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Edited by

Crawford W. Jamieson MS, FRCS
Consultant Surgeon, St Thomas' Hospital, London, UK

James S. T. Yao MD, PhD
Magerstadt Professor of Surgery, Division of Vascular Surgery, Northwestern University Medical School, Chicago, Illinois, USA

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Thoracic outlet syndrome: supraclavicular approach

S. W. K. Cheng MD, FRCS
Visiting Assistant Professor, Vascular Division, University of California, San Francisco, USA

W. V. Ellis MD
Department of Neurosurgery, University of California, San Francisco, USA

R. J. Stoney MD
Professor of Surgery, Vascular Division, University of California, San Francisco, USA

History

Controversy has surrounded the aetiology and treatment of choice of the thoracic outlet syndrome. Mechanical compression of the brachial plexus or post-traumatic inflammation has been thought to be the cause. Operative treatment includes scalenotomy or scalenectomy, with or without excision of a cervical and/or first rib, depending on which anatomical structures are regarded by the surgeon to be the cause of compressive symptoms. Four operative approaches are generally adopted: supraclavicular, transaxillary, infraclavicular and posterior parascapular.

In 1861 Coote was the first to excise a cervical rib as the treatment for thoracic outlet syndrome. This was followed by the removal of a normal first rib by Murphy in 1910 to relieve neurological symptoms. Later the technique of anterior scalenotomy was developed as the role of the scalenus anterior muscle in brachial plexus compression was recognized[1]. In the early 1960s Clagett proposed the posterior approach for first or cervical rib resection in thoracic outlet decompression. This was followed by the transaxillary approach to first rib resection described by Roos[2,3], which rapidly became the most popular operation for the thoracic outlet syndrome in the past two decades.

Principles and justification

Pathophysiology

Neurogenic symptoms of pain, paraesthesia and weakness of the upper limb are caused by brachial plexus compression at the thoracic outlet. The clinical progression falls into two general categories: (1) those with an abrupt (usually post-traumatic) onset: they have little, if any, motor disturbances, but suffer severe sensory symptoms similar to early reflex sympathetic dystrophy; and (2) those with a slow, progressive course over years with the gradual evolution of disabling symptoms.

The predisposing factors are primarily anatomical, including osseous anomalies like cervical ribs or an abnormally long transverse process of the C7 vertebra. Congenital fibrous bands, scalene muscle hypertrophy or aberrant interdigitation constitute another source of brachial plexus irritation. The symptoms are frequently precipitated by neck trauma.

The initial injury, whether gross (usually hyperextension injury to the neck) or from repetitive microtrauma, produces a local perineural inflammation. In certain individuals, this sensitizes the local neural net to produce trophic and inflammatory factors (e.g. substance P) which in turn evoke an organizing extracellular response and scar formation. This perineural fibrosis and consequent local vasoconstriction of the vasa nervorum produces local ischaemia and neurogenic thoracic outlet symptoms. These same factors also stimulate type I muscle growth and local muscular hypertrophy. The ischaemia, whether neurogenic or from mechanical irritation, perpetuates the abnormal sensitivity of the perineural network and creates a pathological positive feedback, which eventually results in the surgically correctable condition we know as thoracic outlet syndrome.

Indications for operation

Most patients have some improvement with a period of conservative physical therapy and analgesics. The results of conservative management are usually better if the symptoms are of recent onset. Surgical decompression of the thoracic inlet should be offered if symptoms do not improve or worsen after several months of conservative treatment, or if the patient is severely disabled. A concomitant cervical sympathectomy may be offered if the patient shows severe digital ischaemia or complains of reflex sympathetic dystrophy.

