to the side of the patient's mouth opposite to the side of the procedure.

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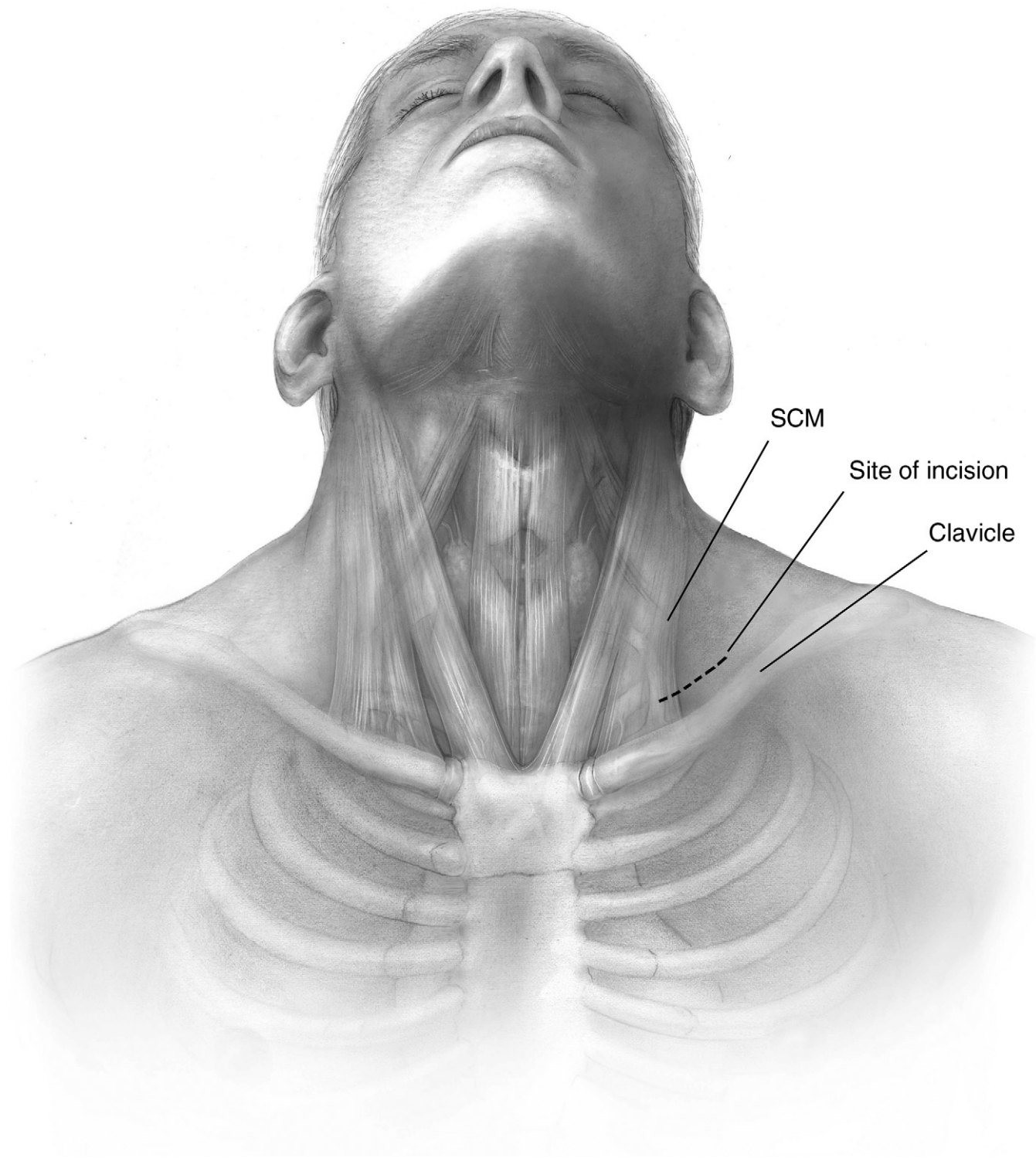
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**Figure 1** Modified semi-Fowler's position with shoulder raised on folded towels to open costoclavicular space.

The patient is placed in a modified semi-Fowler's position (Fig. 1). The back of the table is raised to the optimal height for the focal length of the surgeon's magnifying lenses. The patient's head is placed in a padded roll and rotated 45 degrees to the nonoperative side. If the patient's size allows, both arms are padded and tucked to the side without the use of arm boards. If this is not possible, then the operative side arm is tucked to the patient's side to allow the surgeon to stand closer to the patient. An arm board is placed on the nonoperative side as far down on the bed as possible to allow the assistant to stand close to the table as well. A large roll of gauze is placed for padding in each of the patient's hands, and

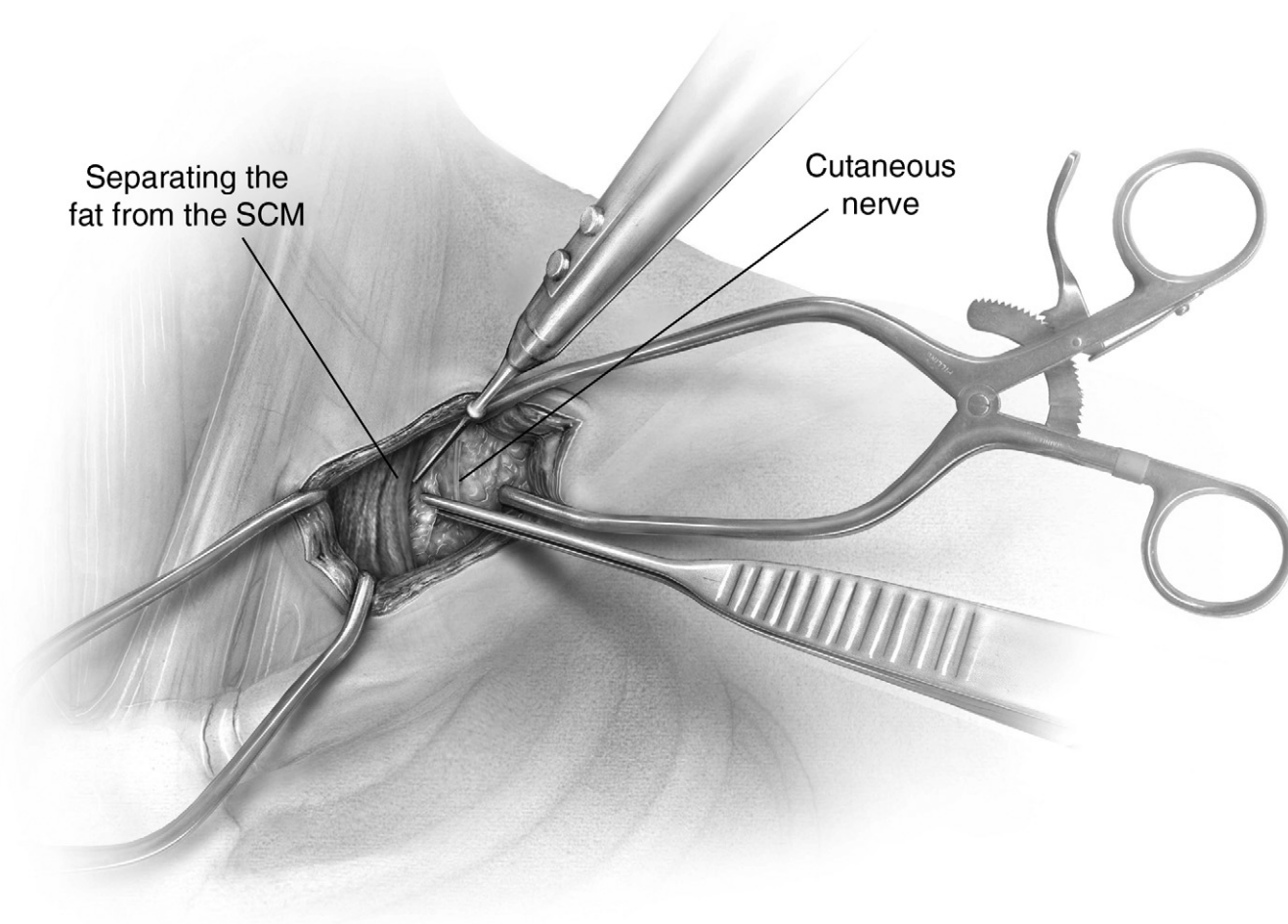
the hand and finger position must be evaluated after tucking the arms. The operative-side shoulder is elevated off of the bed by approximately 6 inches to pivot the shoulder and lateral clavicle anteriorly. This is accomplished by tucking a stack of folded surgical towels behind the shoulder while avoiding elevating the shoulder in a cephalad direction (ie, shoulder "shrug" position). This positioning opens the costoclavicular space and facilitates exposure of the anterior part of the first rib under the clavicle. The skin is then prepped sterilely and draped so that access is still available to perform a full sternotomy in the unlikely event of a major vascular injury.



