Chapter 30
When it is Not Cervical Radiculopathy: Thoracic Outlet Syndrome—A Prospective Study on Diagnosis and Treatment

J. Paul Muizelaar, M.D., Ph.D., and Marike Zwienenberg-Lee, M.D.

Many neurosurgeons see a large number of patients with some type of discomfort in the head, neck, shoulder, arm, or hand, most of which are (presumably) cervical disc problems. When there is good agreement between the history, physical findings, and imaging (MRI in particular), the diagnosis of cervical disc disease is easily made. When this agreement is less than ideal, we usually get an electromyography (EMG), which in many cases is sufficient to confirm cervical radiculopathy or establish another diagnosis. However, when an EMG does not provide too many clues as to the cause of the discomfort, serious consideration must be given to other painful syndromes such as thoracic outlet syndrome (TOS) and some of its variants, occipital or C2 neuralgia, tumors of or affecting the brachial plexus, and orthopedic problems of the shoulder (Table 30.1). Of these, TOS is the most controversial and difficult to diagnose.

Although the neurosurgeons Adson (1–3) and Naffziger (10,11) are well represented as pioneers in the literature on TOS, this condition has received only limited attention in neurosurgical circles. In fact, no original publication in NEUROSURGERY or the Journal of Neurosurgery has addressed the issue of TOS, except for an overview article in NEUROSURGERY (12). At the time of writing of this paper, two additional articles have appeared in Neurosurgery: one general review article and another strictly surgical series comprising 33 patients with a Gilliatt-Sumner hand (7). In one of the neurosurgical handbooks, the heading of TOS in the index only refers to the chapter on EMG where the condition is mentioned as occurring in conjunction with carpal tunnel syndrome (CTS), whereas four pages are devoted to cervical rib syndrome, hyperabduction syndrome, and costoclavicular syndrome, which are all part of TOS (9). In two newer neurosurgical textbooks, together containing over 4,200 pages, one and one half and four pages, respectively, are devoted to TOS (8, 9). Nevertheless, patients with pain in the neck and discomfort in the upper extremity are seen frequently by neurosurgeons. The surgical treatment of herniated cervical discs, CTS, and tardy ulnar neuropathy—all to be considered in the differential diagnosis of TOS—is practically "daily bread" for most neurosurgeons.

The aim of the present paper is to share the personal clinical experience of a single neurosurgeon with a referral practice for TOS with other neurosurgeons. Over a 3-year period, data for this paper were prospectively gathered on all patients referred with a suspected diagnosis of TOS or in whom the author seriously considered TOS in the differential diagnosis.

CLINICAL MATERIAL

From January 1986 to December 31, 1988, 149 patients with TOS figuring prominently in the differential diagnosis were seen by a single neurosurgeon in the outpatient clinic. Features recorded prospectively were name and hospital number, age, sex, hand dominance, date when first examined, name and specialty of referring doctor, reason for referral, duration of symptoms, presenting symptoms, relation to work or accidents, patient working or not plus type of work, presenting signs at physical exam, results of neck radiographs, myelogram, MRI, venogram or arteriogram, EMG and nerve conduction studies, type of therapy instituted and results, diagnosis (TOS or other) and side, date, and findings of surgery if performed, outcome, and miscellaneous. In the case of a diagnosis of TOS, this was divided into a main diagnosis of TOS requiring some form of treatment for TOS, mild TOS just requiring reassurance, or partial TOS in which it seemed that TOS played some role but another condition, such as CTS, required treatment first. In a separate study, extensive somatosensory evoked potentials (SSEPs) were obtained in a group of 14 patients with obvious TOS. A total of 149 patients are considered here (92 women and 57 men, aged 16–65 years; mean, 35.6 ± 9.8 years).

The diagnoses of TOS, mild or partial TOS, and no TOS were evenly distributed in both women and men, and the ages of the groups were 34.5 ± 8.3 years with TOS, 34.5 ± 8.6 years with mild or partial TOS, and 40.1 ± 13.4 years with no TOS. Of the 149 patients, 116 were referred for TOS, and these patients were automatically included in the study, even if it seemed quite obvious that another diagnosis should be considered. The remaining 33 patients were referred with a different diagnosis or were self-referred without diagnosis. The inclusion of patients into this group is admittedly subjective, and in the referred-for-TOS group, a final, main diagnosis of TOS was made more often (72%) than in the nonreferred group (48%; Table 30.2).