Supraclavicular approach

The transaxillary approach for thoracic outlet decompression was originally adopted in this unit, but was later modified to combine supraclavicular scalenectomy with transaxillary rib resection[4] because a significant proportion of patients had persistent or recurrent symptoms after transaxillary first rib resection alone. Supraclavicular reoperation in these patients disclosed reattachment of the anterior scalene muscle to the scarred first rib bed, and symptoms improved after scalenectomy. Most importantly, the supraclavicular approach allows direct visualization of the anatomy of the thoracic outlet, and permits simultaneous treatment of anomalies of the scalene muscles themselves, so that every source of compression of the brachial plexus can be removed. This approach also gives excellent exposure of the neck of the first rib and the courses of T1 and C8 roots. With careful dissection of the neurovascular structures in the supraclavicular fossa, extraperiosteal mobilization and excision of the first rib is possible via the supraclavicular route alone. We abandoned the transaxillary operation completely in 1983 and have reported a 90% success rate with supraclavicular scalenectomy and first rib resection[5].

With increasing experience with supraclavicular decompression, we began to question the necessity of routine first rib resection. The supraclavicular approach enables accurate identification of the offending structures. They are usually soft tissue anomalies such as muscular interdigitation or fascial bands and scars. Osseous abnormalities are rare, and the first rib seldom has actual mechanical contact with the brachial plexus. The prevalence of symptoms occurring after trauma and consistent reports of scalene muscle pathology[6] focused our attention on the role of this muscle in symptom production. Frequently after scalenectomy and a complete neurolysis, the brachial plexus runs a free, unobstructed course through the thoracic outlet. Resection of the first rib in these instances is unnecessary and poses additional problems of increased postoperative pain and morbidity, and a higher risk of pleural damage. Moreover, the bed of the resected first rib is often a site of excessive scarring and contributes to the recurrence of symptoms. Since early 1990 we have performed 34 thoracic outlet decompressions by anterior and middle scalenectomy and neurolysis of the brachial plexus using a supraclavicular approach without resecting the first rib. The results were no different from those of supraclavicular scalenectomy and rib resection.

Preoperative

The diagnosis of thoracic outlet syndrome is mainly clinical. A thorough physical examination of the musculoskeletal system of the neck, shoulders and upper extremity must be undertaken to exclude other pathology. Radiography of the cervical spine should be performed for all patients. Osseous anomalies such as cervical ribs or old fractures may be readily diagnosed. Computed tomography or magnetic resonance imaging of the neck are mainly used to rule out degenerative cervical spinal conditions and are not specific for thoracic outlet syndrome. Electromyography and nerve conduction studies are often normal and are only helpful in excluding nerve entrapments like carpal tunnel syndrome. In patients with vascular symptoms, an arteriogram or venogram is mandatory and may be supplemented by non-invasive vascular laboratory studies.

The patient is admitted a day before or on the day of surgery and no special preparation is necessary.

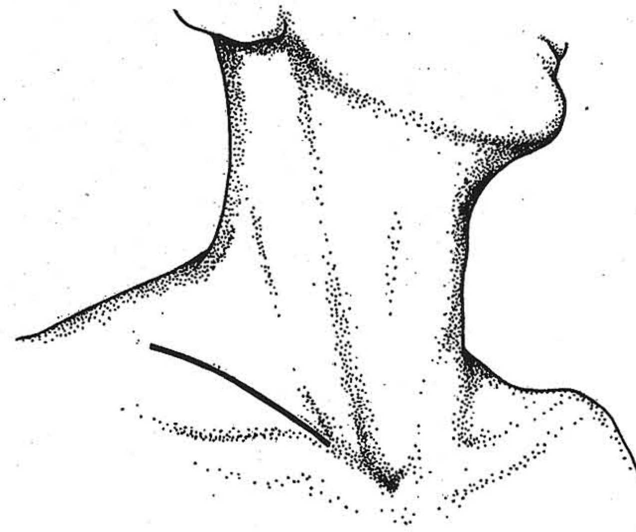
Anaesthesia

The operation is carried out under general anaesthesia with endotracheal intubation. The patient is placed in a semi-recumbent (Fowler) position on the operating table with the head turned away from the side of operation. The arm of the involved side is held parallel to the body with the hand exposed.

