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Supraclavicular first rib resection and total scalenectomy: technique and results

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The symptoms of neurogenic thoracic outlet syndrome (TOS) most frequently described are pain, paresthesias, and weakness of the upper extremity. In addition, most patients also complain of pain in their neck, trapezius muscles, anterior chest walls, and supraclavicular areas, together with occipital headaches.

Physical examination

Several positive findings are observed on physical examination of the affected side. These include supraclavicular tenderness over the scalene muscles, a positive Tinel's sign over the brachial plexus, and radiating symptoms into the arm when exerting thumb pressure over the brachial plexus. Rotating the neck and tilting the head away from the symptomatic side usually elicits symptoms in the affected extremity. Often there is reduced sensation to light touch in the fingertips, usually in the ulnar nerve distribution. The patient's symptoms often can be reproduced by abducting the arms to 90° in external rotation (90° AER position).

Physical examination also should include checking for tenderness over the shoulder tendons, medial epicondyles, and pronator and radial tunnels. Tinel's sign should be tested at the wrist, pronator and radial tunnels, and the medial epicondyle.

A Scalene Muscle Block [1] is performed in almost all patients, either by the surgeon or by an anesthesiologist. (Note: this is not the same thing as an interscalene block.) The block is performed by injecting 4 ml of 1% lidocaine *into* the anterior scalene muscle. A good block is indicated by loss of tenderness over the muscle. The positive physical findings before the block are checked after the block; a good response to the block is indicated by significant improvement in many symptoms at rest and on physical examination, although seldom do all physical findings improve. Most patients with TOS have a positive response to the block [1].

Patients with neurogenic TOS often have positive findings of compression syndromes at the elbow, forearm, and wrist. These findings may be secondary to TOS or they may be compression syndromes in those areas coexisting with TOS.

Diagnosis

Although most TOS patients do not exhibit all of the positive history and physical features, they do demonstrate most of them. Patients with isolated pain or paresthesias in an extremity who lack most of the other findings of TOS should not have a diagnosis of TOS made on the basis of exclusion. In patients in whom symptoms of neck pain and paresthesias are absent, a diagnosis of neurogenic TOS should be made only when supported by several positive physical findings.

Indications for surgery in neurogenic TOS

1. Confirmed diagnosis based on history and physical examination. Does *not* require

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objective findings, such as neuroelectric studies, arterial vascular studies, or angiograms.
2. All associated or differential diagnoses have been evaluated and treated.
3. Appropriate physical therapy and learning the Feldenkrais method has been tried for at least 3–6 months and has failed.
4. The patient is experiencing some degree of disability at work, recreation, sleep, or activities of daily living.

Surgical approach

Steps of the surgical procedure are described in Fig. 1. Below are details and modifications added over the past 20 years.

Position

After general anesthesia with intratracheal intubation is performed, no further muscle relaxants are used. The back is elevated 20°–30°, allowing better exposure of the neck, especially in patients with short necks. To help relax the brachial plexus, the shoulder of the side to be operated on is elevated on a towel and projected 1–2 cm over the table edge. This position permits further shoulder elevation during the operation as needed to relax the plexus. The head is supported by a foam head holder and the neck rotated away from the surgeon. Both wrists are crossed and fixed to each other on top of the abdomen to further elevate the shoulder.

Special instruments

Two instruments are particularly helpful with this procedure: a bipolar cautery and a self-retaining mini retractor (Fig. 2). Use of a bipolar cautery is routine for some surgeons but is not generally used by others. Because the supraclavicular approach puts the surgeon in close contact with the brachial plexus and its branches, bipolar cautery is essential to avoid nerve damage that can occur from the unipolar cautery. The mini retractor is extremely helpful for this procedure. The authors use small rakes and blades in three key positions: (1) laterally, pulling the lateral corner of the incision, (2) medial-inferiorly, pulling the sternocleidomastoid muscle (SCM) and a portion of the fat pad (in placing this retractor blade, the phrenic nerve is identified first and avoided), and (3) the third blade is a small one at the cephalic end of the wound providing exposure of the upper part of the plexus where the phrenic nerve crosses from lateral to medial (most of the time). Add a fourth blade as needed, sometimes medially, sometimes laterally.