Table 30.3 indicates the other diagnoses that were made, either with or without TOS. In the 30 patients without TOS, some had more than one diagnosis, bringing the total to 36. In the largest number of patients without TOS (33%), no diagnosis could be made at all. The most frequent other diagnoses were herniated cervical discs (20%) and CTS (16%). In the category "Other" in patients without TOS, there was one patient each with atherosclerosis of the subclavian artery, brachial plexus neuritis, and polyneuropathy with chemotherapy for cancer. In the patients with TOS, the combination with CTS was frequent, as it was in those whose primary diagnosis was TOS. In Table 30.3, in the category "Other" in patients with TOS, there was one each with limb-girdle dystrophy, long thoracic nerve injury, and nerve injury by electrocution. Although there was an impression of psychological factors playing a major role in many cases, only a small number of patients were formally tested after being sent to a pain clinic. Thus, psychological factors could not be tabulated.

Table30. 4 indicates the specialty of the physician who referred the patient for TOS, the number of patients referred per specialty, and the number of patients in whom this diagnosis was rejected. Two patients were referred by a sibling who was treated earlier by the author for TOS.

Table 30.5 indicates the presenting symptoms. Many patients had more than one symptom, making the total number of symptoms larger than the number of patients. Other symptoms included muscle atrophy, swelling in the supraclavicular fossa, abnormal posture, tendency to faint with certain movements, and no symptoms but with the patient referred for first rib resection before scapulothoracic fixation for scapulohumeral dystrophy or long thoracic nerve injury. Quite obviously, numbness and clumsiness of the hand is the leading presenting symptom of TOS, but pain in the occiput-neck-shoulder area is an important symptom, too. The distribution of symptoms over the three diagnosis categories was even, and there is no symptom that makes TOS either very likely or very unlikely.

Table 30.6 indicates how many patients were left-handed and on which side (dominant, nondominant, or bilateral) the symptoms occurred. Both in the group with TOS and that with mild or partial TOS, a high percentage of patients was left-handed. Of the left-handed patients, eight (50%) had their symptoms on the dominant side, four (25%) on the nondominant side, and four (25%) bilaterally, which is similar to the distribution in the right-handed patients. Apart from left-handedness, no difference could be detected among the three groups with respect to the side of the symptoms.

Table30.7 lists the alleged causes for the symptoms. If the patient did not spontaneously give this information, it was specifically asked for. It should be noted that the relationship between cause and symptoms is only the patient's assessments, without the author's interpretation. However, if a fall or some other incident occurred at the workplace, this was not listed under "Work" but under a more appropriate heading. "Work" usually involved repetitive arm and hand motions, often with heavy equipment such as for welding or grinding in the construction industry; it also often included a large amount of overhead work. Motor vehicle collisions were specified as being rear-ended in most cases. Other causes included electrocution, assault, being struck in the neck by a falling object, and intensive sport activities. If the patient did not ascribe the symptoms to any specific activity or incident, the cause was listed as "None." Of the 44 patients who ascribed their symptoms to their work activities, 15 (34%) were working normally, 19 (43%) were working with restrictions or light duty, and 10 (23%) were not working. For the 56 patients whose symptoms were not related to work, these figures were 39 (70%), 6 (11 %), and 11 (20%), respectively, with most of the 11 nonworking patients being homemakers.

Table 30.8 indicates the positive findings at physical examination in the three groups. The most common finding indicating TOS was the occurrence or aggravation of the presenting symptoms with the provocation tests. Although disappearance of the radial pulse was found almost exclusively in the patients with TOS, it occurred too infrequently (<10%) to be of much value in making a diagnosis. The most specific finding was hypalgesia or hyperesthesia in the distribution of the median cord or, in some cases with a cervical rib, in the distribution of the posterior cord of the brachial plexus; this was never found in patients without a diagnosis of TOS. There was no finding arguing strongly against TOS, although diminished tendon reflexes were three times more likely in patients without TOS than in those with TOS.

Table 30.9 summarizes radiographic findings. All patients had neck radiographs. Ten patients had cervical ribs. All patients with a unilateral cervical rib or large transverse process C7 had this on their symptomatic side. Not all patients with neck findings bilaterally had symptoms on both sides. It is of note that all unilateral cervical ribs were on the left side, whereas all unilateral large transverse processes C7 were on the right. Degenerative disc disease and an abnormal myelogram or MRI scan were much more common in patients without TOS. The three TOS patients with an abnormal myelogram or MRI scan all had undergone cervical spine operations earlier at another institution. Four of five patients without TOS but abnormal myelogram or MRI scan underwent anterior discectomy with or without fusion, all with good results. The senior author (J.P.M.) does not use arteriogram or venograms, but four patients had undergone these procedures elsewhere (Table 30.9). The only patient in whom an arteriogram was requested was found to have an atherosclerotic occlusion of the subclavian artery, as suspected.

