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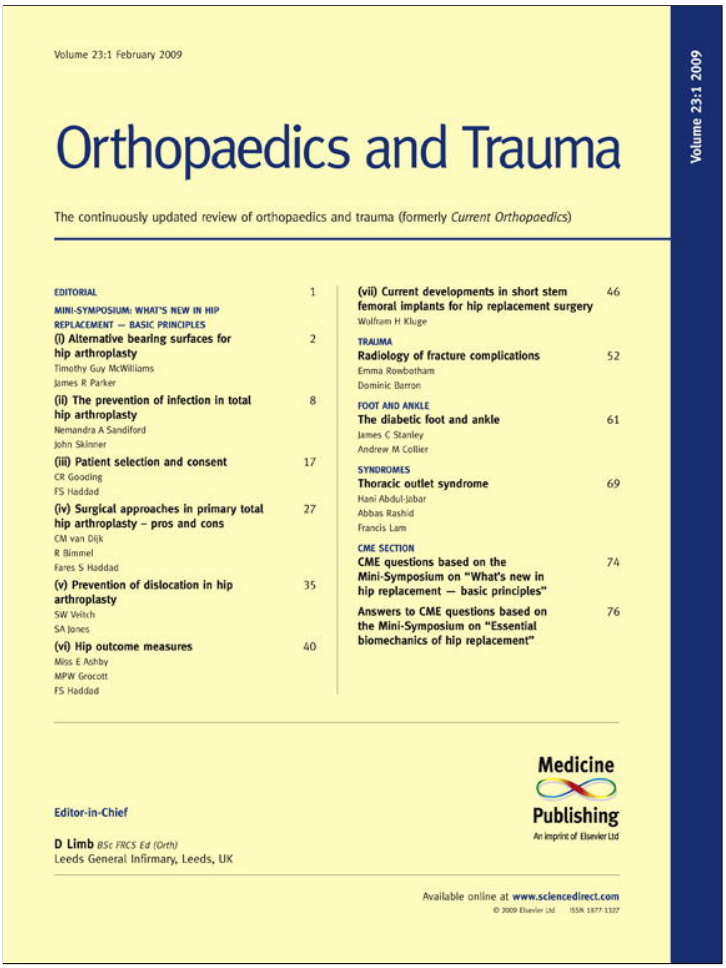

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Editor-in-Chief

D Limb *BSc FRCS Ed (Orth)*
Leeds General Infirmary, Leeds, UK

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Thoracic outlet syndrome

Hani Abdul-Jabar

Abbas Rashid

Francis Lam

Abstract

Thoracic Outlet Syndrome (TOS) is the constellation of symptoms caused by compression of neurovascular structures at the superior aperture of the thorax, properly the thoracic inlet! The diagnosis and treatment is contentious and some even question its existence. Symptoms are often confused with distal compression neuropathies or cervical radiculopathies.

Keywords first rib; scalene muscles; thoracic outlet

Introduction

Thoracic Outlet Syndrome (TOS) involves compression resulting in injury or irritation of neurovascular structures as they course through three narrow passageways from the base of the neck into the arm via the axilla (Figure 1). The most important of these is the interscalene triangle. Its boundaries are the anterior scalene muscle anteriorly, the middle scalene muscle posteriorly and the medial surface of the first rib inferiorly. The triangle is small at rest but can become even smaller with certain provocative manoeuvres. It can be further constricted by other structures such as fibrous bands, cervical ribs and anomalous muscles.

The second passageway is the costoclavicular triangle. Its boundaries are the clavicle anteriorly, the first rib posteromedially and the upper border of the scapula posterolaterally.

The third passageway is the subcoracoid space which lies beneath the coracoid process deep to the pectoralis minor tendon.