Incision

A 6–7-cm incision is made over the SCM and 2 cm above the clavicle, beginning 1 cm lateral to the midline. Extending the incision more than 1 cm lateral to the SCM is unnecessary and encourages injury to supraclavicular nerves. Skin flaps are raised below platysma muscle, staying on top of the SCM. The lower flap extends to the clavicle and the upper flap as high as possible. Supraclavicular nerve branches lie just lateral to the lateral edge of SCM and should be avoided by minimizing dissection here. The omohyoid muscle is encountered in the scalene fat pad. Two to three cm are resected to avoid a loose muscle end adhering to nerve roots postoperatively and causing recurrent symptoms.

The lateral portion of the scalene fat pad may be partially excised to reduce its bulk. The authors have observed the fat pad to be badly adherent to the roots of the plexus in many patients with recurrent TOS. The authors therefore now excise some of the lateral portion of the fat pad but are careful to identify and preserve supraclavicular nerves that sometimes lie in this fat pad. The authors avoid dissecting close to the internal jugular vein and leave alone the fat and lymph nodes next to the vein, as this is where lymphatic leaks occur. The transverse cervical artery and vein often are seen superficial to the anterior scalene muscle (ASM). They are ligated and divided. Occasionally on the lateral edge of the field there is a large supraclavicular nerve trunk that should be preserved. Large veins that cross the area superficial to the ASM should be ligated and divided.

The phrenic nerve is identified on the ASM. It usually runs from lateral to medial as it descends toward the clavicle. The nerve lies just below the transverse cervical artery. In this position the nerve is freed on its lateral side only. If the nerve runs lateral to the ASM, it must be dissected free on both sides. This lateral lying nerve is in the field during most of the procedure and must be moved gently from side to side. Occasionally a vessel loop is used to lift it up during dissection, but it is not left on the nerve throughout the operation. Another method of gently retracting the phrenic is by placing a traction suture in fatty tissue beneath the nerve and holding it with a small