Findings of the EMGs (and nerve conduction studies) are shown in Table 30.10. Seventy-seven patients (52%) underwent EMG testing, but some patients had more than one EMG abnormality, bringing the number of findings in Table 30.10 to 84. In most of the patients with TOS, EMG was normal. EMG findings of CTS or ulnar neuropathy were rather common in TOS patients, indicative of so-called "double crush injury." In the category "Other" in patients with TOS, one man with a cervical rib had signs of denervation in the triceps muscle along with ulnar neuropathy, one woman with a cervical rib had isolated denervation in the triceps muscle, and one man whose symptoms started after a fall from a high scaffold had signs of a long thoracic nerve injury along with mild CTS; all three patients underwent rib resection with good results, with the patient with the long thoracic nerve injury partly in anticipation of scapulothoracic fixation. In patients without TOS, EMG was more often abnormal. Only in these patients was either a monoradiculopathy or polyneuropathy found. However, in general, EMG is not very sensitive or specific in the diagnostic workup of patients with possible TOS.

Extensive SSEP studies were obtained in a subset of 14 patients with obvious TOS. Three of those had a cervical rib, and one had a large transverse process C7. Details of the procedure will be described in a separate publication, but in brief, these patients were sedated with 10–20 mg of intravenous diazepam, the radial, median, and ulnar nerves were stimulated bilaterally with needle electrodes in the forearm close to the wrist, and recordings were obtained from Erb's point, the neck, and the scalp. Recordings were made first with the arm and neck in a neutral position and then repeated in a position best reproducing the symptoms. Abnormalities were discovered in only two patients. In one, with a cervical rib, no recordings could be obtained with stimulation of the radial nerve, although clinically and by EMG criteria, this nerve was functioning normally. In another patient with bilateral TOS, left more than right, who had undergone six cervical myelograms, one posterior cervical discectomy and two anterior cervical fusion operations, the N13-P13 waves were absent with stimulation of the left ulnar nerve, indicative of a lesion at the level of the brachial plexus. Both patients underwent rib resection with good results, and their SSEPs returned to normal after surgery. Another six patients, who had normal SSEPs before surgery, also underwent postoperative studies, 6 to 12 weeks later, which again were normal.

Fifty patients underwent resection of the first rib or cervical plus first ribs. Nine of them were operated bilaterally, five in separate procedures and four in one anesthesia. Results correlated with operative findings are shown in Table 30.11. Fair outcome means either that the patient returned to his or her old job but is still using some narcotic drug (usually acetaminophen with codeine, such as Tylenol #3) or does not use narcotic drugs but did not return to the old job. In the case of bilateral operations, results are noted for each side separately. The one fair outcome in a patient with cervical ribs was because of persistent exertional numbness on one side, forcing her to change jobs, although this patient was able to work full time and did not use any medication.

All patients were operated through a supraclavicular approach (6). A 1- to 2-inch incision is made in a skin crease one fingerbreadth above the clavicle, with the external jugular vein as the lateral landmark. Usually one can work between the heads of the sternocleidomastoid muscle, without needing to divide the omohyoid muscle. Working straight through the fat and under the sternocleidomastoid muscle, the anterior scalene muscle or the brachial plexus or both are easily identified. Next, the phrenic nerve running from lateral to medial on top of the anterior scalene muscle is identified and stimulated with the bipolar forceps for noticeable diaphragm contraction; this nerve is then completely freed from the muscle. Next, the posterior and median cords are dissected of the anterior scalene muscle, and a large right-angled forceps is passed under the muscle, which is then completely divided with the electric knife. Now the subclavian artery and its branches and the pleura can be identified, as well as any abnormal fibrous bands running from C7, or the first rib itself, to the first rib. With blunt finger dissection, the pleura are stripped off from the underside of the rib, and then the complete rib is removed piecemeal with a Raney punch. Special attention is paid to the T1 nerve root, which joins the median cord from under the rib, while removing the most proximal part of the rib. Usually, no drain is left. The platysma and subcutis are closed with Vicryl and the skin with a running nylon subcuticular stitch. The patient is able to leave the hospital 1 to 4 days after surgery.