Classification and Subtypes

TOS was first described by Peet *et al* [1] in 1956. Their original classification focused principally on the mechanism of injury to the neurovascular structures, but was abandoned almost 30 years ago, after the concepts underlying each of its subgroups were either modified or discarded. In contrast the current classification proposed in 1984, is based on the structure(s) injured.[2]

True neurologic TOS

This is a rare unilateral disorder that occurs predominantly in women in their late teens to mid 50s. It is almost invariably associated with a bony anomaly, such as a small cervical rib or an elongated C7 transverse process. A very taut fibrous band extends from the tip of the bony anomaly to the first thoracic rib which results in stretching of the proximal portion of the lower trunk of the brachial plexus or the distal portion of the T1 anterior primary ramus around the band. Symptoms are predominantly motor, i.e. weakness of hand and forearm muscles with substantial atrophy of the lateral thenar muscles (innervated by the median nerve). While patients admit to having experienced intermittent aching in the median arm, forearm, and the last two digits for many years, the symptoms are typically not severe enough to seek medical attention. In a study by Ozcakar *et al* [3] using isokinetic muscle testing to assess weakness (muscle strength) and fatigue (endurance), these patients were found to have muscular strength similar to controls but their upper extremities fatigued more quickly than controls.

Arterial vascular TOS

This is a rare, unilateral disorder affecting young adults either sex. It is caused by a large bony anomaly, usually a fully formed cervical rib or, less often, a deformed first thoracic rib, which compresses the subclavian artery at the base of the neck. Distal to the point of compression, the turbulent blood flow leads to an aneurysm in which thrombus can form. This may propagate distally, occluding smaller vessels resulting in ischemia, which can in turn cause necrosis, and amputation of fingers or even a hand. Symptoms are similar to those seen in 'Neurologic TOS' although they are caused by ischaemia of the nerves distally rather than direct compression of the brachial plexus itself.

Venous vascular TOS

This is also known as "effort thrombosis syndrome" and "Paget-von Schroetter disease,".[2] It is a rare unilateral disorder that affects adults of both sexes and is caused by spontaneous thrombosis of the subclavian and/or axillary vein. The onset of symptoms is very sudden and follows prolonged limb exertion. The entire upper extremity becomes swollen, cyanotic and somewhat painful. Again although symptoms are similar to those of Neurologic TOS, the mechanism is vascular compromise of the peripheral nerves.

Traumatic neurovascular TOS

This is a rare, unilateral disorder which usually affects adult males. It is caused by a focal clavicular abnormality, most often a mid-shaft fracture. The proximal portions of the axillary artery, the axillary vein, and the cords of the brachial plexus (usually the medial cord) are injured either singly or in any combination. Mechanisms of injury include:

- compression or laceration by bone spicules of either or both blood vessels and nerve fibres at the time of fracture
- primary injury of the blood vessels causing an expanding haematoma compressing the brachial plexus elements

Hani Abdul-Jabar *MBBS BSc(Hons) MRCS(Eng) is a ST2 in Trauma and Orthopaedics at Department of Orthopaedic Surgery, Hillingdon Hospital, Uxbridge, UK.*

Abbas Rashid *MBBS BSc(Hons) MRCS(Eng) is a ST2 in Trauma and Orthopaedics at Department of Orthopaedic Surgery, Hillingdon Hospital, Uxbridge, UK.*

Francis Lam *MBBS MSc MRCS(Ed) FRCS(Orth) is Consultant in Trauma and Orthopaedics at Department of Orthopaedic Surgery, Hillingdon Hospital, Uxbridge, UK.*