Operation

Incision

1 A curvilinear incision is made at the base of the neck, two fingerbreadths above the clavicle, beginning over the clavicular head of the sternocleidomastoid muscle, and curving laterally and posteriorly for about 10 cm. The platysma is incised and subplatysmal flaps are raised superiorly to the level of the cricoid and inferiorly to the level of the clavicle. The sternocleidomastoid muscle is retracted medially and its clavicular head divided if necessary.



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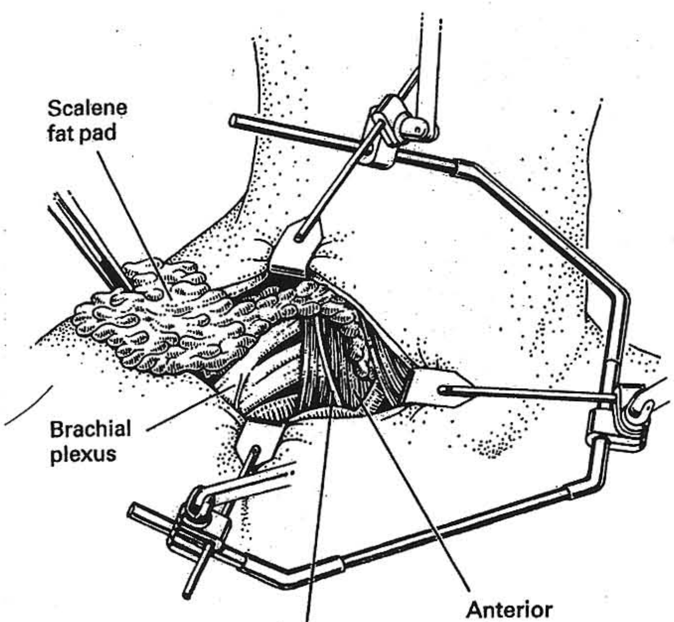


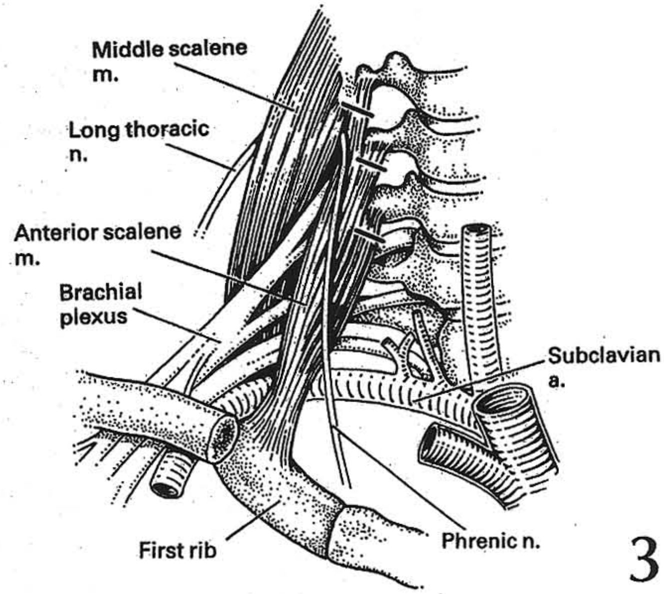
2

Mobilization of scalene fat pad

2 The lateral border of the internal jugular vein is identified and mobilization of the scalene fat pad is begun at this point. The mobilization proceeds laterally onto the anterior surface of the anterior scalene muscle and inferiorly along the clavicle. The omohyoid muscle is divided. The phrenic nerve, which runs obliquely from lateral to medial across the anterior scalene muscle, is identified and gently dissected free. The scalene fat pad is then reflected on a laterally based pedicle.

Anterior scalenectomy

3 The phrenic nerve is retracted medially, and the anterior scalene muscle is mobilized down to its attachment to the first rib, taking care to preserve the subclavian artery and the trunks of the brachial plexus posteriorly. Branches of the thyrocervical artery may be encountered running across the anterior scalene muscle and may have to be divided. The muscle is detached flush with the rib and reflected superiorly. This allows optimal visualization of the plexus and the artery. Any muscle fibres which interdigitate with the middle scalene muscle between the trunks of the plexus or which encircle the subclavian artery are now divided. This process proceeds proximally until the origins of the anterior scalene muscle are exposed from the transverse processes of the upper cervical vertebrae; they are then divided and the anterior scalene muscle is removed.