**Figure 2** Location of skin incision for left supraclavicular first rib resection. SCM, sternocleidomastoid muscle.

An incision of 5-6 cm in length is made beginning 1 cm medial to the lateral border of the sternocleidomastoid muscle (SCM). This extends laterally 1-2 cm above the clavicle (Fig. 2). The subcutaneous tissue and platysma muscle are

divided with electrocautery. Skin hooks are placed under the dermis and lifted to show the areolar layer under the platysma. Flaps below the platysma are then created with electrocautery for 2-3 cm on either side of the incision.



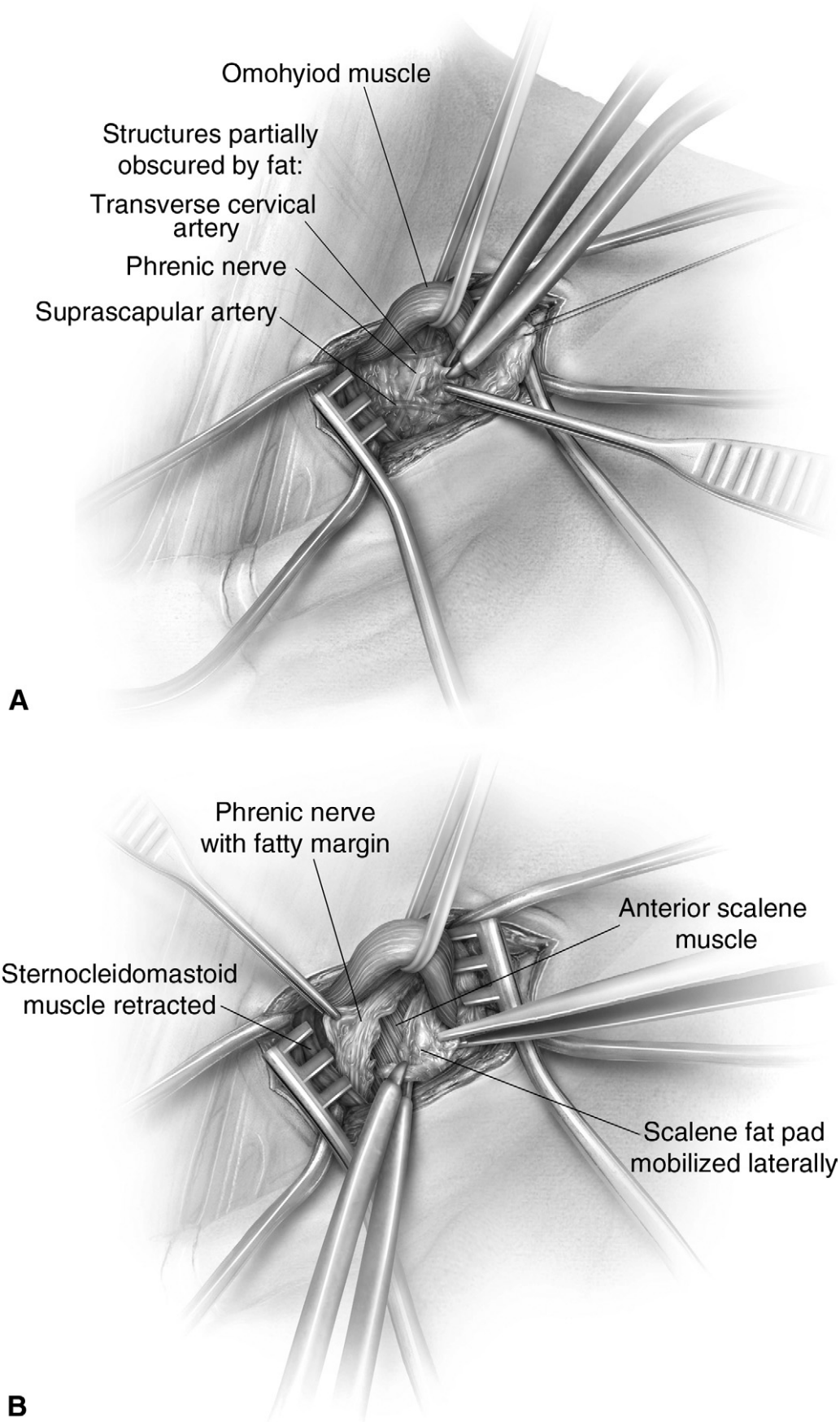
**Figure 3** The scalene fat pad is mobilized off of the lateral border of the sternocleidomastoid muscle (SCM).

Either a single Weitlaner or 2 Gelpy retractors (as shown in the diagrams) are placed below the level of the platysma. The scalene fat pad is mobilized off of the lateral border of the SCM using electrocautery (Fig. 3). Small sensory nerve branches and anterior jugular veins are identified running perpendicular to the incision. These structures are identified as mobilized without tension either medially or laterally depending on their position within the operative field. Another self-retaining Weitlaner retractor can be placed between the lateral wound edge and the lateral border of the SCM to retract the muscle medially. The scalene fat pad is then mobilized, creating a laterally based U-shaped flap. During this mobilization, small sensory nerves are identified running perpendicular to the incision. These are preserved and retracted with minimal tension either medially or laterally depending on their position within the operative field. There may be an anterior jugular vein, which is usually preserved, but may be ligated and divided if necessary.