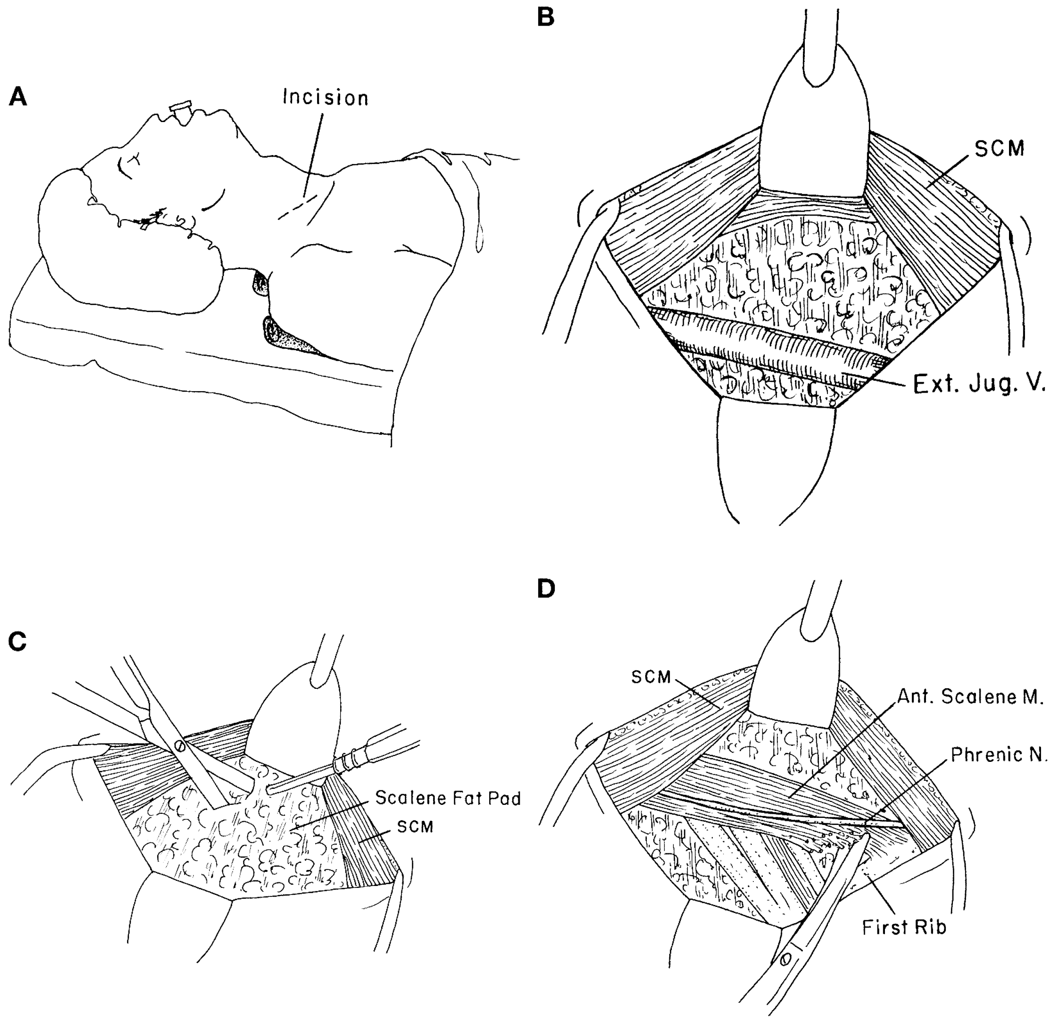

Fig. 1. (*A–H*) Technique of supraclavicular scalenectomy. (*A*) Patient is positioned with the back of the table elevated 15–20°, a small towel beneath the upper dorsal spine, and a bath towel beneath the shoulder. The incision is 6 cm long and 2–3 cm above the clavicle. (*B*) The lateral edge of sternocleidomastoid muscle is mobilized and retracted medially. The external jugular vein is usually preserved. (*C*) The scalene fat pad is divided in its mid-portion with a cautery, taking care to lift the fat above the muscle to avoid cautery injury to the phrenic nerve. The Omohyoid muscle is divided and a 2–3 cm segment resected. (*D*) The anterior scalene muscle (ASM) is divided at its first rib insertion. (*E*) The divided end of ASM has been freed from adhesions to the subclavian artery and brachial plexus, passed below the phrenic nerve, and regrasped. The ASM origin is being divided close to the transverse processes. (*F*) The space between C7 and subclavian artery is cleaned of scalene minimums muscle (when present), connective tissue, and ligaments. This exposes C8 and T1 nerve roots. (*G*) Middle scalene muscle (MSM) is exposed lateral to the brachial plexus and long thoracic nerve (LTN) identified exiting through the muscle. The cephalic end of the lateral portion of MSM is divided above the LTN and again at its first rib insertion. (*H*) When present, a cervical rib lies in the midst of MSM. (*I–L*) Technique of supraclavicular first rib resection. (*I*) After dividing remaining MSM fibers, and freeing lateral and medial first rib edges with an Overholt first rib elevator, a Schumaker rib cutter or Raney rongeur divides the neck of the first rib near the transverse process. The posterior stump is smoothed with a rongeur if necessary. (*J*) The divided rib end is lifted with an elevator as finger dissection frees the pleura from the rib. (*K*) The anterior rib end is divided below the clavicle by a special infraclavicular first rib cutter (Pilling) after first freeing subclavian artery and pleura from the rib. The anterior stump is smoothed with a rongeur. (*L*) The now freed rib is extracted from behind the plexus. (*Modified from* Sanders RJ, Raymer S. The supraclavicular approach to scalenectomy and first rib resection: description of technique. J Vasc Surg 1985;5:751–56; with permission.)