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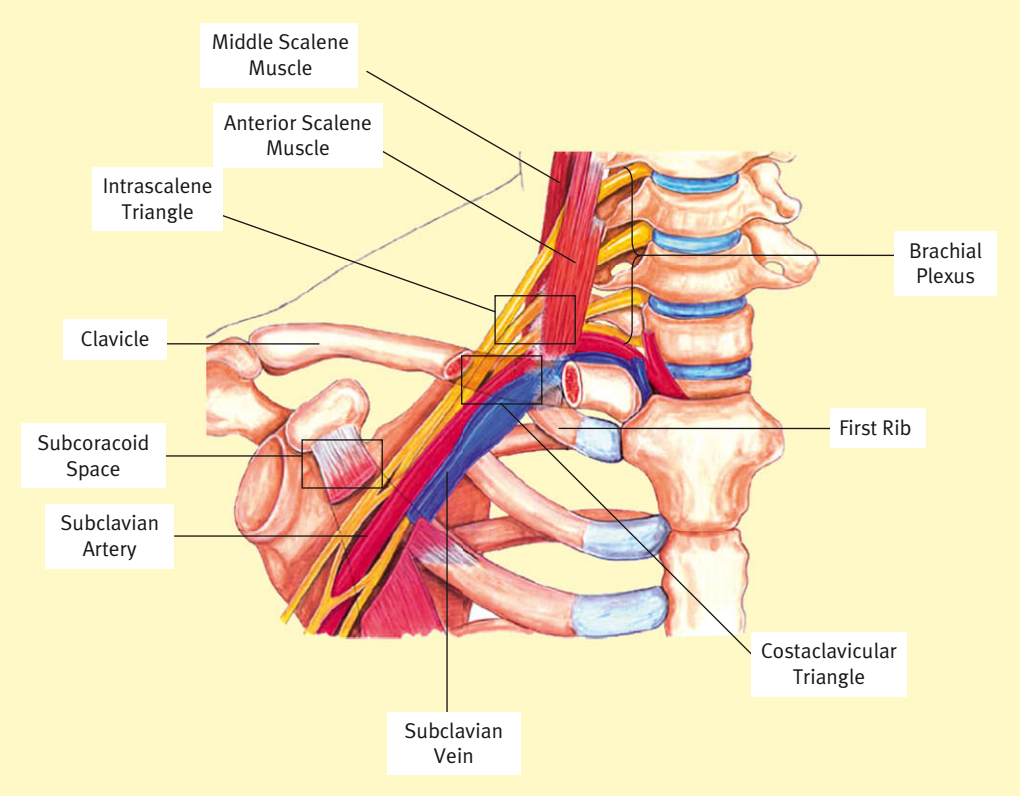

Figure 1 The thoracic outlet.

- delayed damage to blood vessels and/or, nerve fibres or both caused by the formation of a large callus or by excessive clavicular motion due to non-union.

Symptoms and signs are present both locally at the fracture site, and in the distal part of the effected limb. Local findings include tenderness, a bony deformity (e.g., large callus), a mass beneath the damaged portion of the clavicle (e.g., haematoma), or bruit (e.g., pseudo aneurysm).

'Disputed' TOS

This is a disorder with a number of names, including 'non-specific', 'symptomatic' and 'assumed'. It first came to notice in the late 1960's after the publication of the description of a procedure (trans-axillary 1st rib resection) designed to treat it.[2] It is a rare bilateral disorder, which affects predominantly adult females. The most common causes are either acute trauma (e.g. whiplash injury) or repetitive use trauma (common in manual factory or office workers). The exact mechanism of injury is still unclear, although it is thought to be secondary to compression of neurovascular structures between the normal 1st rib and congenital bands damaged at either the time of injury or fibrosis of the scalene muscles due to postural abnormalities caused by imbalance of muscle actions.

Diagnosis

Symptomatic overlap with other conditions makes it very difficult to confidently diagnose TOS. A variety of provocation tests which reproduce TOS symptoms have been devised to aid diagnosis, and tailor investigation and subsequent management. They also help the clinician to confidently exclude other pathologies which can produce similar symptoms.

Adson's test

The patient's radial pulse is palpated (Figure 2a), then the arm is externally rotated, extended and slightly abducted. The patient is asked to look towards the side being examined and to take a deep breath in (Figure 2b). Abolition or a reduction in the radial pulse is a positive test.

Figure 2 a Adson's Test.

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Figure 2 b Adson's Test.

Figure 4 Military Brace Test.

Wright's test (the hyper-abduction test)
The patient's arm is abducted to 90 degrees in external rotation whilst palpating the radial pulse. Again abolition of the pulse suggests a positive test but there is a high false positive rate.

Roos' test
The patient's shoulder is abducted and the elbow flexed to 90 degrees. In this position the patient is asked to open and close their hands for three minutes (Figure 3). Inability to complete this exercise pain free or reproduction of presenting symptoms constitutes a positive result.

The Military Brace test
With both arms at the side, the patient moves the shoulder downward and backward to draw the clavicle closer to the first rib (Figure 4). Diminution or obliteration of the radial pulse constitutes a positive test.

Figure 3 Roos' Test.

Investigations

X-ray and MRI
Chest x-rays with apical lordotic views and cervical spine views are mandatory to demonstrate the presence of a cervical rib (Figure 5), an elevated 1st rib caused by tight anterior or middle scalene muscles and clavicle fractures with the associated non-union and excessive callus.