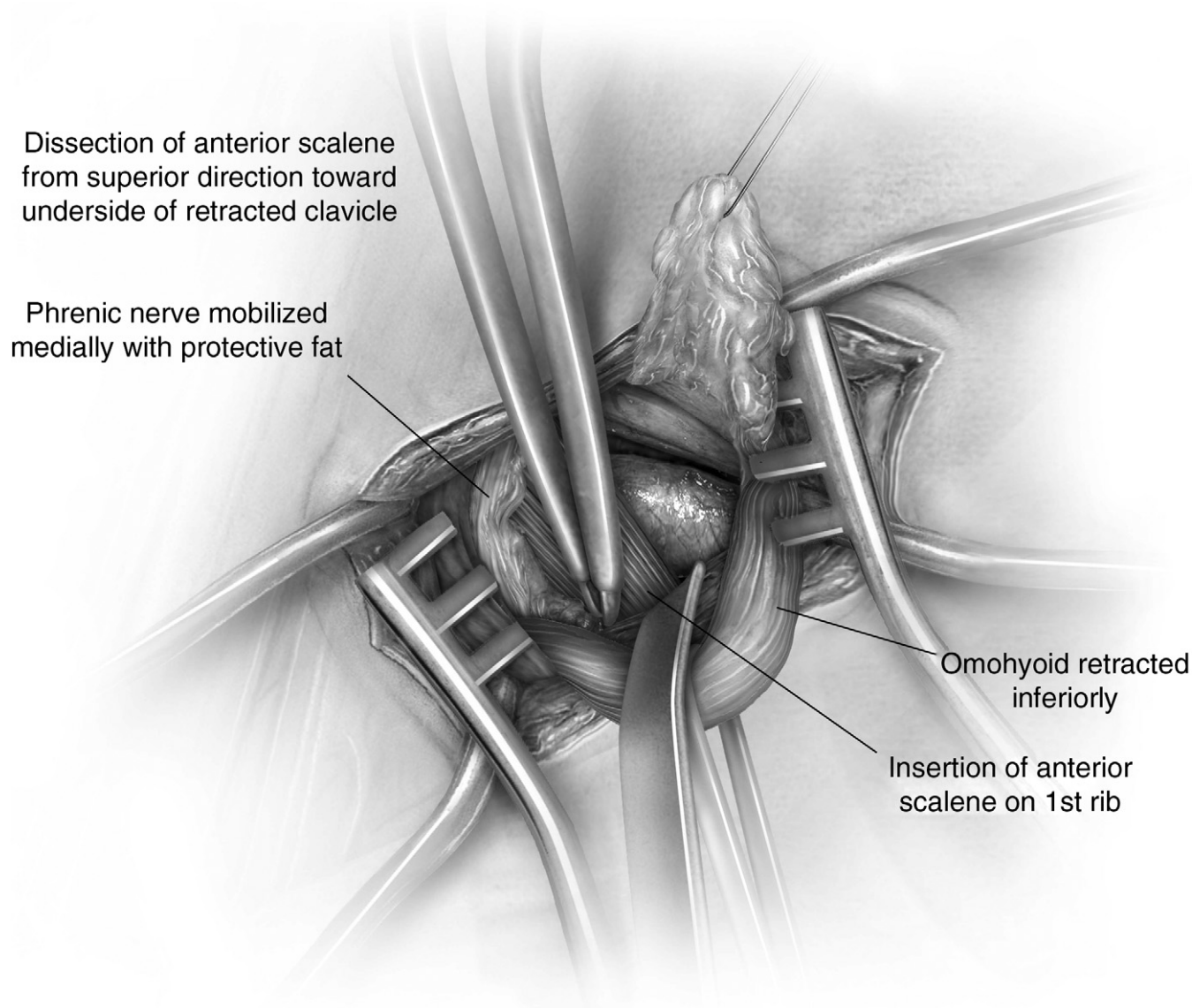
As the dissection through the deeper portion of the scalene fat pad continues, the omohyoid muscle is identified running approximately parallel to the incision. This is preserved and encircled with a vessel loop or small Penrose drain to allow for retraction (Fig. 4A). Deep to the omohyoid muscle, the

dissection through the fat pad continues using bipolar cautery to avoid transmitting electrical current to the phrenic nerve or brachial plexus. At this point, the surgeon should identify the suprascapular and transverse cervical arteries, as these vessels should be preserved. They typically run parallel to the incision, with the suprascapular artery below the level of the incision, and the transverse cervical artery above it. Once these vessels are identified and mobilized, it is usually not necessary to place retracting vessel loops around them. Below the level of the omohyoid muscle, palpation through the fat pad often assists in locating the anterior scalene muscle. The dissection continues with bipolar cautery and scissors until the scalene muscle is identified deep and slightly medial to the lateral edge of the SCM muscle. With identification of the scalene muscle, mobilization of the deep portion of the scalene fat pad continues from medial to lateral exposing the upper and middle trunks of the brachial plexus and the subclavian artery. The lower trunk is deeper to these structures and often not identified at this point. Dissecting the scalene fat pad off of the suprascapular artery laterally completes the mobilization of the fat pad. A 2-0 silk traction suture is placed on the tip of the fat pad, which is retracted laterally by snapping the suture to the drapes.





**Figure 4** (A) Scalene fat pad is mobilized down to the level of the omohyoid muscle which is encircled with a vessel loop and retracted toward the head. (B) The phrenic nerve is identified on the anterior surface of the anterior scalene muscle. With bipolar cautery this is gently mobilized medially.