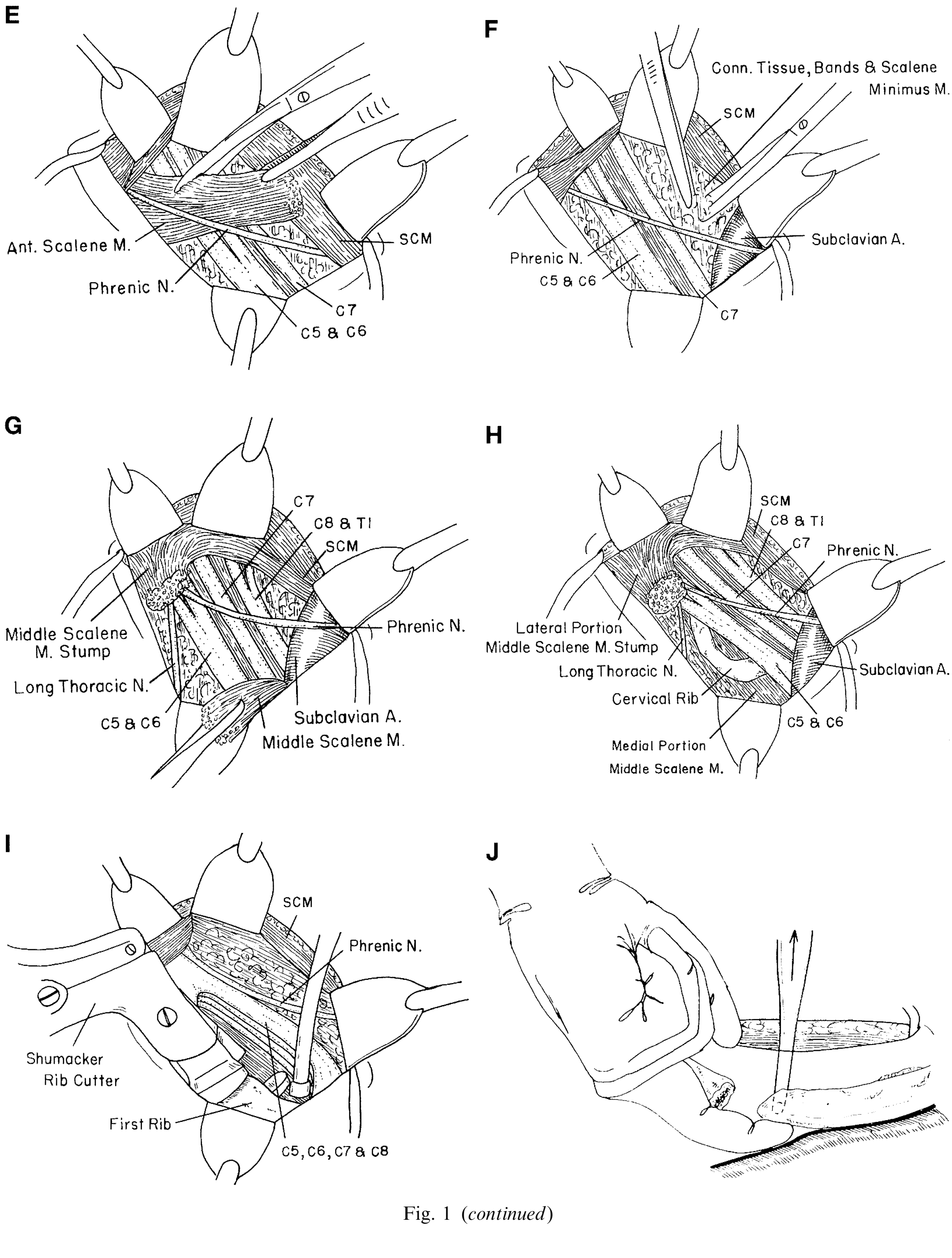

Fig. 1 (*continued*)

clamp, much as a traction suture is used to hold open an artery wall when performing arterial surgery.

The ASM is divided at its first rib insertion. A long, thin, curved retractor is used over the subclavian vein, which usually is not visualized, to protect it. The subclavian artery lies below the ASM and is usually but not always identified before dividing ASM. The ASM is elevated with a tonsil clamp and adhesions to the subclavian artery and plexus are divided. Often the authors pass the ASM beneath the phrenic nerve and

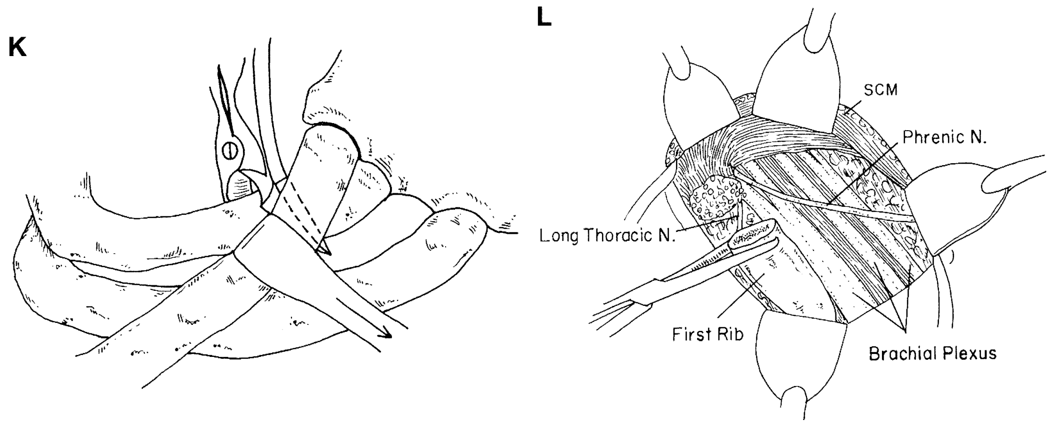

Fig. 1 (*continued*)