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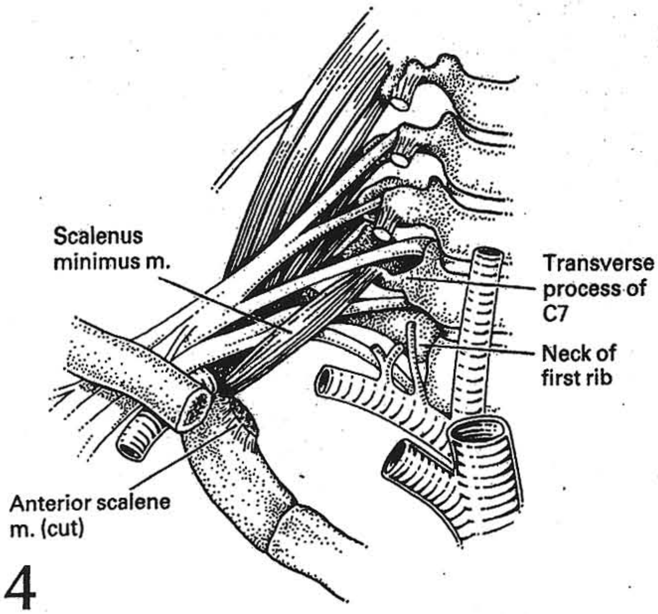
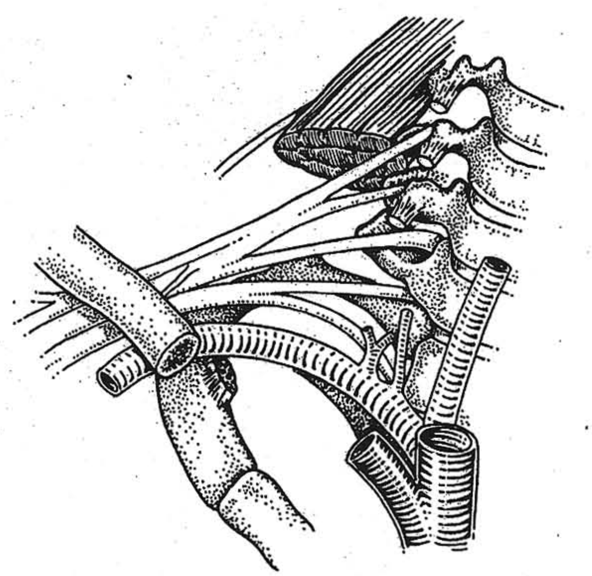


4

Middle scalenectomy

4 Thorough mobilization of the roots and trunks of the brachial plexus is now performed, until gentle anterior displacement of these structures is possible. This is facilitated by elevating the shoulder to relieve tension on the nerve trunks, allowing further mobilization of the trunks from the anterior surface of the middle scalene muscle. The lateral border of the middle scalene is explored until the point of emergence of the long thoracic nerve is determined. The middle scalene muscle is mobilized completely by gently displacing the trunks of the brachial plexus. Any interdigitating muscle fibres or anomalous bands passing between or compressing the nerve roots or trunks are removed.

5 As this dissection progresses towards the posterior surface of the middle scalene, the first rib will be easily felt behind the muscle. The middle scalene muscle is then transected on a line parallel to and inferior to the course of the long thoracic nerve down to the anterior aspect of the neck of the first rib. The muscle insertion, together with the periosteum, is removed from the rib entirely. This leaves a clean bony surface on the first rib with no muscle adjacent to the brachial plexus.