DISCUSSION

Many papers on TOS are either review articles not describing personal series of patients or are accounts on the surgical management and outcome. Therefore, the present paper is different. It includes patients in whom a diagnosis of TOS was considered but rejected and most of the patients with TOS were managed conservatively. Inclusion of patients in whom TOS was only part of the problem or in whom TOS was rejected allows a closer look at the differential diagnosis. If TOS was rejected, no specific diagnosis could be made in most of those patients (33%). However, in the majority of this group, a neurological diagnosis was made: cervical disc herniation in six, CTS in five, sympathetic dystrophy in three, degenerative disc disease in three, tension headache in two, and ulnar neuropathy in one patient. In the patients with partial TOS, concurrent neurological diagnoses included CTS in three, sympathetic dystrophy in one, degenerative disc disease in one, tension headache in four, and ulnar neuropathy in one. In only eight patients (16%) of both groups was a non-neurological diagnosis made.

Most patients in the present series were referred by workman's compensation physicians, and agreement with regard to the diagnosis of TOS was established in 72% of cases. This percentage was much smaller in the patients referred by neurologists (Table 30.4),, but many of these patients came only to have TOS considered in the differential diagnosis and not for surgical treatment. Furthermore, in four of seven patients, no diagnosis could be made at all. Neurosurgical referrals were mostly made for a second opinion (21 cases). In 17 patients (81%), the diagnosis of TOS was made. Moreover, among the patients specifically sent by other specialists for the operative treatment of TOS, the diagnosis had to be altered to herniated cervical disc in three, CTS in one, and sympathetic dystrophy in two, all of which who were to be operated on by neurosurgeons. Thus, it would seem that neurosurgeons are eminently suited to make or reject the diagnosis of TOS. The small percentage of patients with a diagnosis other than TOS who were referred by thoracic surgeons is somewhat misleading; most of these patients were sent for rib resections and had been seen already by other neurosurgeons, neurologists, or orthopedic surgeons during or before the thoracic surgeon's workup. However, agreement with the diagnosis of TOS made by orthopedic surgeons is remarkable. All four patients referred by vascular surgeons had a cervical rib, which renders establishing the right diagnosis easier.

Classically, TOS presents with supraclavicular pain and pain, numbness, and paresthesias in the arm and hand. However, Roos (13) has pointed to the fact that the pain and discomfort often spread to the side or back of the neck and the occipital and mastoid regions of the skull and can even be located exclusively in those areas. Such was also the case in the patients presented here. Headache was the major complaint in only 6% of the patients with TOS, but neck pain, often to the occiput, was spontaneously mentioned by over 60% of patients with TOS. Thus, although neck pain was somewhat more common in the patients without TOS, it is an important feature of true TOS. Disturbed sleep was also common. In most cases with TOS, this consisted of waking up one to three times each night with discomfort in the hand, arm, shoulder, or neck after sleeping prone with the arm overhead. Some patients had been sleeping with a night restraint for their arm, but by most this was experienced as uncomfortable, too. Of course, disturbed sleep is also an important feature of CTS, but with CTS, this is not so much positional, and the discomfort can usually be relieved by shaking the hand, which is not the case with TOS. However, it should be kept in mind that CTS and TOS often are present together. It has been described that cervical ribs are more common on the left than on the right side (15), and indeed, in all four patients in the series with an unilateral extra rib, this was located on the left. However, all unilateral large C7-transverse processes were located on the right. There is no explanation for these findings, but they argue somewhat against the theory that a large transverse process is an aborted anlage for a cervical rib (17).

Alternatively, it could be that for some unknown reason, on the left side, an anlage will develop more readily into a true cervical rib. It was not tested whether this was statistically significant because it is of no clinical value, but it would be interesting to see whether this can be confirmed in other series. Although the dominant side was affected more often than the nondominant side, this was also the case in patients without TOS and thus cannot be used to support a diagnosis.

