First Rib Resection for Neurovascular Syndromes of the Thoracic Outlet

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During the first half of this century, various syndromes attributed to compression of neural and vascular structures in the anatomic area of the thoracic outlet have been described. These include the cervical rib, scalene anticus, costoclavicular, first dorsal rib, and hyperabduction syndromes. This complex array of subdivisions has engendered some confusion in diagnosis and treatment. Although no unanimity of opinion can yet be said to exist, several authors have more recently attempted to relate these conditions to a common denominator, that of compression of the neurovascular bundle between first rib and clavicle, with or without presence of a cervical rib. Such a unifying concept of the fundamental mechanical factor involved has led to new surgical approaches to the relief of symptoms associated with this syndrome. It is our purpose to describe the surgical anatomy of first rib resection as it relates to the thoracic outlet.

Historical Background

The association of cervical rib with symptoms of arterial and neurologic impairment of the upper extremity was well reviewed as early as 1904 by Eisendrath, who reported 35 cases and credited Holmes Coote with the first resection of a cervical rib for this condition in 1861. John B. Murphy in 1905 added a further case, complicated by aneurysmal dilatation of the subclavian artery, treated by cervical rib resection. That the same symptoms might result from compression of the brachial plexus and the subclavian artery by a normal first rib, in the absence of a cervical rib, was recognized by Thomas Murphy, who performed the first resection of a normal first rib for this syndrome in 1910. A supraclavicular approach was used, with division of the anterior scalene muscle. Similar cases were reported by Brickner and by Telford and Stopford.

A new facet was introduced in 1927 with the report of Adson and Coffey, who emphasized an active role of the anterior scalene muscle in compression of the neurovascular bundle, and advocated scalenotomy without cervical rib resection. Their concept was advanced by Ochsner et al and by Naffziger and Grant, who reported cases without cervical ribs but with identical signs, and recommended anterior scalenotomy as the treatment of choice. The term "anterior scalene syndrome" seemed to have become firmly established.

The lack of uniformly favorable response to this procedure, however, made it clear that other factors might be involved. In 1943 Falconer and Weddell described compression of the subclavian artery and vein in the costoclavicular space, and in 1962 Falconer and Li reported further surgical experience with this "costoclavicular syndrome" of brachial plexus and vascular compression by a vise-like action between the first rib and clavicle. They believed this mechanism to be the major factor in production of symptoms. A supraclavicular approach to first rib resection was used in their cases. This opinion was supported by Brintnall et al who, along with Falconer, advocated a "finger pinch" test for costoclavicular compression at operation. In the presence of a positive test, they felt that scalenotomy or cervical rib
resection would be inadequate without first rib resection. Clagett advised a posterior, thoracoplasty-like approach.

A further term was introduced by Wright in 1945, the "hyperabduction syndrome." He indicated that neurovascular compression might occur either in the costoclavicular space, or between the tendon of the pectoralis minor muscle and the coracoid process.

Finally, "thoracic outlet" symptoms associated with abnormalities of the first rib were reported by White et al in 1945.

The problem of causal factors in these variously described syndromes was well discussed by Walshe et al, whose analysis led them to believe that multiple factors were involved in every case of thoracic outlet rib pressure syndrome. They stressed that an abnormal cervical rib or first rib should be considered as an indication of an abnormal thoracic outlet in general, rather than as a sole cause in itself, and concluded that the concept of the scalenus anticus syndrome was an oversimplification. They also pointed out the vise-like action of the clavicle and first rib upon the adjacent neurovascular bundle.

On the basis of this rationale, attention was focused upon resection of the first rib as treatment of choice. The most popular methods at this time are the transaxillary approach, based on the work of Roos and Sanders, and the infraclavicular approach, based on the work of Gol, Brodsky, Hamlin and Nelson.

Symptoms and Signs

The symptoms and signs of the thoracic outlet syndrome have been thoroughly described in a number of publications, and need be only briefly summarized here. Neurologic symptoms are more common than vascular, but the two may occur concurrently. There are usually intermittent paresthesias, pain, or numbness in the ulnar distribution, which may sometimes involve the median nerve as well. These symptoms are worsened by certain movements of the shoulder girdle, which approximate the clavicle to the rib, such as downward and backward pulling of the arm, as in carrying weights, or hyperabduction of the arm. Symptoms may be primarily nocturnal, depending upon sleeping positions. The symptoms may spread to the shoulder, side of the neck, or distal extremity. There may be subjective weakness or fatigability of the extremity. Objective neurologic deficit is relatively uncommon, but there may be ulnar sensory loss or atrophy of the hand muscles of ulnar or median innervation.

Vascular symptoms include arterial insufficiency with pallor, coldness, and ischemic numbness in the hand and fingers, simulating Raynaud's phenomenon in some cases. Fusiform, poststenotic dilatation of the subclavian artery may occur, which may be complicated by thrombosis and embolization to the digital arteries with gangrene. Least commonly, there may be venous occlusion, with edema and cyanosis of the hand.

