Thoracic outlet syndrome: Fact or fancy?
A review of 409 consecutive patients who underwent operation

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Objectives: From an analysis of patients operated on by a single surgeon between 1973 and 1994 for thoracic outlet syndrome (TOS), to determine what findings are helpful in substantiating this diagnosis and what are the results of decompressive thoracic outlet surgery in the management of TOS.

Design: A chart review with emphasis on signs, symptoms and results. A preoperative questionnaire was presented to all patients operated on since 1989. Postoperative follow-up was by interview or telephone.

Setting: A 560-bed university-affiliated tertiary-care teaching hospital.

Patients: There were 409 adults; 83% were women and the average age was 36 years. In 95% of patients physiotherapy had been unsuccessful. Patients presented with neurologic type (368 [90%]), arterial impingement (29 [7%]) and venous obstructive symptoms (12 [3%]). The series included 44 patients with bilateral symptoms and 26 patients with cervical ribs. Some form of litigation or compensation was associated with 177 patients.

Interventions: Transaxillary first rib resection in 380 (93%) patients and supraclavicular thoracic outlet decompression in 29 (7%). In 244 patients there was a follow-up of at least 2 years. These patients constituted the follow-up group.

Results: Preoperatively, in the 368 patients who had neurologic TOS, 99% displayed supraclavicular brachial plexus tenderness and 98% exacerbation of symptoms with arms in the abduction external rotated position. There were eight complications of surgical intervention (1.9%). In the follow-up group, there were no deaths, no subclavian/axillary artery or vein damage and no brachial plexus injury. Seventy-eight percent of the patients with neurologic TOS in this group improved postoperatively; 21% had complete relief, 32% had good relief and 25% had fair relief. Twenty-two percent showed no improvement.

Conclusions: Signs and symptoms helpful in making the diagnosis of neurologic TOS are supraclavicular tenderness on palpation and exacerbation of symptoms with the arms in the abducted external rotated position. The surgical procedures are safe. Patients with TOS refractory to medical management can benefit from thoracic outlet decompression.

Objectifs : À partir d'une analyse de patients qui ont été opérés par un même chirurgien entre 1973 et 1994 pour un syndrome du défilé thoracobrachial (SDT), déterminer les constatations qui aident à appuyer ce diagnostic et les résultats d'une décompression chirurgicale du défilé thoracobrachial pour traiter le syndrome.

Conception : Étude de dossiers portant surtout sur les signes, les symptômes et les résultats. Avant l'intervention, on a soumis un questionnaire à tous les patients qui ont été opérés depuis 1989. Le suivi postopératoire a été effectué en personne ou par téléphone.

Contexte : Hôpital d’enseignement de soins tertiaires de 560 lits affilié à une université.

Patients : Il y a eu 409 adultes : 83 % étaient des femmes et l’âge moyen était de 36 ans. Chez 95 % des patients, la physiothérapie avait échoué. Les patients qui se sont présentés avaient des problèmes de type neurologique (368 [90 %]), des symptômes de pincement artériel (29 [7 %]) et de blocage veineux...
Thoracic outlet syndrome (TOS) is a term used to describe patients with upper extremity, shoulder, neck, facial and head pain caused by impingement or entrapment of brachial plexus, subclavian artery or vein, in the thoracic outlet. The diagnosis of TOS is elusive, confusing and poorly understood by many physicians to whom the term conjures up vague thoughts of complicated neck anatomy, various poorly understood pinch mechanisms in the shoulder and neck and distrust of patients who complain of postinjury whiplash symptoms or job-related shoulder fatigue. Such an attitude can make the patient confused and desperate when no direct management or therapeutic direction seems to be given. Many patients have neurotic-type symptoms. Enhancing the physician’s distrust of the diagnosis are published reports stating that this syndrome is extremely rare and that radiographic or electrophysiologic abnormalities should be demonstrable before surgery is carried out. Other reports emphasize significant, serious complications of the surgery.

Treatment of TOS was first described by Coote, in 1863, who removed an “extosis of the cervical rib.” In the ensuing years, bony abnormalities, such as cervical rib, callus of the clavicle or first rib or first-rib abnormalities were recognized and the parts removed, and in 1927, in a classic paper by Adson and Coffey, the scalenus anticus muscle was sectioned for a patient with neurologic TOS symptoms. Following this description, there was a wave of unwarranted enthusiasm for this operation. The results were unacceptably poor, probably because of poor patient selection.

In 1962, Clagett introduced first rib resection for TOS and in 1966, Roos emphasized accurate diagnosis and the transaxillary approach to first-rib removal. Following this, clinical and research endeavours by Roos, Sanders and colleagues, and Makoul and Machleder have established in the minds of many a firm belief in the existence of TOS.

