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Complications of surgery for thoracic outlet syndrome

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Failure to make the correct diagnosis or to appreciate the presence of a significant shoulder problem or additional peripheral nerve problems is a major concern in treatment of patients with thoracic outlet syndrome (TOS). Although this article is devoted to a consideration of complications of the surgery of TOS, the author believes it would be unwise not to comment on what is probably a major problem facing the patient and the physician involved with this disorder. The debate as to whether TOS is under diagnosed or over diagnosed will probably never end [1–3], but if one considers the possible complications of misdirected surgery, the issue of making the correct diagnosis assumes great importance.

Unfortunately there is no thoroughly reliable and reproducible laboratory study with which to make the diagnosis, which remains clinical. A careful history and physical examination are mandatory, even in those patients who have been labeled by previous evaluators as being simply somatocizers or neurotic. As with other entities, real organic pathology may be present in the patient who is neurotic, depressed, or otherwise emotionally unstable.

The specifics of the evaluation are beyond the scope of this article. It is important not to miss the presence of a significant shoulder problem or additional peripheral nerve problems, however. One should consider the differential diagnosis and realize that some patients could have been given a diagnosis of TOS, whereas one of these entities may be responsible either for the symptoms or may coexist with a bona fide TOS [4,5] (Box 1).

Pneumothorax

The intimate relationship of the pleura and the first rib makes pneumothorax the most common complication of first rib resection. In the author's experience with this procedure, the incidence was 33% for the first 280 cases done by the axillary route [6]. Although the pleura and the rib are separated by the suprapleural membrane, the apex of the pleura fills the inner curve of the first rib and rises above it behind the subclavian vessels. During its resection, it would be theoretically desirable to isolate the first rib and its periosteum without stripping the soft tissues from the bone. A subperiosteal dissection, however, conveys the safety factor of retaining a protective layer of tissue between a surgical instrument and the pleura and vessels.

In addition, periosteal elevators with sharp corners or burrs should be avoided in this situation because they can catch the pleura, whereas a smooth instrument would glide over it. It can be helpful when dissection is done on the inner surface of the first rib and beneath it to have the anesthesiologist deflate the lung so as to lower the pleura and provide additional room in which to maneuver. Nevertheless, the paper-thin character of the pleura at this level may make perforation virtually impossible to avoid.

It may not be immediately apparent to the operating team that the pleura have been torn. Periodically, during the course of the surgery, the operative field should be flooded with normal saline and the anesthesiologist asked to hyperinflate the lung. In the event that there is a small rent, air bubbles are observed; with larger tears, the fluid level decreases as it drains into the pleural cavity. In rare cases, the anesthesiologist may report a decrease in oxygen saturation, thus

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Box 1. Differential diagnoses of thoracic outlet syndrome

1. Carpal tunnel syndrome
2. Cervical radiculopathy
3. Ulnar neuropathy
4. Complex regional pain syndrome (Reflex sympathetic dystrophy)
5. Factitious lymphedema
6. Supraclavicular fossa pathology
7. Lung tumors
8. Double crush syndrome
9. Dead arm syndrome

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informing the unaware surgeon that a pneumothorax has occurred. It is not practical to attempt to repair this filmy tissue, because invariably the tear increases in size rather than allowing for suture.

After it has been determined that an adequate decompression has been done and before the closure is started, a small rubber chest tube can be inserted into the pleural apex. If the tear is a small one and it is easily apparent, the chest tube can be pushed gently through it with care to protect the vessels. The other end of the chest tube then is led out through a small stab wound just caudal to the skin incision, where it is secured with a purse-string suture. It may be connected then to underwater suction that is usually maintained for 24 hours. In the recovery room it is imperative to obtain a semi-sitting chest radiograph to ascertain the degree of inflation of the lung and the placement of the catheter. Some surgeons prefer to avoid an indwelling chest tube and simply aspirate the pleural cavity as they close and then withdraw the catheter. Because the method described previously is extremely effective and the author has never had a complication attributable to it, the author recommends that a noncommunicating pneumothorax be handled as described. Finally, if the tear in the pleura is not easily visible, then one would simply make a small incision in the pleura for placement of the chest tube.