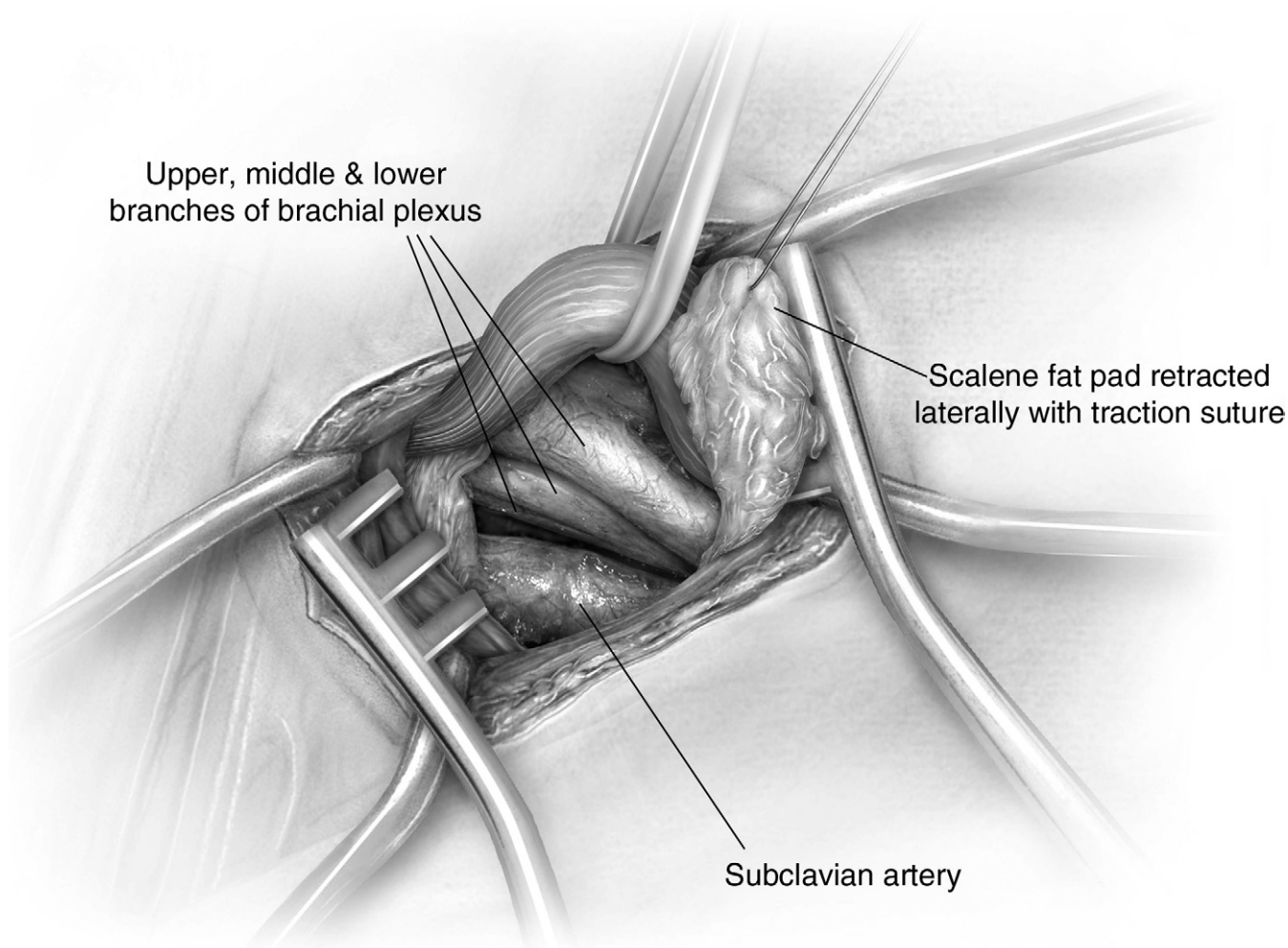


**Figure 5** Dissection of the anterior scalene muscle under the clavicle toward the scalene tubercle on first rib.

The surface of the anterior scalene muscle is exposed with caution, and the phrenic nerve is identified running from lateral to medial. A nerve stimulator (current setting 0.5-1.0 mA, frequency setting 30 Hz) is used to confirm the location and function of the nerve. The bipolar stimulator is applied to the nerve while palpating the abdomen for diaphragmatic contraction. This may be repeated during the procedure and prior to wound closure to confirm phrenic nerve function. There is frequently an areolar plane between the surface of the scalene muscle and the phrenic nerve, and tissue adjacent to the nerve is grasped and gently retracted to mobilize the nerve medially (Fig. 4B). Traction on the phrenic nerve must be strictly avoided, and it is important to keep some surrounding areolar tissue on the nerve. Occasionally, there is an accessory phrenic nerve branch located laterally to the main nerve, and a nerve stimulator helps in identification of this branch. At the cephalad portion of the scalene muscle, the phrenic nerve receives its contribution from the C5 spinal nerve. This limits the degree that the phrenic nerve can be mobilized medially in this location. With the phrenic nerve mobilized off of the anterior surface of the scalene muscle, the

plane along the medial border of the muscle is developed using bipolar cautery. The subclavian artery is identified medially, prior to passing behind the muscle. The dissection around the anterior scalene is continued down to the scalene tubercle on the first rib using bipolar cautery. A Richardson or Cloward retractor can be placed below the clavicle and gently lifted to facilitate exposure. The location of the tubercle is confirmed by palpation. The muscle frequently has a broad insertion on the first rib, extending laterally and connecting with fibers from the middle scalene muscle. This appears to create a muscular “sling” around the subclavian artery and lower trunk of the brachial plexus. There may also be fibers connecting the anterior and middle scalene muscles that must be divided to facilitate mobilization of the brachial plexus trunks.

The anterior scalene muscle is then partially divided medially and laterally directly on the scalene tubercle exposing part of the first rib. The central part of the muscle remains attached to the rib, as this connection facilitates division of the cephalad portion of the anterior scalene muscle. The scalene muscle is divided with bipolar cautery as far cephalad as



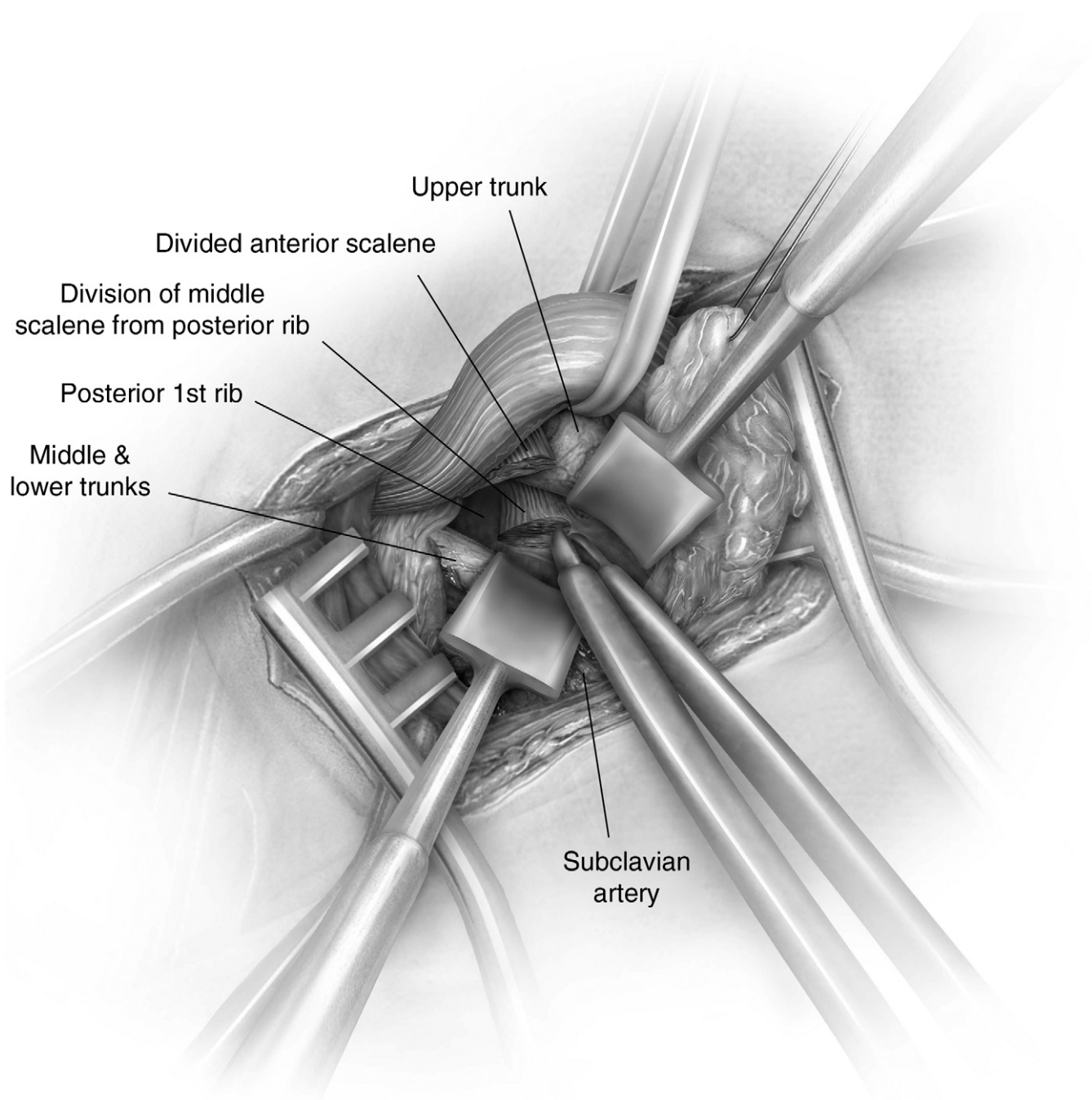
**Figure 6** Identification of brachial plexus trunks and subclavian artery after removal of the anterior scalene muscle.

possible. During this step, the phrenic nerve and its C5 spinal nerve contribution must be protected. Once the muscle is divided at this location, the remainder of the muscle inferiorly is divided off of the scalene tubercle and the muscle is then removed.

With the anterior scalene muscle removed, the dissection continues by mobilizing the brachial plexus trunks and the subclavian artery. The upper trunk and subclavian artery are often the first 2 structures identified. The middle scalene muscle is deep to the brachial plexus trunks and is easiest identified cephalad to the upper trunk. The subclavian artery is then mobilized to improve the exposure of the lateral aspect of the first rib. The dorsal scapular branch originating along the cephalad aspect of the subclavian artery is identified and preserved. This branch is typically 1-2 cm lateral to the lateral border of the anterior scalene muscle. It is important to remember that the brachial plexus trunks are oriented obliquely, with the middle trunk lying more dorsal (or deeper) to the upper trunk, and the lower trunk lying further dorsal to the middle trunk (Figs. 5 and 6). There may be a

variable amount of scar tissue associated with these structures, and this tissue is removed to allow for mobilization of the nerves during the remainder of the dissection. Removal of this scar tissue is frequently done sharply, with fine-tip bipolar cautery forceps used for hemostasis. Identification of the proper plane can be difficult, but the goal is not to disrupt the epineurium layer containing the blood supply to each nerve. Tissue adjacent to each nerve is grasped with atraumatic forceps and gently retracted away from each nerve to assist in identifying the proper dissection plane. Occasionally, blunt dissection is performed using a no. 4 Penfield elevator to peel scar tissue away gently from the epineurium. During the dissection of the upper trunk, the dorsal scapular nerve may be identified originating from the cephalad border. This initially runs parallel to upper trunk and then turns dorsally toward the suprascapular notch. Circumferential dissection of the middle and lower trunks is performed in a similar manner. It is important to remove any remaining scalene muscle fibers completely that may be present around the nerve trunks and artery.