Angiography can demonstrate thromboembolic vessel blockage and aneurysms that may be compressing the plexus. The

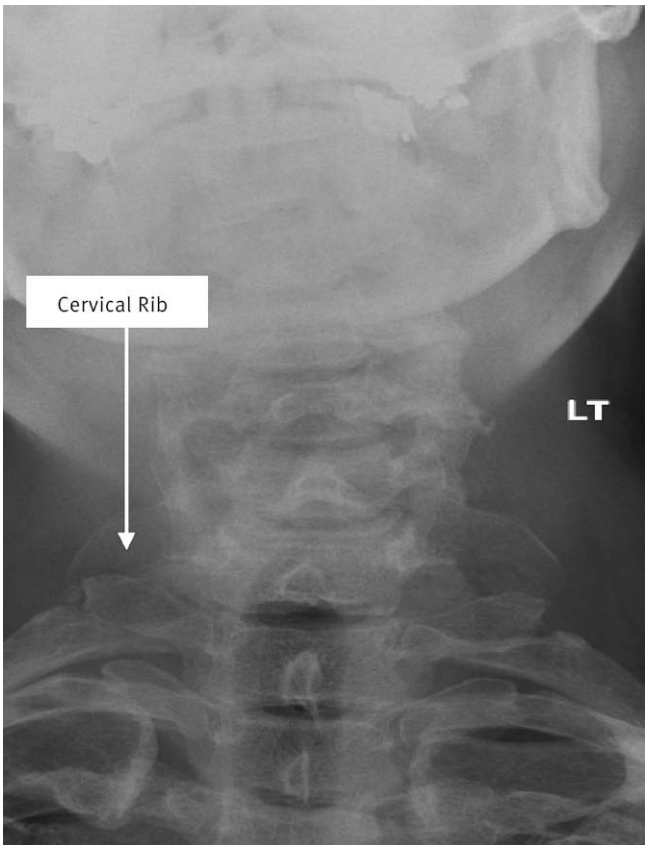

Figure 5 Cervical rib.

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latest techniques give an easy and unequivocal insight into the vascular and non-vascular (indirect) nature of the condition thus aiding clinical management decision making.[7]

Computed Tomography (CT) may show abnormal fibrous bands in the thoracic outlet [4] and, coupled with MRI, distinguish cervical root injury from degenerative spurs or herniated discs. MRI of the cervical spine and supra-clavicular or brachial plexus area is useful to exclude other pathologies.

Ultra-sound

Doppler ultra-sound studies will show impeded blood flow in vascular TOS. A near cut-off of flow during the stress manoeuvre with reproduction of symptoms would be most suggestive, but given the high prevalence of abnormal Doppler ultrasound findings in asymptomatic population, duplex may only have a limited role in the investigation of TOS.[5] Full occlusion of blood flow can occur in normal subjects but is unusual and is not related to age.[6]

Electro-physiological testing

There are clearly established diagnostic criteria for electro-diagnostic testing, particularly in true Neurologic TOS,[8] viz; altered ulnar sensory conduction (low amplitude sensory nerve action potentials) and motor median conduction (low amplitude compound muscle action potential). Routine electro-diagnostic studies can sometimes yield normal results but when there is strong clinical suspicion of a neurogenic TOS and the classical electro-diagnostic abnormalities are not found, F waves may be used at rest and in provocative positions to help support the diagnosis.[9,10]

Anterior scalene block

This can sometimes be diagnostic, but the test is difficult and not without risk (e.g. direct damage to the plexus by the needle). If positive, there is usually a good chance of successful surgical decompression.

Treatment

Management can either be non-operative or surgical depending on the underlying cause. If surgical intervention is not warranted, the use of heat, physical therapy, analgesics and muscle relaxants coupled with shoulder strengthening exercises, and modification of daily activities and sleeping habits will give relief from symptoms.[11]

Surgery should be considered in cases where symptoms persist over 3–4 months, if there is intractable pain, vascular loss or neurologic deficit. Depending on the underlying cause, a multi-disciplinary approach to management with both vascular and orthopaedic surgeons will result in a good to excellent surgical outcomes.[13]

Operative surgical approaches

Surgical decompression can be achieved by scalenectomy with or without resection of the 1st rib using either a supraclavicular or a transaxillary approach. Scalenectomy combined with 1st rib resection gives better results than 1st rib resection alone, whilst simple excision only appears to be sufficient in patients in whom symptoms are caused purely by the presence of a cervical rib.