re-grasp it to divide the ASM as high as possible, close to transverse processes.

Neurolysis

Neurolysis on the anterior surface of the plexus is easy to perform over C5, C6, and C7. Loose muscle fibers, bands, and connective tissue are removed, going down to but not entering the nerve sheaths. C8 and T1 often are covered by various tissues, including the scalene minimus muscle. This muscle is present in approximately 25% of patients and must be removed. Often a band is seen over or under T1 and is excised. Neurolysis is facilitated by first ligating the transverse scapular artery flush with the subclavian artery. The distal end is found behind the plexus in the middle scalene muscle (MSM) where it is dissected and ligated. The excluded segment of artery is excised to permit completion of the neurolysis over the anterior surface of the plexus.

Middle scalenectomy

Middle scalenectomy begins by gently retracting C5 medially and identifying the long thoracic nerve (LTN) as it exits the belly of the MSM. The LTN arises from C5, C6, and C7. The branches from C5 and C6 often unite in the middle of the MSM, but not always. The position of the three contributing branches to the LTN varies. Sometimes they run directly behind the nerve roots and don't go through the muscle. The C7 branch is not seen in most cases. When present, it is found coming off the back of C7 and traversing the lower part of the MSM before joining the C5 and C6 branches to form the complete LTN.

In performing middle scalenectomy, the plexus must be retracted for safe exposure. Maneuvers that help relax the nerve roots to avoid stretch injury include initial positioning of the patient as described previously. More relaxation is obtained by further elevation of the shoulder by an assistant's hand or against the surgeon's abdomen.

Once the LTN is identified, the MSM is excised, moving from lateral to medial, taking the insertion off the first rib and excising the cephalic end as high as is safe. The medial portion of the MSM is divided at the first rib and at the transverse processes. This removes the entire MSM except for a few lateral fibers that lie cephalad, well above the field. In controlling bleeding from muscle ends against the transverse processes, the authors avoid heavy cauterization at the junction of rib and spine. The cervical chain lies close to this area and although it is not visualized it can be injured by the cautery, producing a Horner syndrome. The authors have used Gelfoam soaked in thrombin to control oozing in this area.

Scalenectomy and neurolysis are now complete. The operation can end here or first rib resection may proceed.

First rib resection

First rib resection begins by stripping intercostal muscles from medial and lateral edges of rib with an Overholt #1 periosteal elevator (Fig. 2). The posterior rib is easy to free. Index finger dissection on the top and lateral edge of the rib helps tear persistent bands and muscle fibers. Scissors dissection between the subclavian artery

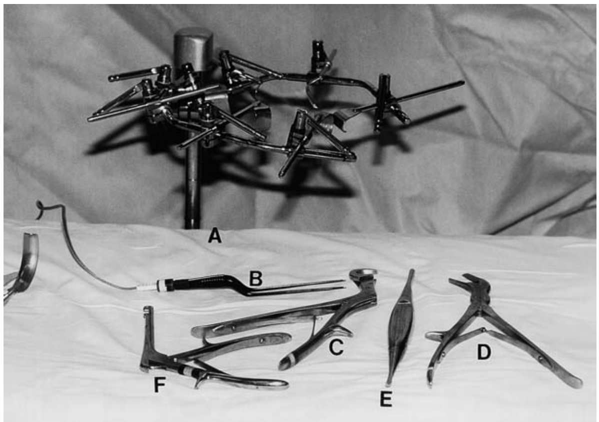

Fig. 2. Instruments used in supraclavicular scalenectomy and first rib resection. (*A*) Omnitract self-retaining retractor. (*B*) Bipolar cautery. (*C*) Schumaker rib cutter. (*D*) Infraclavicular rib cutter (Pilling). (*E*) Overholt #1 periosteal elevator. (*F*) Raney rongeur. (*From* Sanders RJ, Cooper MA, Hammond SL, Weinstein ES. Supraclavicular and infraclavicular approach to subclavian artery and vein compression. In: Yao JST, Pearce WH, editors. Techniques in vascular and endovascular surgery. Stamford (CT): Appleton & Lange; 1997; with permission.)