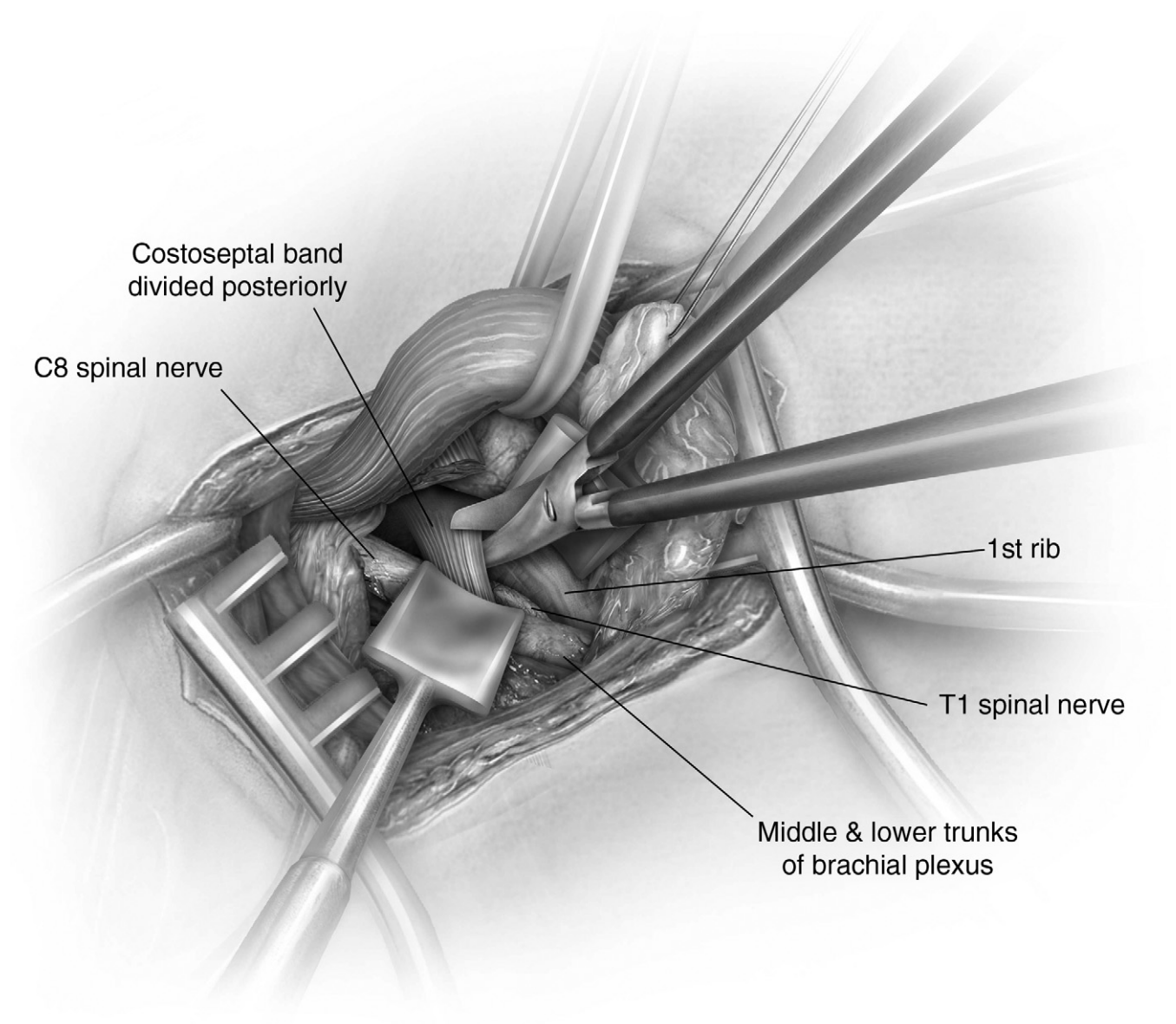


**Figure 7** Division of middle scalene muscle fibers off of the anterior and upper surfaces of the first rib posteriorly. Gentle retraction of the upper and middle trunks of the brachial plexus provides this exposure.

Once the brachial plexus trunks are mobilized, modified Love nerve root retractors can be used to retract the trunks to identify the middle scalene muscle lying immediately posterior to these nerves. It is of critical importance to minimize the degree of retraction on the nerves to avoid injury. With palpation both above and below the middle trunk, the posterior aspect of the first rib can be identified. The rib can be exposed posteriorly by dividing middle scalene fibers overlying it with bipolar cautery (Fig. 7). Because of individual anatomic variability, there is no universal ideal path to the

posterior first rib. Typically, this is approached by working between the upper and middle trunks, but occasionally this is accomplished between the middle and lower trunks. If cervical ribs or elongated C7 transverse processes are to be removed, then the best approach is often by working over the top of the upper trunk. Because the dorsal scapular nerve (originating from the C5 spinal nerve) and the long thoracic nerve (originating from the C5, C6, and C7 spinal nerves) penetrate the middle scalene muscle, it is important to divide middle scalene fibers inserting on the first rib close to the cephalad