Supraclavicular approach

The operation is performed with the patient supine and intubated under general anaesthetic, through a lazy "S" incision parallel to the clavicle and extending from the midpoint of the clavicular attachment of the sternomastoid muscle to the anterior edge of the trapezius. Platysma is identified for later careful approximation, then the external jugular vein is ligated and omohyoid divided at its mid-point. The phrenic nerve should be identified on the surface of the anterior scalene muscle as it proceeds distally and protected. Then scalenus anterior is divided from its insertion into the first rib allowing it to retract, carefully dissecting the subclavian artery and vein from its belly. Scalenus medius is then divided from its insertion into the 1st rib, thus fully exposing the 1st rib. The 1st rib is divided anteriorly first with a rib cutter and the entire posterior portion is then removed in a twisting motion ensuring there is no residual first rib left which may otherwise produce new bone and cause recurrence of symptoms.

Transaxillary approach

This approach was originally described by Roos in 1982.[16] Under general anaesthetic with a double lumen endotracheal tube in the lateral decubitus position the ipsilateral lung is collapsed. Draping the patient should be such as to permit free movement of the arm as well as access to upper hemithorax, axilla, shoulder area and neck. A transverse incision is made below the hairline between the pectoralis major muscle anteriorly and the latissimus dorsi muscle posteriorly. The underlying fascia is incised longitudinally and the tissues are bluntly dissected digitally. The incision is then deepened directly towards the chest wall without angling up towards the 1st rib. When the chest wall is reached the dissection is carried superiorly to the 1st rib. Blunt dissection by touch is continued until the face of the 1st rib can be palpated. Then the dissection is continued subperiosteally along the 1st rib until scalenus anterior is identified. This is then divided near its insertion on the 1st rib and the subperiosteal dissection of the rib continued to separate it from the pleura. A triangular piece of the 1st rib is excised from the avascular area allowing the anterior part of the rib to be removed by dividing the costo-clavicular ligament. Then the posterior part is dissected subperiosteally to the transverse process at which point it is divided and excised.

Vascular surgery

In cases of venous TOS, subclavian venous thrombectomy can usually be carried out through the supraclavicular approach. In arterial TOS, subclavian endarterectomy can be possible in those patients whose only arterial lesion is occlusion of the subclavian artery secondary to compression.[4] If required, arterial reconstruction is best achieved with vein grafts rather than synthetic grafts as low flow through the prosthesis into the high resistance areas distally arising from previous embolisation may predispose to early failure.[15]

Surgery for recurrence

Complete scalenectomy in redo procedures can offer an improved outcome,[12] i.e. scalenus anterior should be removed and not simply sectioned. If part of the brachial plexus penetrates the scalenus medius muscle as an anatomical variant, then the muscle should also be resected, as well as any fibrous bands that may lie behind these muscles.

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Whilst the cause of recurrence remains controversial, it is thought to be due to adhesions of scar tissue to the vessels and nerves in the axilla. As a result, surgical intervention should be carefully planned and performed by surgeons experienced in this area. In recurrent cases, where scalenectomy alone was performed primarily, the 1st rib is better resected via the trans-axillary approach. This is thought to improve symptoms in almost 80%.[14]

Complications of surgery

Pneumothorax is common, occurring in up to 30% of cases, arising during resection of the 1st rib due to the proximity to the apical pleura.

Vascular damage, particularly to the subclavian artery, where it passes posterior to the scalenus anterior muscle is at risk.

Neurological damage can occur to the long thoracic nerve (which will cause scapular winging) to the intercosto-brachial nerve (causing paraesthesia along the posterior aspect of the arm and the lower trunk of the brachial plexus is at risk when the rib is divided posteriorly.

Conclusion

The prognosis is generally good with most patients obtaining relief of paresthesiae and numbness and return of strength or activity tolerance. However recurrence is common and to prevent it accurate clinical evaluation, careful preoperative planning and meticulous dissection are essential.

Surgery comprising anterior and middle scalenectomy combined with 1st rib resection should be considered in all chronically symptomatic patients, but should be undertaken by surgeons experienced and comfortable with the anatomy and management of potential complications and best by a combined team approach. ◆

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