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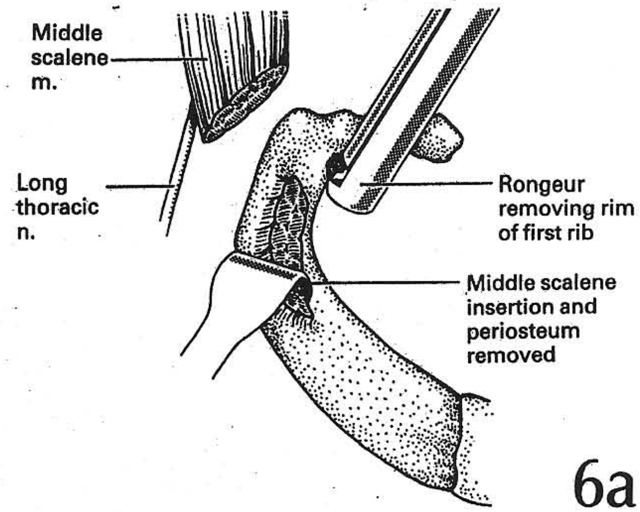
Brachial plexus neurolysis

The brachial plexus is now carefully inspected and each root traced from its interforaminal origin to the level of the clavicle. Any scar tissue and residual muscle fibres are removed by a complete neurolysis until the nerves are skeletonized.

6a–d A prominent transverse process of the C7 vertebra may be shortened with a rongeur or cut with a pair of heavy scissors. If the medial neck of the first rib is impinging on the course of the T1 root of the plexus, a bone rongeur is used to remove a small rim of the medial border, allowing a free course of the root on its way through the thoracic outlet. The first rib does not cause actual compression of the plexus and is not disturbed.



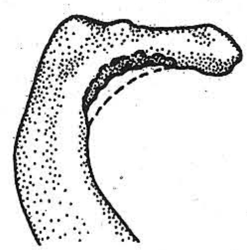
6a

Intraoperative monitoring

The effectiveness of surgical decompression of the brachial plexus can be monitored during surgery. This involves imaging the pattern of infrared heat emission from the hand on the operated side and observing the pattern of change during the operation. Previous experience in intraoperative monitoring during laminectomy and discectomy has validated the usefulness of this technique in determining the completeness of surgical decompression of the nerve roots.

Using an on-line infrared camera processed by a colourizer, we have monitored over 60 cases during surgery through a draped tunnel, with no physical contact with the patient. The initial thermal asymmetry as determined before operation is characterized by asymmetrical cooling of, principally, the ulnar aspect of the dorsum of the hand and involves multiple dermatomes, unlike disc disease in which only one dermatome is affected. This image is displayed on a small video terminal and is monitored continuously during the operation.

Consistently, we have observed a decrease in heat emission in the dermatome of the cervical nerve root being retracted or manipulated. Conversely, the atraumatic perineural dissection of scar tissue results in increased heat emission in the dermatome corresponding to that nerve. This increase in heat emission is seen when myofascial anomalies and osseous deformities are removed. Interestingly, this heat increase is often dramatic when perineural fibrosis is removed, suggesting that this may be important in plexus irritation. The sensitivity of the brachial plexus roots and trunks to continued irritation directs further surgical exploration and decompression of affected roots. Without this information, an incomplete decompression would result in nearly one-third of patients.



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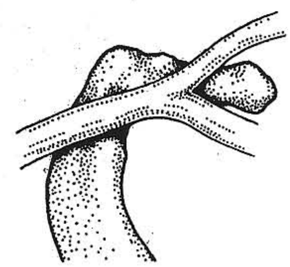