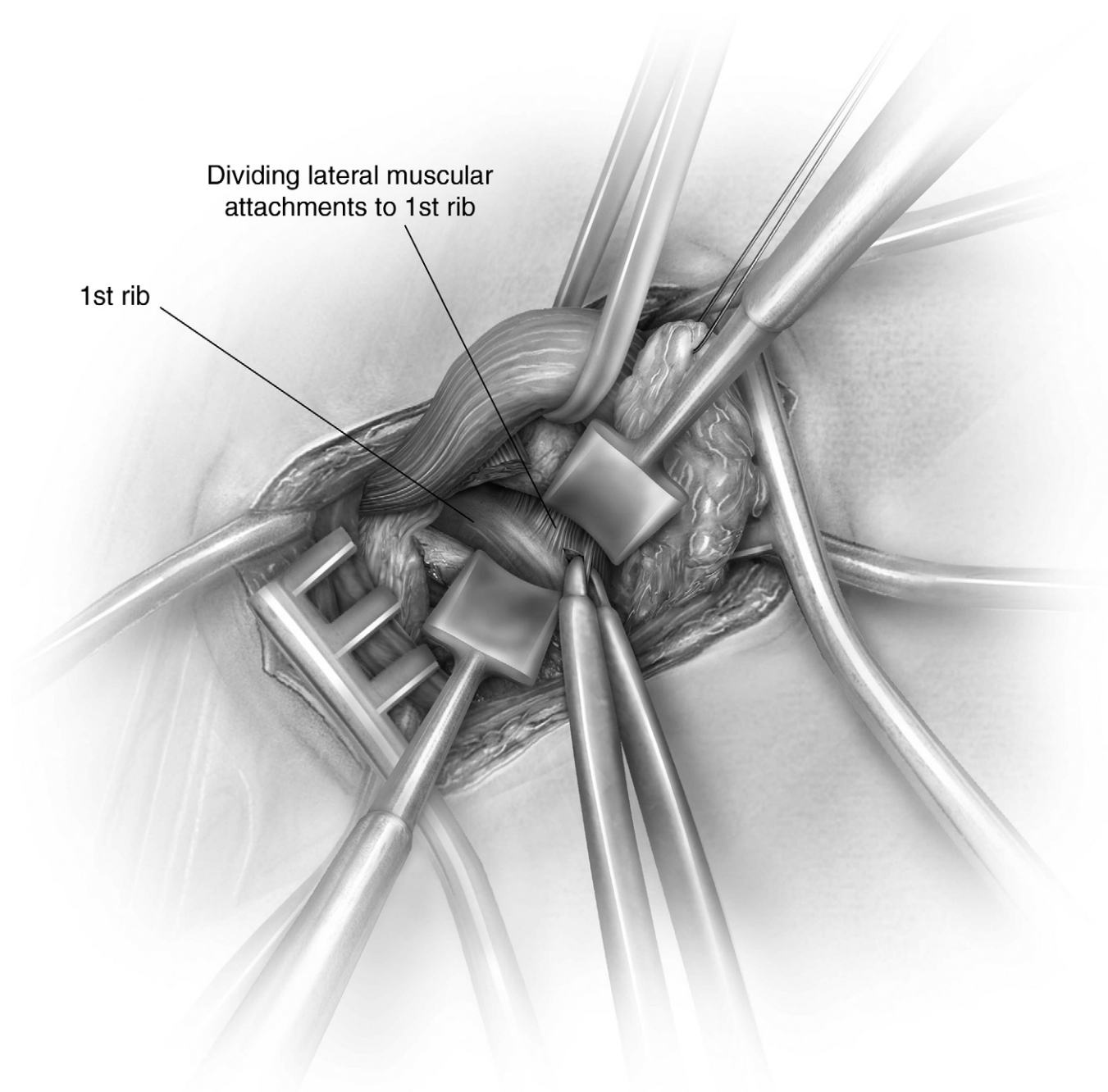




**Figure 8** Division of soft tissues attached to the first rib. These may connect to the spine, the suprapleural membrane or the first rib anteriorly. The T1 spinal nerve must be identified and protected during this maneuver.

surface of the rib. The inner edge of the posterior first rib is then exposed. There is frequently firm tissue bands attached to the rib posteriorly. These costoseptal bands may communicate with the “septum” (ie, the suprapleural membrane or Sibson’s fascia). There may also be a ligament between the posterior and anterior aspect of

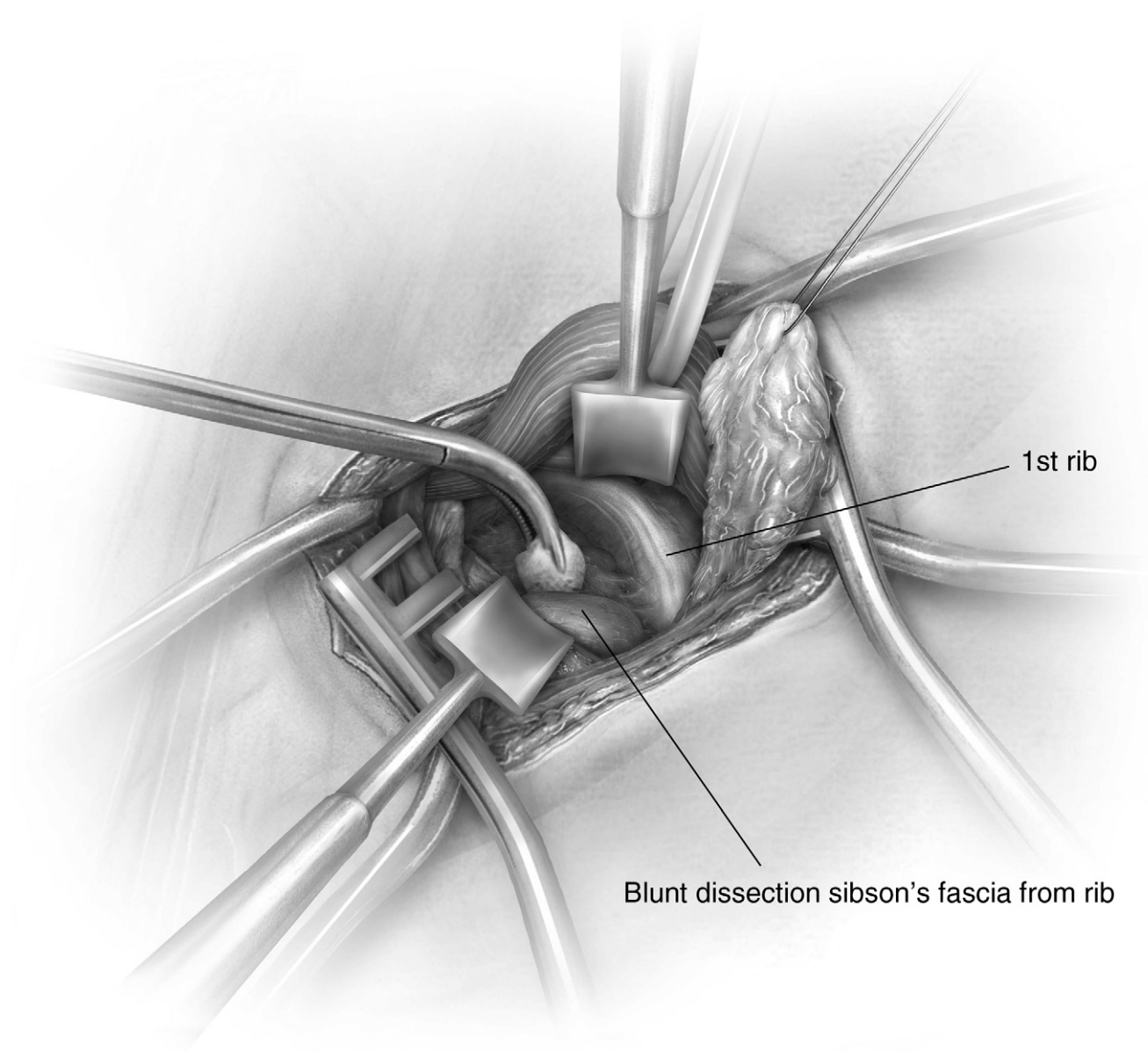
the rib (costo-septal-costal ligament, or Roos type 3 band). These structures may create a site of entrapment of the T1 spinal nerve as it arises from below the first rib and joins the C8 spinal nerve to form the lower trunk and must be divided to release the T1 nerve completely (Fig. 8).



**Figure 9** Middle scalene and serratus anterior muscle fibers are divided off of the first rib laterally with bipolar cautery.

The muscle fibers are divided off of the cephalad and dorsal surfaces of the first rib with bipolar cautery working from medial to lateral (Fig. 9). As this proceeds laterally, the exposure of the rib is improved by working both above and below the lower trunk of the

brachial plexus with minimal traction on these nerves. In addition to middle scalene muscle fibers, there are fibers from the upper aspect of the serratus anterior muscle, which are divided off of the rib posterior to the subclavian artery.