Many patients with TOS ascribed their symptoms to their work, but patients without TOS also did so. The question whether work is really causing the symptoms is rather difficult to answer. Supposedly, the anatomical variations predisposing to TOS are already in place, but the actual symptoms are brought about or aggravated by work. A number of patients reported that the pain or other symptoms were much less after weekends or during vacation, whereas the response to work restrictions or change of jobs was also often favorable; thus, only 34% of patients with work-related TOS were working normally, compared with 70% for patients with non–work-related TOS. According to Roos (13), motor vehicle collisions or other incidents set off a chain of events, starting with spasm of the paravertebral cervical muscles, in particular the scalene muscles, and ending in self-perpetuating TOS. This also seemed to be the case in the present patient population. The legal implication of this is that it is the incident and not some anatomical variation that sets off the symptoms. When trying to discern between TOS and other conditions on the basis of physical examination, two features stand out.

From the five provocation tests, usually only one or two were negative in patients with TOS, whereas only a single of these tests would provoke or aggravate the symptoms in patients without TOS. Second, abnormalities at sensory testing in the distribution of the median or posterior cord occurred in 37% of TOS patients and 0% of non-TOS patients, making this finding highly specific, albeit not very sensitive. The only other moderately specific finding was tenderness over Erb's point with radiation to the shoulder or forearm, occurring in 57% of TOS patients and 27% of non-TOS patients. As can be seen in Table 30.8, the radial pulse hardly ever disappeared with provocation, which again confirms that TOS is a neurogenic rather than a vascular condition. It has been noted that weakness and wasting of the abductor pollicis brevis and opponens pollicis muscles is typical for TOS (7, 14, 18), but this pattern was never seen in the present series of patients, and, in fact, any muscle weakness was very uncommon.

The radiologic findings concerning cervical ribs and large transverse processes have already been previously discussed. Although these abnormalities were found only in patients with TOS, it is also likely that establishing that diagnosis was influenced by such abnormalities, introducing some bias. All the other radiographic findings were not specific or sensitive enough to support or reject a diagnosis of TOS. Arteriograms and venograms are, in the author's opinion, not helpful. Thus, although every patient should have radiographs of the neck, and those in whom a herniated disc cannot be excluded clinically should also have a cervical MRI or myelogram, diagnostic radiology does not play a large role in this condition.

Not all patients in this series had electrophysiological studies. The author has had a tendency to request these studies only in patients without an obvious diagnosis, but a number of patients had these studies already. In the so-called true neurogenic type of TOS, nerve conduction studies and EMG show typical abnormalities (14, 18), but these were not seen in the present series. Prolonged distal motor latency, however, is not part of these typical abnormalities, and this variable was used to establish a diagnosis of CTS or ulnar neuropathy, which were rather common in combination with TOS. Ulnar motor conduction velocity across the thoracic outlet was never studied in these patients, so no comments can be made about its usefulness (4, 16). As previously mentioned, extensive SSEP studies were obtained in a subset of patients with the most obvious TOS. The findings will be discussed more extensively in a separate paper, but the conclusion must be drawn that SSEPs are also not helpful in making the diagnosis of TOS, which is in contrast with the sparse literature on this subject (5, 18, 19).

The conclusion is that the diagnosis of TOS must be made by taking a careful history, combined with some rather "soft" physical findings, and by excluding other causes for the symptoms these patients present with. A decision tree for establishing the diagnosis of TOS is outlined in Figure 30.1. Although the present management of TOS may well have resulted in an over-designation of TOS in this series of patients and an overuse of operative treatment, the results of operation in patients with cervical ribs were good, whereas in those with fibrous bands they were not bad either. Unfortunately, the presence of fibrous bands can be established only during surgery. In this series, no patient was worse after surgery, although one patient required a chest tube for 2 days and another had a wound infection. But, it should be kept in mind that cervical and first rib resections are rather difficult and treacherous procedures. However, the most difficult task remains making the right diagnosis on the basis of history and physical examination alone, and in view of their experience with conditions to be considered in the differential diagnosis, neurosurgeons are eminently suited to perform this task.

TABLE 30.1. The differential diagnosis of thoracic outlet syndrome

Cervical disc or osteophyte

Pancoast tumor

Nerve sheath tumor

Ulnar and /or median nerve entrapment

Brachial plexitis

Syrinx

Spinal cord tumor

Shoulder injuries (e.g., rotator cuff injury)

Fibromyalgia

Multiple sclerosis

Raynaud disease

Acute coronary syndrome

Vasculitis

Vasospastic disorder

Complex regional pain syndrome

TABLE 30.2. Diagnosis in patients referred for thoracic outlet syndrome and in patients not referred for thoracic outlet syndrome [a]

	TOS	MILD/ PARTLY TOS	NO TOS
All patients (149)	100 (67%)	19 (13%)	30 (20%)
Referred for TOS (116)	84 (72%)	10 (9%)	22 (19%)
Not referred for TOS (33)	16 (48%)	9 (27%)	8 (24%)

[a] TOS, thoracic outlet syndrome.