If the patient does have a pneumothorax during the procedure, then postoperative antibiotics are indicated for 1 week, and travel by air is not permitted for 10 days.

Injury to the subclavian vein or artery

The thoracic outlet can be classified definitely as "tiger country" from the point of view of its anatomic potential for disaster. Because both the subclavian and axillary vessels require careful yet decisive manipulation during the course of all approaches to decompression, the surgeon and operating team must be capable of dealing with anything that might go wrong in the course of the procedure. This necessitates that expertise, instruments, and organization be available or accessible on an immediate basis. If the surgeon does not feel capable of handling a massive hemorrhage either by temperament or training, then either she or he shouldn't be doing the surgery, or a vascular surgeon should be present or immediately available.

Typed blood and chest and vascular instruments should be present in the operating room before the skin incision is made, because if they are needed, moments can make the difference between a difficult repair and a patient who has exsanguinated. The subclavian vein can be particularly troublesome because of its fragility when compared with the artery.

When removing spicules of bone with a rongeur, for example, if the instrument is dull, twisting wrist motion can result in splintering of the bone rather than removal of the desired small bit. This has the potential for producing multiple holes in these large vessels. The author has experienced one such episode that was resolved quickly by placing a pressure pack on the vein, thus stopping the bleeding, and with the aid of a vascular surgeon, repairing three small yet productive tears in the vein. Since that time the author has maintained a separate set of pristine rongeurs for such surgery, because in many other orthopaedic procedures the instruments tend to develop burrs or lose their cutting edges quickly.

Finally, depending on the nature of the vascular injury should it occur, it may be necessary

to perform a median sternotomy to gain control. Fortunately the author has been spared that experience over the 27 years of doing this surgery.

Injury to the brachial plexus and long thoracic nerve

Injury to the brachial plexus may occur in one of two ways, either as a result of a maneuver on the part of the surgeon or assistants that traumatizes the nerve locally, or indirectly by excessive and prolonged traction on the arm of the anesthetized and paralyzed patient [7]. In this latter case, the problem can be avoided by exerting only as much traction on the arm as is absolutely necessary to gain exposure and mobilization and doing so only intermittently. Under no circumstance should the arm be suspended in unrelenting traction as it might be for shoulder arthroscopy.

A supraclavicular approach conveys the advantage of better visibility of most of the critical structures. Specifically, anterior approaches usually are used for scalenectomy; the most common operation involves removal of the anterior scalene. With proper respect for the phrenic nerve anteriorly and the vessels and pleura posteriorly, this is a safe maneuver. Even though the long thoracic nerve usually is found posterior to the middle scalene, however, in some cases it or one of its branches actually pierce the muscle as it goes to the medial wall of the axilla. In this case it is at risk with middle scalenectomy, which in the author's opinion is rarely necessary except in cases of extreme scarring from previous surgery.

Although the nerve to the serratus may be injured at the level of the first rib, it also may be traumatized along the chest wall if there is an intercostal bleeder that is cauterized without due regard for the nerve's location. Following first rib resection by the axillary route, many patients experience transient winging of the scapula caused by a traction injury of the long thoracic nerve or because the first digitation of the serratus must be detached from the first rib. Often the patient is unaware of the problem, which usually recovers spontaneously. In those cases in which the nerve has been divided or destroyed by the cautery, lifting objects in front of the plane of the body is severely compromised. Successful repair of such a damaged nerve occasionally can be accomplished but it is by no means assured.

In the transaxillary approach, the major nerves at risk are C8 and T1, which come together on the superior surface of the first rib to form the lower trunk of the brachial plexus. It is imperative that any mobilization of the lower trunk be done with the utmost care.