and the plexus is used to clean this portion of the rib on its superior surface. The elevator then is passed in this plane to further free the medial and lateral edges of the rib. The subclavian artery is freed easily from the rib and the elevator is used to free the rib edges to below the clavicle as far as possible. The neck of the rib is now divided close to the transverse processes, leaving a 5-mm stump. Either a rib cutter (Schumaker) or a Raney rongeur (7-mm) is used to divide the rib (Fig. 2). The rib cutter divides it in one cut, but in tight quarters it can stretch nerve roots. When exposure is tight, the authors therefore use the rongeur and take several bites. The remaining rib is now mobilized by finger dissection, either by way of the posterior end of the rib or by placing the finger under the medial rib edge just below or just above the subclavian artery. The finger separates the rib from the pleura and breaks remaining intercostal fibers down to the level of the clavicle.

Anterior division of the rib can be removed by rongeur or by using a special infraclavicular rib cutter.

The rib cutter is inserted from the medial side, first going superficial to the subclavian artery, then going around the rib caudal to the artery (Fig. 2). The phrenic nerve and subclavian artery must be observed and avoided as the cutter encircles the rib. The subclavian vein is protected with a thin, long retractor over it. The anesthesiologist puts the patient in exhalation to reduce chances of entering the pleura. The rib is divided with a single cut. The anterior stump is smoothed with the Raney rongeur. The rib then is extracted from behind the plexus with a clamp.

Closure

A 10 French round suction drain is inserted below the plexus and brought out through the lateral corner of the incision. The average amount of drainage postoperatively is 75–100 ml of blood in the first 24 hours. Drainage usually stops in 24–48 hours and the drain is removed. The pleura is entered approximately 25% of the time and is not closed. When the pleura has been opened, the anesthesiologist expands the lung and then breathes for the patient in PEEP to prevent air entering the pleural cavity during closure and thereby avoid pneumothorax. The authors do not use a chest tube. Should a pneumothorax of significant size occur (as evidenced by a routine postoperative chest radiograph in the recovery room), needle aspiration by way of the second or third anterior interspace usually relieves it. Such needle aspiration is necessary less than 1% of the time.

The deep layers of the scalene fat pad are reapproximated with sutures, attempting to close the deepest layers to avoid fat adhering to nerves roots. The authors no longer wrap the plexus with the fat pad, as we have observed in many patients with recurrent TOS that the fat pad was firmly adherent and scarred to the nerves. The platysma muscle is closed and the skin is reapproximated with a subcuticular, absorbable, monofilament suture.

Postoperative physical therapy

Postoperative physical therapy includes a home program of neck stretching and wall climbing exercises. The authors encourage patients to learn and use the Feldenkrais method preoperatively and postoperatively. Following recovery from surgery, strengthening exercises may be instituted gradually to help regain strength.

Complications

Plexus injury

The roots of the plexus are injured more by traction than by transection. In mobilizing the first rib with periosteal elevators, the plexus can be stretched too far. To avoid this one must first be aware of the potential problem. Raising the shoulder and bending the head toward the operative side are maneuvers to help relax the plexus to avoid stretch injuries. The authors' incidence of permanent plexus injury is less than 1%.

Phrenic nerve injury

The phrenic nerve is sensitive to minor traction or lifting with a forceps. All efforts are made to avoid touching the phrenic. When it is in the way, as it sometimes lies directly in the middle of the field, it can be lifted gently with a vessel loop. The authors do not tag this nerve with a loop or suture for fear that unrecognized traction on the holder might injure the nerve. The authors have found, however, that a traction suture placed in the fatty tissue beneath the phrenic can hold the nerve safely out of the way without injuring it. The phrenic also can be injured by the cautery, even the bipolar cautery. Bleeders very close to the nerve often can be controlled by Gelfoam and thrombin. The incidence of phrenic nerve paresis has been reported at 6% [2], 8.9% [3], 10% [4], and 12% [5]. These have all been temporary, but recovery has taken a few weeks to several months and occasionally, longer than 1 year. Only in reoperations in the presence of scar tissue making the phrenic difficult to identify has the nerve been transected. In these cases paresis was permanent.