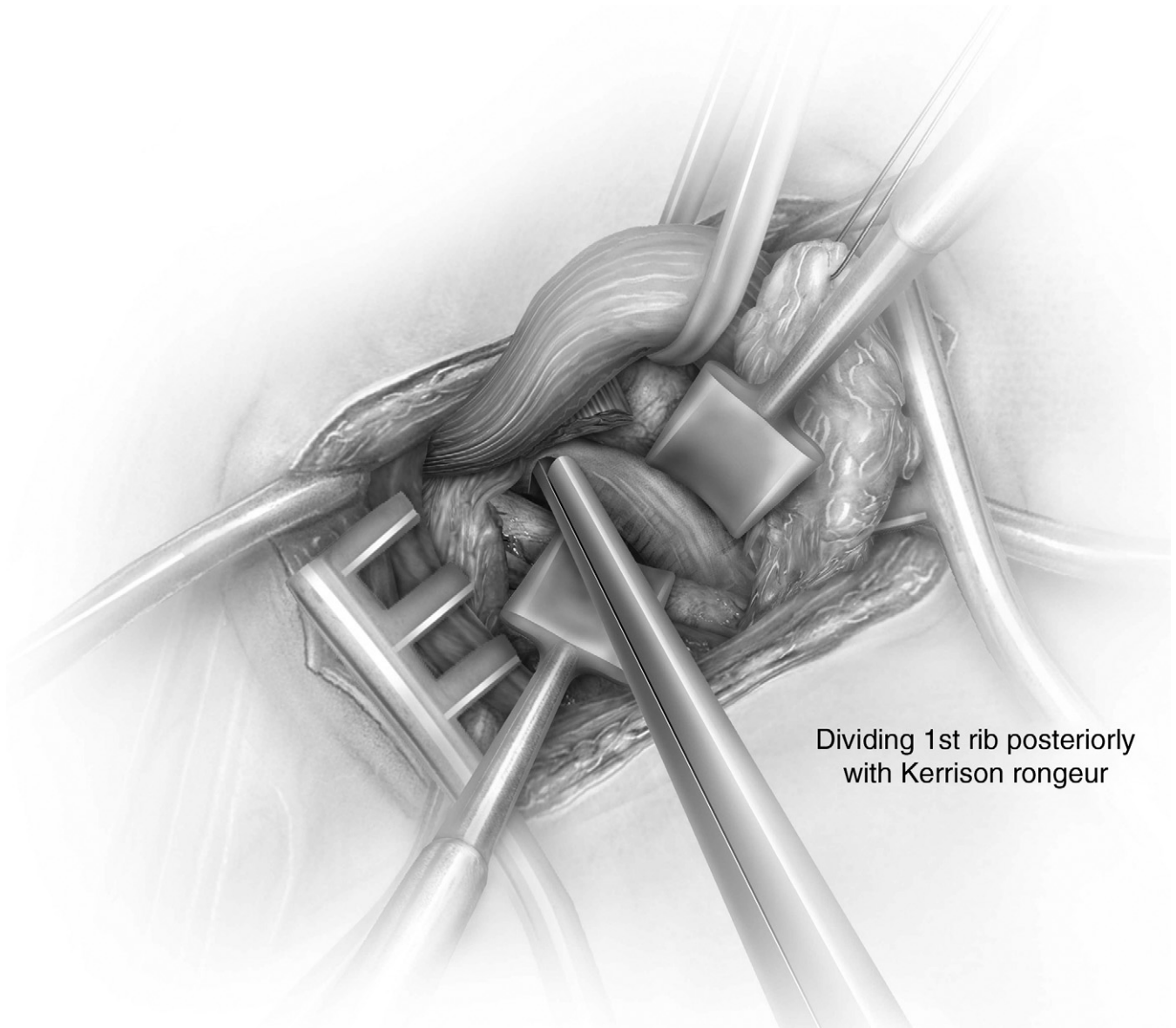


**Figure 10** The suprapleural membrane (Sibson's fascia) is bluntly peeled off of the underside of the first rib.

Once the muscle tissue is completely divided off of the cephalad surface of the first rib, the plane along the under-surface of the rib is developed. This may be started with either sharp dissection or bipolar cautery. This plane is then developed under the rib with blunt dissection of Sibson's fascia using a small sponge (Fig. 10) or the surgeon's finger. There appears to be little negative consequence if the pleural space is entered, but the goal is to avoid this.

At this point, the only remaining attachments to the first rib are intercostal muscle fibers between the first and second ribs. Although some of these may have been divided during the division of the middle scalene and anterior serratus muscles, completely dividing them is often facilitated by division of the first rib anteriorly and posteriorly. This allows the rib to be retracted in a caudal direction to expose the intercostal muscle.

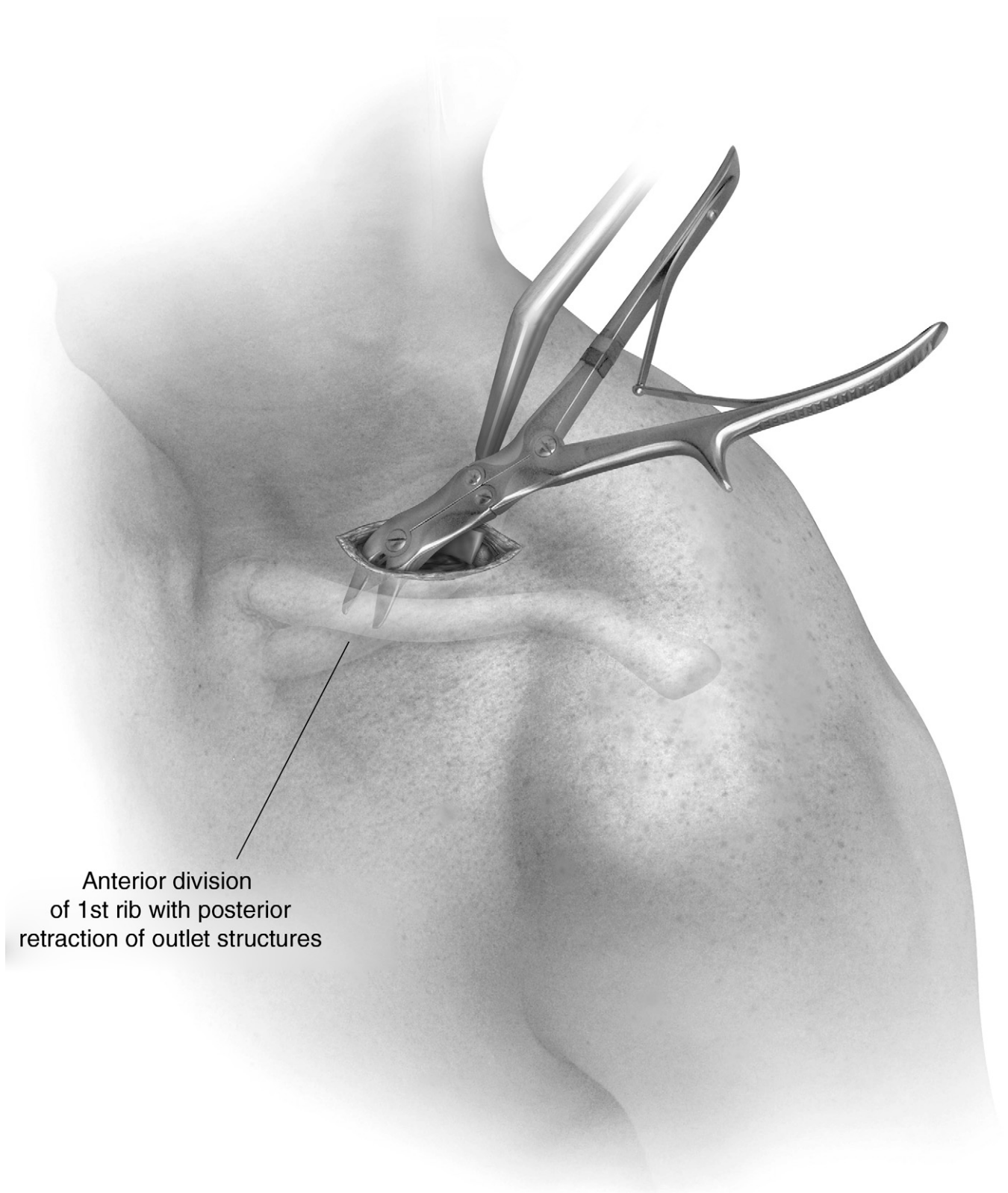




**Figure 11** Working between the trunks of the brachial plexus, the posterior first rib is divided medial to the transverse process of the T1 vertebrae.