The functional deficit that results from injury to the lower trunk of the brachial plexus or either of its contributing roots is major and usually permanent. Although the sensory deficit involves only the small finger in the hand (and the medial side of the forearm), the motor deficit includes the long flexors of the fingers and the intrinsic muscles of the hand. Surgical repair at the level of the thoracic outlet has such a poor prognosis that it is not worth attempting. Reconstruction of the hand by means of tendon transfer can palliate the situation so that some useful prehension is restored, but it remains greatly inferior to function that has been lost. This is the most important non life-threatening complication of thoracic outlet surgery.

Apical hematoma

The presence of the subclavian and axillary vessels in the operative field presents the possibility of massive hemorrhage as a result of surgical missteps. Cutting soft tissues and bone during the course of dissection, however, may cause seemingly insignificant bleeding that is not obvious until such time as a postoperative radiograph demonstrates an apical density, a hematoma. If the surgeon is confident that at the end of the procedure all major bleeding has been averted or controlled, then nothing more aggressive than close monitoring of the patient's vital signs and follow-up chest films is required. Usually these apical hematomas spontaneously reabsorb within 7–10 days.

Intercostobrachial nerve injury

The intercostobrachial nerve is of considerably less concern to surgeons operating in the axilla than to the patient having the surgery, and it can be a source of extreme patient distress if injured. It is probably the sensory nerve in the body that is injured and ignored more than any other, with the expectation that there is no significant consequence. Most of the information regarding this condition comes from cases wherein the axilla has been explored for diagnosis or treatment of malignancies, although the generally unreported incidence of injury to the intercostobrachial nerve during transaxillary first rib resection must be significant.

The nerve originates constantly from the second intercostal nerve with occasional contributions from the first and third. It appears in the midaxillary line beneath the second rib, where it pierces the intercostal muscles and travels through fat and lymph nodes to the posterior arm. Its size and location in the middle of the axillary operative field require constant retraction and make it an anatomic nuisance. Unfortunately, after it emerges from below the second rib, there is considerable variation in its size, its relationship to adjacent nerves, and ultimate cutaneous distribution. The intercostobrachial nerve is usually approximately the size of a digital nerve in the hand, and because of early division it may seem to be two nerves [8].

In approximately 20% of the cases, there is a connection with the medial cutaneous nerve of the arm and a reciprocal relationship in size between these two nerves. This arrangement may serve to explain the great variations in deficits and symptoms in patients who have had documented severance of the intercostobrachial nerve. In some of them, there are few sensory changes with mild symptoms, whereas in others there may be extreme discomfort [9] reminiscent of causalgia. The pain may result in intolerance to any contact with the dysesthetic skin, creating difficulty in cleansing the axilla or in having clothing rub against it.

It is generally taught that the intercostobrachial nerve merely supplies the skin of the axilla and a small area of the back of the arm. Careful examination in the living patient with this nerve lesion may demonstrate extreme dysesthesia down to the level of the elbow. Anatomic studies have demonstrated definite branching of the nerve in some specimens that corresponds to this distribution [8].

Although it is tempting when one has more potentially serious things to be concerned about during the course of first rib resection, the temptation to sever the nerve at the level of the intercostal muscles is to be condemned. Some release of tension on the nerve may be achieved by gentle dissection distally as it becomes surrounded by adipose tissue and lymph nodes. Constant reminders to the assistant retracting the nerve, however, help ensure its preservation.

In cases in which the surgeon is reasonably confident that the nerve has been preserved, although the patient may experience significant discomfort postoperatively, there is a good chance that over 2–3 months the sensibility will normalize and the symptoms will disappear. Unfortunately in some cases the annoying sensory disturbance is permanent.