At present, there seems to be no controversy surrounding surgery to correct bony abnormalities causing TOS or surrounding the diagnosis and operation for patients having arterial and venous impingement. The concern arises when patients are operated on without objective radiologic evidence or positive findings on electrodagnostic studies. Physicians concerned with this group of patients have coined the term “disputed neurologic TOS.” Currently, proponents of surgery for TOS indicate that with accurate patient selection and adequate decompressive surgery there is a possible 70% to 80% overall improvement rate.

In this paper we reviewed 409 consecutive patients operated on for TOS, with emphasis on signs, symptoms and outcome and we present an overall practical and clinical approach to the problem. Discussion will also include the relationship of this syndrome to litigation, compensation and other psychologically significant problems that influence and confuse the overall management of this rather rare, poorly understood chronic pain syndrome.

Patients and methods

The series comprised 409 consecutive patients (339 women, 70 men) operated on by one surgeon over 21 years (1973 to 1994).

All patients had undergone extensive history-taking and physical examination and those seen in the last 5 years of the study had completed a preoperative questionnaire. Cervical spine x-ray films, thoracic outlet views, and chest x-ray films were obtained routinely to rule out cervical vertebral problems, thoracic bony abnormalities and Pancost-like upper lung disease.
Since electrophysiological studies (i.e., electromyography, studies of nerve conduction and somatosensory evoked potentials) as well as computed tomography and magnetic resonance imaging of the neck are neither specific nor sensitive in the diagnosis of the TOS, they were not performed routinely except to investigate the possibility of nerve entrapment at the elbow or wrist.\(^\text{15}\)

No patients were operated on earlier than 6 months after the onset of symptoms because it was felt that this period of conservative management aided in ruling out other minor, time corrected conditions. Ninety-five percent of the patients had preoperative physiotherapy and none of the patients operated on were improving with physiotherapy.

Of the 409 patients, 244 had a follow-up of at least 2 years, and they constituted our follow-up group. The follow-up study was done by a clinical trial nurse by telephone or direct interview asking standardized questions in an attempt to reduce potential bias.

Postoperative results were classified using the following measurement scale: 0 — poor, no improvement in symptoms and signs; 1 — fair, relief of some symptoms but with major symptoms remaining; 2 — good, with relief of the majority of symptoms; 3 — excellent, with complete relief of symptoms.

A correct diagnosis is the basis of ensuing surgical results. Signs and symptoms depend on whether the axillosubclavian artery and vein or the brachial plexus is involved in the compression in the thoracic outlet.

**Diagnosis of arterial TOS**

Arm blood pressure and palpation of the radial pulse may be decreased on the affected side in varying positions, especially in the abducted external rotated (AER) position. Rarely, finger-tip gangrene results from emboli to the digital vessels and is the presenting complaint. The diagnosis of arterial TOS can often be confirmed by upper extremity angiography with the arm in the AER position and with the patient in a semi-sitting position.

**Diagnosis of venous TOS**

Swelling and cyanosis of the arm on exertion is the classic finding. This occurs in athletes, labourers who work with elevated arms and in sedentary workers doing multiple repetitive motions. Classically, the patient experiences discomfort when the arm is swollen. This is often relieved by placing the arm in a relaxed position. The diagnosis is verified by an upper extremity venography with the arm in the AER position, which shows impingement of the subclavian vein at the level of the first rib.

**Diagnosis of neurologic TOS**

Pain, paresthesia (tingling, burning, pricking) and dysesthesia (impairment of sensation, up to anesthesia) in the head, face, neck, shoulder, arm or hand are the rule. If the classic symptoms are present in the ulnar or median nerve distribution, nerve conduction studies are done to delineate the diagnosis of peripheral nerve entrapment.

There are four physical findings that help in the diagnosis of neurologic TOS:

- Tenderness to palpation in the supraclavicular fossa over the brachial plexus and the scalenus anticus muscle is a common, repeatable, easily elicited finding.
- Accentuation of the arm symptoms, when the arm is in the AER position.
- Point tenderness (i.e., trigger points over the ipsilateral trapezius muscle) is an easily repeatable positive finding.
- Pain over the ipsilateral brachial plexus when the head is tilted to the opposite side.

Muscle atrophy and weakness of the hand and arm are rare and usually present with obvious chronic, severe problems of fixed neck impingement. An additional rare physical finding is unilateral Raynaud’s-like symptoms of the involved side.