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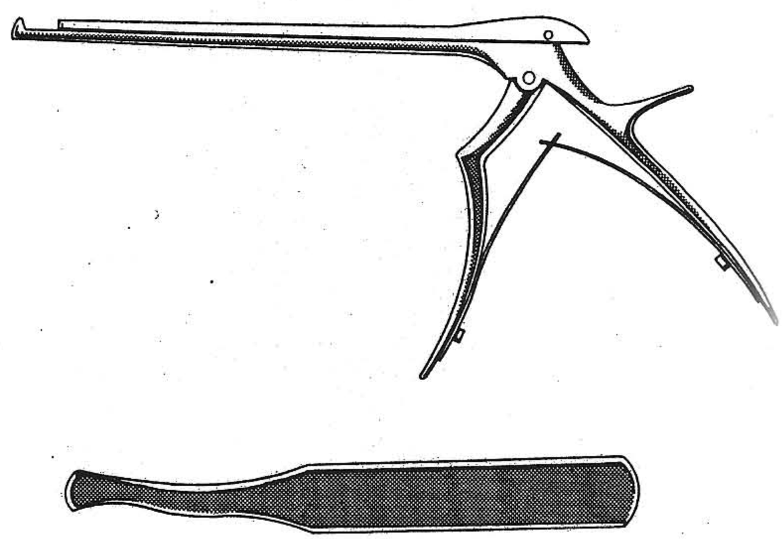

6d

Closure

Haemostasis is carefully secured and the wound inspected for any chylous or lymphatic leakage. The lung is inflated and the pleura examined for any disruption. If a pleural defect is detected, a small catheter is placed through a pleurotomy into the thoracic cavity and the air evacuated by aspiration before closure. The catheter is later withdrawn from the closed wound. A smaller tear in the pleura can be closed directly with absorbable sutures. The mobilized prescalene fat pad is positioned loosely over the trunks of the brachial plexus. This provides a soft insulating pad to help protect the nerves. The platysma is reapproximated and the skin closed with a subcuticular suture around a suction drain. An epidural catheter placed through a stab wound and positioned along the course of the proximal root of the brachial plexus can be used for instillation of topical anaesthetic agents for postoperative pain relief or steroids to reduce scar tissue formation in patients undergoing reoperation.

Operative concerns and hazards

The supraclavicular fossa is the seat of many vital neurovascular structures and a thorough understanding of the anatomy is essential to the success of the operation. The surgeon should also bear in mind that diverse anatomical variations and anomalies exist in this region. The anterior and middle scalene muscles may be hypertrophied or have abnormally broad insertions into the first rib. Often, interdigitating bundles from these muscles pass between the roots of the brachial plexus. The plexus may emerge high up in the interscalene space. Frequently, a scalene minimus muscle or a fibrous band will originate from the C7 vertebral body, crossing in front of the lower brachial plexus to insert into the medial border of the first rib, compressing the nerves. Particular attention should be paid during dissection to identify and preserve the following nerves, vessels and lymphatic structures.

Nerves

The roots and trunks of the brachial plexus are prone to damage as they emerge through the intervals between the anterior and middle scalene muscles. In reoperations they may be encased by scar tissue. The T1 root lies close to the neck of the first rib and may be damaged if the rib is resected.

The phrenic nerve, which runs from lateral to medial across the surface of the anterior scalene muscle, must be identified and protected before the muscle is resected. Excessive traction on the nerve should be avoided.

The long thoracic nerve emerges on the lateral border of the middle scalene muscle. Its identification serves as a landmark for the division of this muscle. It may have two roots which join to form the main nerve.

The vagus nerve and its recurrent branch on the right side may be subjected to damage as it courses in front of the subclavian artery.

The cervical sympathetic chain and the stellate ganglion lie behind the common carotid artery and in front of the prevertebral fascia. Damage to the ganglion will result in a Horner's syndrome.

Vessels

The internal jugular vein joins the subclavian vein behind the medial end of the clavicle and runs in front of the anterior scalene muscle.

The subclavian artery lies behind the anterior scalene muscle as it emerges from the thoracic outlet. Any abnormal bands compressing the artery should be freed and the artery protected when the muscle is excised.

Lymphatic structures

Chylous and lymphatic structures, especially the thoracic duct on the left side when it turns laterally at the level of the transverse process of C7 and runs in front of the subclavian artery to drain into the innominate vein, should be preserved.

Postoperative care

The drains are usually removed within 48 h and the patient discharged on the third or fourth postoperative day. Passive arm motion is allowed immediately and a physical therapy programme is started to allow gradual recovery of the range of motion of the shoulder and neck and normal muscle function.