Failure to appreciate the presence of congenital bands

One of the descriptive terms that is used rarely today for describing compression within the thoracic outlet is "cervical rib syndrome." Although initially great interest was shown in cervical ribs, which originate at the seventh cervical vertebra, it has been realized subsequently that even in the absence of such bony abnormalities, radiolucent fibrous bands can cause significant neurovascular compression [10,11]. These may take origin from an overly long transverse process at C7 and then attach at various points along the first rib, with the nerves or vessels resting immediately on them. The index of suspicion therefore should be raised when an anteroposterior radiograph of the cervical spine in a patient believed to have TOS shows transverse processes significantly longer at C7 than at C6.

At surgery in such patients it is imperative to make a careful search for these fibrous bands and to ensure that they are removed carefully. Dr. David Roos, who popularized the transaxillary approach to the first rib, has described seven different types of bands, and the author has seen all of them at the operating table. According to Roos, the most common is a taut muscular band originating on the anterolateral surface of the first rib and passing straight across the thoracic outlet inside the posterior curve of the rib to attach just behind the scalene tubercle. The removal of the fibrous bands usually is not technically difficult, but their effects on the neurovascular structures can be significant.

Inadequate resection of the medial end of the first rib

In its anterior and medial portion, the first rib must be disarticulated from the manubrium to achieve adequate decompression.

To accomplish this part of the procedure, it is necessary to identify the costoclavicular ligament. It attaches to the superior and medial part of the first rib cartilage and to the inferior surface of the clavicle. It is also in relation to the tendon of the subclavius, which also must be severed. The subclavian vein is located immediately dorsal to it,

so that it must be protected while these ligaments are detached and the rib is totally removed.

Inadequate resection of the posterior portion of the first rib

Visualization of the area of the first rib that lies adjacent to and behind the lower trunk of the brachial plexus is extremely difficult, because of the pyramidal configuration of the thoracic outlet. This is particularly so in cases in which the muscular relaxation provided with anesthesia is insufficient for the task. It is desirable to resect the posterior portion of the rib as close to the vertebral articulation as possible, and some surgeons state that disarticulation is necessary for adequate decompression. In most cases, however, the author believes that resection to a level of 2 cm or less of the posterior portion of the rib is sufficient to prevent later adherence of the lower part of the brachial plexus at the point of osteotomy and adequately decompresses the nerves.

Because the brachial plexus is the structure that is most at risk during this portion of the operation, it is essential that the rib cutter be applied gently to the rib after it has been denuded of soft tissue and then, under direct vision, closed before it is pushed posteriorly so that there is no opportunity for any soft tissues to become interposed between the cutting jaws. The blind use of a rongeur in this situation is dangerous and should be avoided.

In the event that a secondary operation is necessary, it may be possible to resect the offending retained rib fragment either through a posterior approach or possibly through a supraclavicular approach. The problem with a repeat axillary approach is that the brachial plexus is usually adherent to the stump of the rib anteriorly, and it is therefore difficult with this approach to define nerve from scar tissue clearly enough to accomplish the additional resection. This problem carries a significant risk for nerve injury and should not be attempted by an inexperienced surgeon.

The "missing middle third"

In the approach to the first rib through the axilla, the portion of the rib that presents to the operator is the middle third. Because this is the easiest to visualize and is the site of the nerves and vessels, the temptation for the inexperienced or timid operator is simply to resect the middle third of the rib. Unfortunately, in cases in which a prior attempt at resection has been insufficient, the resulting situation presented to a subsequent surgeon is a very difficult one. Specifically, anteriorly the subclavian vein will have adhered to the medial stump of the rib, and the brachial plexus will be scarred to the remaining rib posteriorly. The artery generally falls down between the two ends of bone.

Although it would be tempting simply to remove the middle third of the clavicle for exposure, this creates more problems than it solves. If a clavicle osteotomy is required, the soft tissue should not be stripped from the clavicle because the likelihood of nonunion of the osteotomy is virtually assured. An alternative is to detach the pectoralis major from the clavicle and retract the clavicle as necessary through an anterior approach. Another alternative is a longitudinal pectoral split, but under no circumstances should claviculectomy be considered [12]. This situation should not be one of a surgeon's first cases [13].