The first rib is divided at the neck of the rib medial to the end of the T1 transverse process with a straight 3- or 4-mm Kerrison rongeur. Although other bone-cutting instruments may be used, the narrow space between brachial plexus

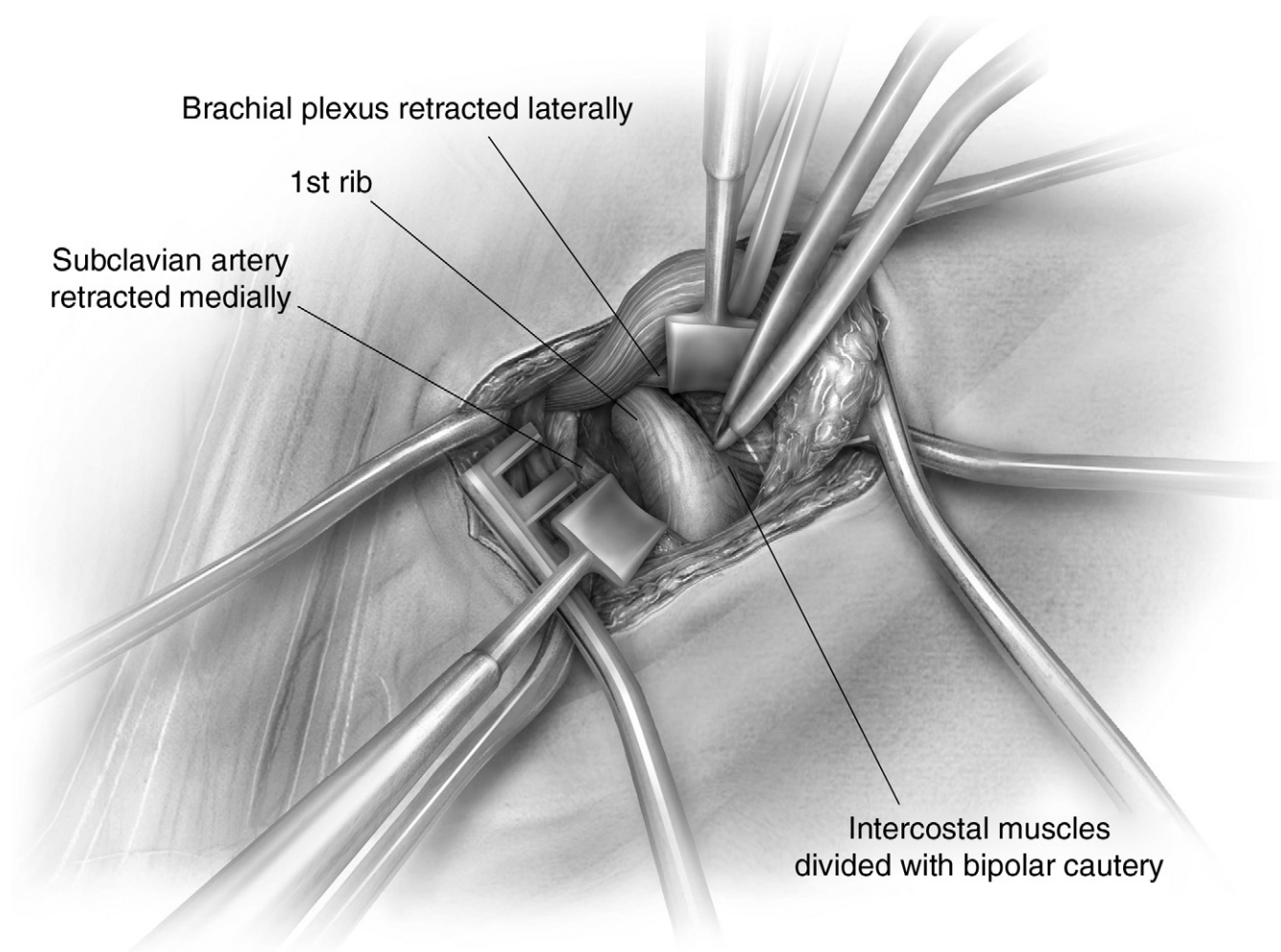
trunks is ideally suited for a Kerrison (Fig. 11). Because of the relatively small amount of bone that is removed with each bite, this frequently requires 4-6 passes working from both the inner and the outer edges of the rib.



**Figure 12** An angled duck-bill rongeur is used to divide the anterior first rib medial to the scalene tubercle. If necessary, both the anterior and posterior bone edges can be trimmed back with a rongeur once the first rib is removed from the field.

Division of the anterior rib is more difficult because of limited exposure. Dividing the posterior rib first allows the rib to be pushed in a caudal direction to improve exposure to the anterior first rib. This maneuver also exposes the insertion of the subclavius muscle onto the first rib medial to the

scalene tubercle. This muscle is divided to expose the tubercle further, and the rib is divided at a point medial to the scalene tubercle. This is performed with a 45-degree angled duck-bill rongeur (Fig. 12). Occasionally, a curved Kerrison rongeur is used for the deepest, most caudal aspect of the rib.



**Figure 13** The intercostal muscle between the first and second ribs is the only remaining soft tissue attachment to the first rib. The rib can be retracted inferiorly to expose this muscle, which is divided with cautery.

With the first rib detached both anteriorly and posteriorly, it is pushed downward toward the pleura to expose the intercostal muscle. This muscle is then divided off of the first rib with bipolar cautery (Fig. 13). Once the first rib is completely free of soft tissue attachments, it is removed intact while avoiding any traction on the brachial plexus or subclavian artery. The posterior rib stump is then inspected and any residual bone exposed by dividing soft tissue attachments with bipolar cautery. The residual posterior first rib is then removed with a Kerrison rongeur.

The surgical field is then inspected and hemostasis is achieved with bipolar cautery. This must be meticulous, as postoperative hematoma can lead to nerve irritation and possibly increased scar formation. Each component of the proximal brachial plexus must be thoroughly inspected to assure that there are no residual points of entrapment, and any residual scar tissue is removed. The continuity of the phrenic nerve is confirmed with a nerve stimulator.

If an entry into the pleural space is present, a no. 14 red rubber catheter is placed into the pleural space. This is used to evacuate a pneumothorax after the wound is closed. A no. 15 round closed suction drain is placed through a separate stab wound laterally, and this is secured to the skin with a 2-0 silk suture. This drain is placed in the posterior bed of the resected first rib. A final inspection for hemostasis is

performed, and the vessel loop is removed from around the omohyoid muscle. The scalene fat pad retraction suture is cut allowing it to return to its normal position. The platysma muscle is reapproximated from medial to lateral with a running 3-0 Vicryl (Ethicon, Inc, Sommerville, NJ) suture. Before tying this suture, the pleural space is evacuated in the following manner. A sustained positive-pressure breath is applied by the anesthetist, and suction is intermittently applied to the red rubber catheter while withdrawing it from the wound. Suction is then applied to the wound drain via a vacuum bulb. The stitch for the platysma is then tied, and the skin is closed with a subcuticular 4-0 Vicryl suture. A sterile dressing is then applied, which remains on for 24 hours.

A chest radiograph is done in the recovery room, as well as the first morning after surgery. Postoperative pain control is initially an intravenous patient-controlled analgesia system. Intravenous ketorolac (Toradol; Roche, Reinach, Switzerland) 15 mg every 8 hours may be used for the first 24 hours in patients without renal impairment. As soon as the patient is tolerating oral intake, pain control is switched to oral medication. Oral narcotics are used, but typically are able to be weaned off over the first 2-3 weeks following surgery.

The closed suction drain is removed in 24-48 hours depending on the amount of drainage. Ideally, the patient



should eat a regular diet before removing the drain, as rarely a branch of the thoracic duct can be injured resulting in chylous drainage.

Range-of-motion exercises for the neck and arm are begun the first postoperative day. This includes gentle flexion, extension, rotation, and lateral bending of the neck. Simple range-of-motion exercises of the shoulder including abduc-

tion and flexion with wall support (ie, “wall-crawls”) are also performed 3-4 times daily.

The hospital stay is typically 1 or 2 days, and an office follow-up visit is recommended 3 weeks postoperatively. Patients are then followed regularly depending on their clinical progress, with all patients followed long term with phone calls or office visits.