Long thoracic nerve injury

The C5, C6, and C7 branches to LTN usually run through the belly of the MSM. They usually can be found on the lateral edge of the MSM, having burrowed through muscle fibers. The nerves are identified and freed before dividing the MSM. If the branches are not found on the lateral side of the MSM, the authors look for them behind the nerve roots of C5, C6, and C7. Injury to LTN is usually by cutting one of the three branches. It can cause difficulty in elevating the arm above shoulder level or it can produce a winged scapula. In most patients the remaining intact branches of the nerve provide enough function to permit full recovery in several months. The authors' incidence of LTN injury is approximately 1%.

Sympathetic chain injury

The sympathetic chain lies on the transverse processes of the cervical spine, fairly close to where the rib articulates with the transverse process. The authors began observing a few incidences of Horner syndrome as we became more aggressive in totally excising the posterior rib stump and MSM back to the transverse process. Because the sympathetic chain is not visualized, the authors postulate that the chain was injured when cauterizing bleeders just above and medial to the tip of the transverse process. To eliminate this risk, the authors now transect the MSM a few millimeters away from the spine instead of against bone to permit cauterization of muscle fibers away from the transverse process, or the authors use Gelfoam soaked in thrombin. Should ptosis of an eyelid occur, it might be temporary or permanent. If it fails to improve after several months, it can be corrected by taking a small tuck in the levator palpebrae superioris muscle.

Thoracic duct injury

The thoracic duct lies in the midst of the scalene fat pad in the lower portion of the left neck. It is hard to see, but its injury is recognized by clear or milky fluid leaking into the operative field. The authors try to avoid the duct by minimizing dissection to the fat pad in this area. Exposure here is gained simply by retracting the fat pad. If lymph is seen leaking, the area is controlled by the bipolar cautery, ties, or hemoclips. When there has been a leak, the authors try to minimize lymph production postoperatively by placing the patient on a diet of ice-chips only for 24 hours and placing a pressure dressing over the incision. On occasion the authors have explored the incision on the second or third postoperative day for leaks that persisted. A hemoclip has been the most effective tool to control the leak. The incidence of leaks requiring re-exploration has been 2%–3% [6].

Results

The authors' success rates from 1965–1986 for transaxillary first rib resection, anterior and middle scalenectomy, and combined scalenectomy and rib resection were approximately the same (Fig. 3). The 5-year success rate, defined as enough symptomatic improvement to believe that the surgery was worthwhile, was 68% using life-table methods. The results can be expressed several percentage points higher by using short to long ranges of follow-up [7].

In the early 1990s the authors compared our results of scalenectomy with and without first rib resection. It was noted that scalenectomy plus first rib resection gave slightly lower failure rates than scalenectomy without rib resection, although the results were not statistically significant. Between 1999 and 2001, first rib resection was performed with all scalenectomies. The 1–2-year results in these 200 patients were no different than the authors' earlier results; in fact, in the automobile accident group, failure rates were almost identical following scalenectomy with versus without first rib resection (28% versus 29%).

Etiology continues to be a significant variable in failure rates. Patients whose TOS arose from automobile accidents continue to have lower failure rates than patients whose condition arose from work-related causes. The difference in results between automobile and work accidents has been observed by others also [8,9].

Is first rib resection necessary?

Unless there is a cervical rib or anomalous first rib and even when such ribs are present, the pathology in the large majority of patients with neurogenic TOS lies in the scalene muscles. Excision of the first rib does not remove the cause of the symptoms. Patients improve not because the rib is gone, but rather because excision of the rib requires division of anterior and middle scalene muscles where they insert on the rib. Rib resection thus includes anterior and middle scalenotomy. Support for this opinion is the observation that anterior and middle scalenectomy without rib resection has achieved the same improvement rate as scalenectomy with first rib resection or transaxillary first rib resection as reported by other investigators [6,9–13]. Further support is the histology of the scalene muscles, which consistently has demonstrated more fibrosis in the muscles of patients with TOS than in those of control subjects (see the article by Sanders et al elsewhere in this issue).