Failure to recognize that the second thoracic rib may be contributing to the problem of compression

The angle that the first rib makes with the horizontal (costal angle) is of more than academic interest, as originally described by Todd in 1912 [14]. Although superficially it might be believed that the first rib is horizontal, at birth in both sexes it makes approximately a 30° angle with the horizontal. With growth the angle increases, more in males than in females, so that in males it averages approximately 50° and in females approximately 47°. The interaction between the angles of the clavicle and the first rib are complex and causally related to the increased incidence of thoracic outlet compression in mature females. This relationship is worth studying in the published papers of Todd.

The practical consequence of these facts is that in addition to the first rib, the second rib also can be a significant factor in causing compression. An awake and normally mobile patient demonstrates different anatomic tolerances from one under anesthesia in the supine position. The most practical method of evaluating the possibility of second rib compression is for the surgeon to insert

two fingers at a right angle to the clavicle into the bed of the resected first rib and then push the shoulder backward to test clearance for the nerves and vessels. In the event that the fingers are trapped, it may be necessary to remove that portion of the second rib compressing the neurovascular structures. The entire second rib does not have to be resected, however, to assure decompression.

Mistaking the second rib for the first

This particular problem is not likely to be encountered by the experienced operator. In the transaxillary approach to the first rib, before anything other than simple exposure is done, all named structures within the operative field of the thoracic outlet must be clearly visualized and delineated. Clearly, cervical ribs may be confusing, because they may be long enough to actually articulate with the first rib, with artery and nerves running over the cervical rib. The author has seen these conjoined bones actually surround the artery, resulting in an aneurysm that presented as emboli to the hand. Fusion of the second thoracic rib to the first has been reported.

Skeletal abnormalities should be apparent with preoperative evaluation of adequate multipane radiographs. This does not protect the operator or the patient from the consequences of failure to recognize that the position of the artery and vein may be reversed, or that these vessels may be duplicated. There are several anatomic variations that have been described that are not obvious on skeletal radiographs. The work of H. Minor Nichols is particularly enlightening in this regard [15], as is the demonstration of congenital bands as described by Roos [11].

Although most surgeons do not experience great difficulty in identification of the first rib if provided with adequate muscular relaxation and a head-mounted light using the axillary approach, the posterior approach to the thoracic outlet can present problems when the inclination of the first rib is extreme. In this situation the second rib actually may hinder visualization of the first rib; the operator, not realizing the situation, may proceed to resect the second rib. Having actually made this mistake myself and only realizing it after inspection of the recovery room chest radiograph, it was necessary to take the patient back to the operating room and remove his relatively short, yet extremely inclined and still-present first rib. Fortunately there were no permanent or unpleasant consequences beyond embarrassment.

Injury to the thoracic duct or its tributaries

The author does not know of any reported cases of injury to the thoracic duct in the course of surgery for decompression of the thoracic outlet. Certainly there would be no likelihood of this occurring with the transaxillary approach. In approximately 500 first rib resections performed over a 30-year period, however, the author had the unfortunate experience once.

This was in the case of a patient who had had previous thoracic outlet surgery for resection of the first rib elsewhere, and postoperatively her symptoms were considerably more severe. The author elected to re-explore the supraclavicular fossa through the previous incision that extended the entire length of the clavicle and I encountered very dense scar involving virtually all of the structures. After a tedious dissection and identification of the neurovascular structures, the author removed the first rib without difficulty.

Everything seemed normal in the postoperative period until the next day when the nurse reported that the dressing was soaked with yellow fluid. Initially this did not provoke any anxiety, but when in the next 24 hours we realized that she had drained more than 300 ml of this fluid, it was obvious that there was something terribly wrong. Because the exploration had been on the left side, the only thing that could be producing this fluid was the thoracic duct. Going back in my mind over the operative procedure and realizing that in most cases the thoracic duct joins the venous system at the junction of the subclavian vein and internal jugular, it was not easily apparent to me why there should be a tear in the thoracic duct when the dissection had not extended that far medially.