Provoking factors in the development of symptoms seem to include drooping shoulders, particularly in women, excessive muscular development or postural attitudes in some athletic or occupational endeavors, hypertrophic breasts, hyperextension trauma to the neck, and injury to the shoulder girdle and clavicle.
The paucity of objective findings in many cases leaves one with a clinical diagnosis based largely upon subjective symptoms. The Adson, costoclavicular, and hyperabduction tests are not consistently clearly positive in reproducing clinical symptoms, and may conversely produce some degree of radial pulse obliteration in asymptomatic subjects. They are helpful when the symptoms produced clearly simulate the patient's complaints and correlate with accompanying pulse changes. Reproduction of the neurologic symptoms with the arm abducted to 90 degrees, the hand externally rotated, and the neck extended was found to be the most reliable test by Sanders. In contrast, relief of symptoms when the arm is hyperabducted is often found to occur in patients with cervical disc disease.

Further adjuncts to diagnosis advocated by some are nerve conduction velocity tests, plethysmography, and arteriography. Again, such tests cannot always be expected to be conclusive, depending not only upon the severity of the condition but also upon whether the problem is predominantly neural or vascular compression. Nerve conduction velocity studies across the thoracic outlet would appear to be the most directly measurable objective test for neurologic impingement. However, the normal range for the ulnar nerve conduction velocity across the thoracic outlet as shown by Jebson is 52 to 78 meters per second, with a mean velocity of 61.3 meters per second. The wide range of normal here would seem to limit its value as a specific test for thoracic outlet obstruction, and we have not found its use to be as good a diagnostic tool as reproduction of the patient's symptoms by the Adson, costoclavicular, or hyperabduction tests. We do, however, advocate pre- and postoperative nerve conduction velocity studies across the thoracic outlet as a basis for comparison. Arteriograms and phlebograms are not routinely done. They are indicated only when objective vascular findings are present. Neurologic involvement is more common than vascular in our experience, and we agree with Sanders and Falconer that the brachial plexus may be compressed between the clavicle and the first rib without involvement of either subclavian artery or vein. In many cases, myelography may be necessary to exclude an intraspinal lesion.

The differential diagnosis includes other neurologic disorders which may mimic the thoracic outlet syndrome, particularly cervical disc disease, cervical tumors, syringomyelia, tumors of the superior sulcus, and entrapment neuropathies of the ulnar nerve at the elbow and the median nerve at the wrist. Thorough competent neurologic evaluation of patients prior to surgery is essential.

Surgical Treatment

Operation is indicated in those patients who fail to respond to conservative measures such as a change in occupational, athletic, or sleeping habits, or to appropriate physical therapy. The appropriate physical therapy concentrates on a thoracic outlet exercise regime which will stretch the anterolateral cervical muscles, anterior shoulder muscles, and pectoral muscles, and will strengthen the posterior shoulder girdle, and in particular the shoulder girdle elevators. Patients are also shown postural correction and are referred to a competent physical therapist to administer this program.

The objective of operative treatment of this syndrome is obviously to relieve thoracic outlet compression. There are three possible sites of compression to be considered. The first rib is common to the two major sites: the scalene triangle, bounded by the first rib, anterior, and middle scalene muscles, and the costoclavicular space bounded by the first rib, clavicle,
and subclavius muscle. The third site, the pectoralis minor space, is thought to be much less significant. Many anomalies of the ribs, clavicle, muscles, or fascial band attachments may be associated with these syndromes; first rib resection will, however, decompress the thoracic outlet through both the scalene triangle and costoclavicular spaces. In addition, the pectoralis minor tendon can easily be divided when carrying out first rib resection when deemed advisable. Sympathectomy can be done through either the transaxillary or infraclavicular approach, but even in the presence of Raynaud's phenomenon, is probably not necessary since removal of mechanical arterial obstruction seems the more important factor in relief.

Transaxillary First Rib Resection

First rib resection is outlined here basically after the method of Roos. We feel that certain surgical instruments are very helpful for this technique. They are as follows: (1) Sauerbruch double action rib rongeur, (2) Bethune or Moure-Coryllos right angle rib shear, (3) Doyen costal elevator, (4) Coryllos raspatory, (5) Overholt periosteal elevator No 1. The patient, under general endotracheal anesthesia, is positioned in a true lateral position with the hips supported and the shoulder of the operative side rotated posteriorly approximately 60 degrees with the arm suspended initially by a sling to an IV pole. It is important that the thorax be supported so that there is no undue stress on the spine. The entire hand, arm, axilla, shoulder, and anterior and posterior chest are prepped. The hand and arm are held by an assistant and wrapped with stockinette while the remainder of the operative field is draped to appropriately expose the axilla. One should not undertake the transaxillary approach without having a separate assistant who does nothing but hold the arm.