First rib resection is accompanied by a little higher morbidity and a slightly longer recovery time. Because the authors cannot demonstrate significantly better results by adding first rib resection to scalenectomy, we have returned to

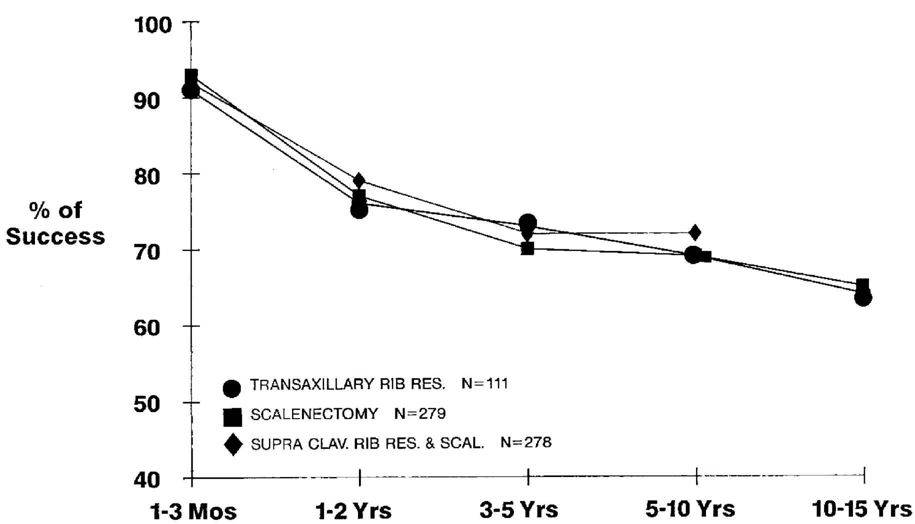

Fig. 3. Results of three primary operations for TOS. N = number of operations. (*From* Sanders RJ, Haug CE. Thoracic outlet syndrome: a common sequela of neck injuries. Philadelphia: JB Lippincott Co.; 1991. p. 182; with permission.)

performing anterior and middle scalenectomy without first rib resection as our primary operation.

Total anterior and middle scalenectomy

The operation described here is more extensive than the procedure described several years ago [14]. The previous procedure was a subtotal anterior and partial middle scalenectomy. The current scalenectomy removes almost all muscle. It was the introduction of the self-retaining mini retractor by Dr. Ronald Stoney that permitted improved exposure and made total scalenectomy possible and safe. Long-term results of the more complete scalenectomy, however, do not demonstrate better success rates than the authors noted with subtotal and partial scalenectomies.

Transaxillary versus supraclavicular first rib resection

First rib resection is not an easy procedure by way of any approach. Success rates for relief of neurogenic TOS symptoms are similar for transaxillary and supraclavicular approaches. Having used both approaches in many patients, the authors prefer the supraclavicular approach, because it provides better exposure of the nerves and vessels, and injuries to these structures are easier to avoid through the neck. Should bleeding occur from major vessels, it is easier to control. The supraclavicular route is an easier one to teach others to perform, and the surgeon's learning curve is shorter through the neck than the axilla.

The disadvantage of the supraclavicular route is that complications of injury to phrenic nerve and thoracic duct occur more often through the neck. Because the long-term results to date of first rib resection are no better than the results of anterior and middle scalenectomy alone, currently the authors have stopped performing first rib resection for neurogenic TOS by either approach except for patients with cervical ribs. For patients in whom the cervical and sometimes the first rib must be excised, the authors prefer the supraclavicular route.

In contradistinction to the supraclavicular approach for neurogenic TOS, the authors do not use this route for venous TOS. The authors use the infraclavicular approach when the vein requires opening and the transaxillary route when venotomy is not needed. These two approaches for venous decompression allow a more thorough removal of the subclavius tendon and costoclavicular ligament, both of which are attached to the anterior end of the rib and sometimes to the costal cartilage. It is crucial that these structures be excised to externally decompress the vein.

Summary

The supraclavicular approach has been a successful route for thoracic outlet decompression. It permits many more options than the transaxillary route. Anterior and middle scalenectomy, together with brachial plexus neurolysis can be performed with excellent exposure. The same incision can be used to perform cervical or first rib resection, although the success rate is not significantly improved by removing ribs. The 5-year success rate for scalenectomy with or without first rib resection using life table methods is approximately 70%.

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