**FINDINGS**

The average age of the 409 patients was 36 years (range from 17 to 73 years). The average duration of symptoms before surgery was 2.95 years (Fig. 1). Etiologic factors were major upper extremity trauma 37%, whiplash 11% and repetitive arm motion at work 43%. The average time off work before surgery was 1.6 years (range 0 to 5 years). Litigation and compensation were involved with 43% of the cases.

Symptoms present in all patients with neurologic TOS were pain, paresthesia and dysesthesia in the involved head, neck, shoulder and arm. Headaches were present in 47%, face and ear pain in 14.6%, neck pain in 70%, arm and shoulder pain in 54%, and forearm and hand pain in 65%.

Signs present in neurologic TOS were supraclavicular brachial plexus tenderness (99%), pain accentuated with the arm in the AER position (98%), point tenderness on the ipsilateral trapezius muscle (63%) and neck and shoulder pain on tilting the head to the contralateral side (60%).

All patients with arterial TOS had a history of ischemia with the arm in various positions and diminution of pulse in the AER position with con-
comitant hand ischemia.

All patients with venous TOS had a history of arm swelling and cyanosis with exertion.

Of the 409 patients operated on, 368 (90%) had neurologic TOS, 29 (7%) the arterial variant and 12 (3%) the venous variant. Cervical rib excision was carried out in 26 cases and first rib resection in 383 cases.

The mean follow-up in the 244 patients who constituted the follow-up group was 3.4 years. The results in the follow-up group for the three types of TOS are shown in Table I. A 4-year follow-up was done in 66 patients, with the following results: excellent in 20 (30%), good in 28 (42%), fair in 12 (18%) and poor in 6 (9%).

Thirty patients had bilateral surgery (60 arms) and were followed up over 2 years with the following results: excellent — 27%, good — 53%, fair — 7%, poor — 13%.

Headache, both ipsilateral and occipital was present in 307 (75%) of the 409 patients; 230 of these (76%) had significant relief following thoracic decompressive surgery. In the 409 cases there were eight significant complications, none of which led to death, a rate of 1.95%. There was one major hemorrhage requiring one unit of blood, one major wound infection requiring re-exploration and packing, two removals of the second rib requiring secondary surgery for removal of the first rib, three pneumothoraces requiring placement of a chest tube and one prolonged radial nerve paresis. There was no brachial plexus, subclavian artery or vein damage in the series.

Discussion

The diagnosis and management of patients with TOS are extremely controversial. Opinions on the syndrome vary from scepticism with respect to the diagnosis to complete belief, resulting in series describing hundreds of patients operated on. The divided opinion is generated because many patients in whom the diagnosis is neurologic TOS have no objective findings to substantiate the diagnosis. Patients with bony abnormalities such as cervical rib, malunion of the first rib or clavicle or demonstrable first-rib exostosis and patients with either arterial pinch or venous impingement are accepted as true cases of TOS.

The remaining large group (80% to 90%) of cases have no radiologic or electrophysical demonstration of nerve irritation. This group has been labelled “disputed TOS, neurological type.” Recently, the term nonspecific neurologic TOS has been suggested.

This series has analysed closely signs and symptoms that are present in the neurologic, arterial and venous variants of TOS, with special emphasis on cases in which there are no objective radiologic or laboratory findings.

The diagnosis of patients with arterial entrapment is straightforward. They have ischemic forearm and hand symptoms during activity, especially with the arm in the AER position. There is obliteration of the pulse when the arm is raised and back, associated with symptoms. Arterial impingement can be demonstrated by upper extremity angiography with the patient in a semi-sitting position and the arm in the AER position. Patients with venous obstructive TOS have engorged cyanotic edematous arms dur-

Table I

Results in the Follow-up Group of Patients (244) After Operative Treatment for Three Types of Thoracic Outlet Syndrome (TOS)

<table>
<thead>
<tr>
<th>Type of TOS</th>
<th>No. of patients</th>
<th>Excellent</th>
<th>Good</th>
<th>Fair</th>
<th>Poor</th>
</tr>
</thead>
<tbody>
<tr>
<td>Neurologic</td>
<td>228</td>
<td>47 (21)</td>
<td>72 (32)</td>
<td>58 (25)</td>
<td>51 (22)</td>
</tr>
<tr>
<td>Arterial</td>
<td>12</td>
<td>4 (33)</td>
<td>5 (42)</td>
<td>2 (17)</td>
<td>1 (8)</td>
</tr>
<tr>
<td>Venous</td>
<td>4</td>
<td>1 (25)</td>
<td>3 (75)</td>
<td>0</td>
<td>0</td>
</tr>
</tbody>
</table>