An approximate 4 inch incision is made at the lower margin of the axillary hairline and continued subcutaneously directly to the serratus anterior muscle fascia of the chest wall. Once the appropriate subcutaneous plane is reached, blunt dissection is continued up to the first rib. It is important to identify the second intercostal brachial cutaneous nerve as it exits via the second interspace and gently retract it out of the way. Once dissection has been developed up to the first rib, adequate exposure of the thoracic outlet is only possible during elevation of the extremity by an assistant. The hammerlock, as mentioned by Roos, is very important and helpful. The arm should not be elevated for more than 10 minutes at a time in order that undue stress not be placed upon the brachial plexus.

The subclavian muscles tendinous attachment is incised with scissor dissection flush on the first rib, carefully retracting the subclavian vein away from the dissecting scissors. The anterior scalene muscle can be palpated as it attaches to the scalene tubercle, and with the subclavian artery and brachial plexus held away with an appropriate instrument, the anterior scalene muscle is incised adjacent to and flush on the first rib. A nerve root retractor or similar instrument is used to hold the adjacent neurovascular structures away while these muscles are being incised under direct vision. Utilizing either the Coryllos raspatory or Overholt periosteal elevator No 1, the scalenus medius muscle posteriorly and the intercostal muscular attachments are pushed away leaving the periosteum attached to the rib. It cannot be overly emphasized that elevation of the arm for appropriate visualization of the structures involved during this dissection is imperative, and that the neurovascular structures must be visualized at all times and held away from the cutting instruments. The first rib is then transected posteriorly within 1 cm of the transverse process of the first thoracic vertebra using a right angle Bethune or Moure-Coryllos rib shear. This is probably the most difficult part of
the operation and it requires expert elevation of the arm with concomitant displacement of the first thoracic nerve root with a nerve root retractor or other suitable instrument and transection of the rib under direct vision. Sometimes the cut cannot be made smoothly, and when this happens after the initial transection, a segment of the rib can be removed and the remaining portion of the rib attached to the transverse process can be nibbled away with a Sauerbruch double action rib rongeur to leave a smooth surface. This nibbling procedure must also be done under direct vision.

Both Roos and Sanders feel that the removal of the first rib posteriorly is important to prevent future entrapment of the brachial plexus nerve roots with periosteal development. We feel that this particular portion of the operation is better done through the transaxillary approach and, although this certainly gets beyond the area where the clavicle approximates itself to the first rib, we recommend resection of the first rib to within 1 cm of the transverse process of the first thoracic vertebra. The first rib anteriorly is then either disarticulated from its sternocostal junction or transected with a rib shear as done posteriorly, being careful to avoid the subclavian vein. A cervical rib, if present, is divided posteriorly under direct vision immediately after posterior transection of the first rib. We would agree with Roos that if the cervical rib is 2 cm or less in length, resecting it would endanger the adjacent nerve roots and is not necessary. Fibrous bands and cervical ribs attaching to the first rib should be resected as far posteriorly as can be safely accomplished. Following removal of the first rib, hemostasis should be obtained and pleural leaks should be checked for by putting saline in the wound and having the anesthesiologist inflate the lung. If there are any air leaks, this, of course, will be demonstrated by air bubbles in the field. If there is an air leak, we merely insert a catheter into the pleural space and close the wound in layers around it with the catheter being attached to suction during the closing process. Following complete closure of the wound, we then remove the catheter. Patients recover rapidly from this procedure and are usually able to be discharged within 5 days postoperatively. We do not do bilateral rib resection when utilizing the transaxillary approach. The pectoralis minor muscle tendon may be divided where it inserts on the coracoid process of the scapula by freeing up the lateral margin of the pectoralis major muscle for exposure. We do not routinely do this, but some people feel that it is advisable.

**Infraclavicular First Rib Resection**

The patient is positioned supine with a pad to elevate the scapula and shoulder, with the arm abducted. A muscle-splitting incision approximately 12 cm in length is carried through the pectoralis major muscle to expose the first rib below the clavicle, beginning medially at the costochondral junction. The periosteum is elevated subperiosteally from the rib, and the costochondral junction is removed piecemeal with the Leksell rongeur. The pleura can then be stripped from the posterior surface of the mobilized rib with careful blunt dissection. The rib is next retracted inward, and the neurovascular bundle traversing the costoclavicular space is palpated and retracted with the index finger. With the neurovascular structures thus constantly protected beneath the index finger and the pleura retracted, the rib with its periosteum is rongeured away, scraping off the insertions of the anterior and middle scalene muscles. Posterior to the neurovascular bundle, rib removal is accomplished by feel rather than under direct vision, but usually can be taken back to within 3 to 4 cm of the transverse process without excessive retraction of the neurovascular bundle; and in some asthenic patients, to within 1 to 2 cm of the transverse process. If a cervical rib is present,
it can also be trimmed through this approach. This incision can be extended slightly downward to the deltopectoral junction if the pectoralis minor tendon is to be divided. If a tear occurs in the pleura, it is closed around catheter suction with the lung inflated. The pectoral fascia, subcutaneous tissue, and skin are closed in layers. Bilateral rib resection can be done as a one-stage procedure by this technique.