Over the next 24 hours the drainage actually increased. There was nothing to do but to explore the wound immediately, which revealed that in the depths of the area that the author had previously explored, fully 1 inch from the normal juncture of the thoracic duct and the venous system, there was a small tributary that was leaking lymph fluid. Rather than attempt to close it with a stitch, a single vascular clip sufficed to stop the flood. Fortunately the patient did extremely well postoperatively and had no ill effects from her repeat surgery.

With some rare exceptions, injuries to the thoracic duct are usually iatrogenic and have been reported mostly in the literature concerned with esophageal surgery for neoplasm and radical neck dissections and other thoracic operations [16]. There are few cases reported following explorations of the anterior triangle of the neck, but it seems a consensus that this is a serious and potentially fatal complication with a mortality rate greater than 50% if it is not treated promptly.

The deleterious effects of the loss of lymphatic fluid, which can be more than 1500 ml per day, are not surprising, because in a normal adult approximately 4 L of fluid pass through the thoracic duct every 24 hours. Ultimately, however, this loss can produce progressive nutritional and immune deficiency and electrolyte imbalance and increased risk for infection.

With reference to management, if the diagnosis is unclear one can feed the fasting patient cream through a nasogastric tube and observe a change in the fluid to a more milky appearance. Conservative measures formerly touted a low fat diet, now more likely total parenteral nutrition. There are some reports of the use of somatostatin [17] with benefit, although most workers in the field now agree that conservative therapy for more than 72 hours without cessation of drainage is an indication for surgical intervention.

The precise location of the leak is best determined by lymphangiography, which is superior to CT scanning. Ligation of a leaking tributary or of the main thoracic duct does not seem to have any significant long-term adverse effects. The lymphatic system has the ability to reconstitute itself and develop additional tributaries, which explains why in the case described previously there were lymphatics where one would not expect to find them. The other important caveat is that the anatomy of the thoracic duct may be variable, and although in the "classic" situation there is one thoracic duct, there may be two, and there also may be significant branching and subsidiary cervical lymph trunks [18].

Phrenic nerve injury in the course of anterior approach to the thoracic outlet

The phrenic nerve, a motor nerve to the diaphragm, originates from the third, fourth, and fifth cervical nerves. In the posterior triangle of the neck it lies on the anterior surface of the scalene anterior muscle, crossing lateral to medial. It is not in significant danger with the transaxillary approach because at the point of attachment of the anterior scalene to the first rib the nerve is medial and most of it is considerably more proximal by at least 2 cm.

With anterior approaches that involve resection of the muscle or even in the axillary approach with subtotal scalenectomy there is a danger of injury to the phrenic nerve. Paralysis of the hemidiaphragm compromises respiratory tidal volume, diminishing the patient's ability to exercise. The nerve first should be carefully defined before anterior scalenectomy. Because anterior approaches require little muscular relaxation, a nerve stimulator can facilitate identification of the nerve, which can then be protected by means of a soft plastic or rubber band and kept under constant observation.

Summary

Having read through the previous litany of potential disasters and complications, one could ask the obvious question, "Why would anyone want to do this kind of surgery?" The answer is that most people elect not to! Nevertheless, for those who decide to venture into this field, there is the tremendous reward of being able to help patients who would otherwise continue to live with extremely disabling and disheartening symptoms.

A sound knowledge of the regional anatomy [19–23] and tutelage by those knowledgeable in particular areas of surgery that may not have been a part of the individual surgeon's prior training is essential. The author was fortunate to have the help of a very accomplished and generous vascular surgeon, Dr. William Abbott of the Massachusetts General Hospital for many months when I began on what I have considered a fascinating and intellectually rewarding odyssey.

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