Complications

Wound collection

A collection of serous fluid or lymph under the supraclavicular wound poses an occasional problem. The swelling usually subsides with needle aspiration and antibiotics. In rare cases it becomes encapsulated and operative removal together with ligation of the leaking lymphatic ducts is necessary.

Pleural complications

A small tear in the pleura is the most common complication in our experience. The patient can usually be adequately treated by aspiration with a catheter. Postoperative pneumothorax is rare and may be observed if it is small.

If a major lymphatic duct is damaged, a continuous chylous leak from the drain or wound will result. This may lead to a chylothorax and compromise respiration. Treatment by chest tube drainage followed by re-exploration of the neck and ligation of the leaking lymphatic is essential.

Haemothorax is a rare occurrence and can be avoided by careful haemostasis before closure.

Neuropraxia

Operative irritation or traction can cause neuropraxia of the phrenic or long thoracic nerves and occasionally the brachial plexus. Transient elevation of the diaphragm, winging of the scapula, or weakness of the arm or hand in the brachial plexus distribution will result. A permanent nerve palsy is uncommon.

Accelerated healing

In a few patients excessive scar formation around the brachial plexus can result in early recurrence of pain, tightness, muscle spasm and limited motion. Vigorous physical therapy, steroids and interferon have been tried to alleviate these symptoms without much success. Reoperation to remove the scar tissue may be necessary if the symptoms become too severe. Postoperative magnetic resonance image scan is useful to assess scar development.

Pain syndrome

After a successful thoracic outlet decompression some patients report burning pain and increased sympathetic tone in the upper extremity. These are exaggerated by compressing 'trigger zones' in the supraclavicular area. Neuromas, nerve entrapment by scars and reflex sympathetic dystrophy have been advocated as the cause. Stellate ganglion blocks, trigger point injections and physical therapy including ultrasound and hot packs can provide temporary relief, but the problem is often protracted.

Outcome

From January 1983 to September 1991 we have performed 225 thoracic outlet decompressions using the supraclavicular approach on 196 patients (36 men and 160 women). More than half (58.7%) of the patients gave a history of trauma to the neck or shoulders. The majority (188) were primary operations and 37 patients were operated upon for recurrence of symptoms after a previous decompression elsewhere.

Of the 188 primary operations, 128 were combined scalenectomy and first rib resections, 26 were scalenectomy and excision of a cervical rib, and 34 were scalenectomy and neurolysis with sparing of the first rib. Anatomical anomalies were frequent operative findings (*Table 1*), and many patients had more than one abnormality.

Table 1 Number of anomalies detected in primary operations

Osseous anomalies	
Cervical rib	26
Abnormal first rib	5
C7 transverse process	24
Soft tissue anomalies	
Anterior/middle scalene	108
Scalenus minimus	52
Fibrous bands	76
Scar	56

Pleural damage occurred during operation in 40–60% of operations. Most were small tears and could be managed adequately with catheter aspiration alone. Postoperative complications are listed in *Table 2*. Most were minor and were treated conservatively. Nine patients underwent re-exploration, of whom seven had chylous leaks and two suffered from haemorrhage.

Table 2 Complications of supraclavicular thoracic outlet decompression (total 225 procedures)

Pulmonary	
Pleura injury	123 (54.6%)
Pneumothorax	21 (9.3%)
Pleural effusion	21 (9.3%)
Nerve injury	
Phrenic nerve	11 (4.9%)
Long thoracic nerve	8 (3.6%)
Brachial plexus	3 (1.3%)
Recurrent laryngeal nerve	2 (0.9%)
Lymphatic injury	13 (5.8%)
Haemorrhage	5 (2.2%)

All patients were examined after operation with a mean follow-up time of 12 months. The assessment of the results of surgery was based on the percentage improvement of preoperative symptoms, and less than 50% were regarded as unchanged. A cure or partial cure was achieved in nearly 90% of primary operations. The results of reoperation were less favourable, with an overall success rate of 76.5%.

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