FIG. 1. Duration of symptoms before surgery in 409 patients with TOS.
ing activities such as swimming, other athletics and repetitive motions in the workplace. Diagnosis is substantiated by venography showing venous impingement at the first rib.19

A significant, repeatable, sign in patients with neurologic TOS is tenderness over the brachial plexus and scalenus anticus muscle in the supraclavicular position.20 This sign was present in 99% of our cases. Such a finding was extremely significant in our series, and we believe that the diagnosis of neurologic TOS should be questioned if this finding is absent. Exacerbation of symptoms with the arm in the AER position was present in 98% of the cases. These two easily elicited physical findings should alert the physician to the possibility of neurologic TOS.8

Two other physical findings are point tenderness (i.e., trigger points over the ipsilateral trapezius muscle). This is a definite finding when present, is repeatable and was present in 63% of patients in this series. On examination of the cervical vertebrae, patients with TOS have pain in the ipsilateral brachial plexus on tilting the head to the opposite side; no other head position (e.g., chin on chest, neck extension, rotary moves or tilting the head toward the involved side) is positive in cases of TOS. This finding was present in 60% of neurologic TOS patients in this series.

Before the diagnosis of neurologic TOS is made, a careful examination of cervical vertebrae, chest, shoulder, elbow and wrist joint will help differentiate TOS patients from those with arthritis of cervical vertebrae and disc problems, Pancoast-like lung problems and intrinsic shoulder, elbow and wrist disorders.

Nerve entrapment at the elbow in the cubital tunnel and at the wrist in the carpal tunnel and Guyens canal are readily diagnosed because these are single peripheral nerve entrapments and the diagnosis can be substantiated with appropriate nerve conduction studies. Patients can exhibit both brachial plexus and peripheral nerve impairments21 — the double crush nerve compression. Proximal pain in the carpal tunnel syndrome can be significant and confusing.

These four physical findings, in the absence of cervical vertebrae disease, lung disease, clavicular, shoulder, elbow and wrist disease, form a diagnostic tetrad for neurologic TOS.

Ninety-four percent of our arterial and venous TOS cases were improved, with 81% either excellent or good.

Seventy-eight percent of neurologic TOS patients were improved, with a 53% excellent or good outcome, a gratifying result in the management of patients with a chronic pain syndrome.

Investigators realize the extreme difficulty of dealing with patients with chronic pain.1 Grading of pain in each patient is difficult; this, in association with litigation and compensation consequences and psychologically maladjusted patients, makes the outcome results questionable, probably favouring a negative result. Despite these caveats, this series overall showed pain reduction in almost 80% of the cases.

Bilateral first rib resection was done on 30 patients (60 arms). Philosophy for surgery in this group was to operate on the worst side first, to carry out no surgery on the second side for 3 months and to insist that patients themselves must request to have the second side done. These criteria were developed to give the patient a chance to evaluate original results and to take the initiative in having the second procedure done. In this group, overall results with a minimum 2-year follow-up were 80% excellent and good.

Eighteen patients followed-up over 1 year for cervical rib removal had 100% improvement with good and excellent results.22–24

There were no deaths in the series, and the rate of significant complications was 1.95%. No injury occurred to the brachial plexus, subclavian artery or subclavian vein. The surgery should be done by experienced surgeons familiar with the thoracic outlet anatomy as indeed some cases are difficult, especially in a well-muscled patient. The surgeon MUST have two assistants, one to retract the plexus and artery and vein and one to elevate the arm. Some reports indicate a high rate of nerve and vessel injury; however, in this series no injury of this type occurred.24

In this paper we have offered criteria for the diagnosis of arterial, venous and neurologic variants of TOS. If time, physiotherapy, analgesia and anti-inflammatory drugs failed to correct the condition, thoracic outlet decompression was carried out.

Wilbourn and Porter25 recently suggested a carefully planned prospective study. At present we are conducting a preoperative psychological study in collaboration with the Department of Psychology at the University of Western Ontario of all TOS patients in an attempt to determine the preoperative psychological make-up and its relationship to postoperative results.

CONCLUSIONS

Neurologic TOS can be diagnosed by a history of head, neck and upper extremity pain and a tetrad of physical findings: supraclavicular brachial plexus tenderness, accentuation of pain with the arms in the AER position, trigger point tenderness over the ipsilateral trapezius muscle and ipsilateral base-of-neck pain on tilting the head to the opposite side. From the follow-up results in which 78% of patients had symptomatic relief, with
1.95% short-term morbidity and no deaths, we conclude that decompressive thoracic outlet surgery is indicated for patients with TOS refractory to conservative measures.

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