TABLE 30.3. Other diagnoses in 149 patients with possible thoracic outlet syndrome [a]

	TOS (n=100)	Mild/partly TOS (n=19)	No TOS (n=30)
Unknown	-	-	10 (33%)
Herniated disc	-	-	6(20%)
Carpal tunnel syndrome	9 (9%)	3 (16%)	5(16%)
Sympathetic dystrophy	3 (3%)	1 (5%)	3(10%)
Degenerative disc disease	3 (3%)	1 (5%)	3(10%)
Shoulder bursitis	-	1 (5%)	3(10%)

Tension headache	4 (4%)	4 (21%)	2(7%)
Ulnar neuropathy	2 (2%)	1 (5%)	1(3%)
Other	2 (2%)	1 (5%)	3(10%)

[a] TOS, thoracic outlet syndrome. More than one diagnosis could be made in each patient, making the total number of diagnoses (171) higher than the total number of patients.

TABLE 30.4. Specialty of referring doctors, number of patients for each specialty and number of patients in whom diagnosis of thoracic outlet syndrome was rejected [a]

Specialty of referring doctor	No. of patients	No. of patients with diagnosis other than TOS
Company physicians	40	11(28%)
Thoracic surgeons	25	2(8%)
Neurosurgeons	21	4(19%)
Orthopedic surgeons	12	0
Neurologists	7	3 (43%)
Vascular surgeons	4	0
General practitioners	3	2 (67%)
Plastic surgeons	1	0
General surgeon	1	0
Siblings (former patients)	2	0

[a] TOS, thoracic outlet syndrome.

TABLE 30.5. Presenting symptoms in 149 patients with possible thoracic outlet syndrome [a]

	TOS (n=100)	Mild/partly TOS (n=19)	No TOS (n=30)
Numbness or clumsiness hand	75 (75%)	12 (63%)	18 (60%)
Pain in neck and shoulder	62 (62%)	13 (68%)	24 (80%)
Disturbed sleep	28 (28%)	3 (16%)	6 (20%)
Tired feeling arm	18 (18%)	2 (11 %)	2 (7%)
Swelling hand	15 (15%)	2 (11%)	5 (17%)
Headache	5 (5%)	2(11%)	1 (3%)
Other symptoms	19 (19%)	1 (5%)	3 (10%)

[a] TOS, thoracic outlet syndrome.

TABLE 30.6. Left-handedness and the side of symptoms in patients with possible thoracic outlet syndrome [a]

	TOS (n=100)	Mild/ partly TOS (n=19)	No TOS (n=30)
Left handed	16 (16%)	3 (16%)	1 (3%)
Dominant side	49 (49%)	12 (63%)	14 (47%)
Non-dominant side	34 (34%)	5 (26%)	10 (33%)
Bilateral	17 (17%)	2 (11%)	6 (20%)

[a] TOS, thoracic outlet syndrome.

TABLE 30.7. Cause of symptoms as indicated by the patient [a]

	TOS (n=100)	Mild/ partly TOS (n=19)	No TOS (n=30)
work	44 (44%)	4 (21%)	12 (40%)
automobile accident	8 (8%)	5 (26%)	1 (3%)
fall	8 (8%)	1 (5%)	1 (3%)
other	7 (7%)	2(11%)	4 (13%)
none	33 (33%)	7 (37%)	12 (40%)

[a] TOS, thoracic outlet syndrome.

TABLE 30.8. Signs in 149 patients with possible thoracic outlet syndrome [ab]

	TOS (n=100)	Mild/ partly TOS (n=19)	No TOS (n=30)
Adson maneuver	77 (8) (77%)	11 (0) (58%)	6 (0) (20%)
traction	77 (6) (77%)	11 (0) (58%)	4 (0) (13%)
elevation	76 (10) (76%)	11 (0) (58%)	7 (0) (23%)
hyperabduction	72 (7) (72%)	11 (0) (58%)	5 (0) (17%)
military attitude	71 (8) (71%)	13 (0) (68%)	6 (1) (20%)
Tenderness Erb's point with radiation to arm	57 (57%)	8 (42%)	8 (27%)
Hypalgesia median cord	29 (29%)	5 (26%)	0 (0%)
hypalgesia other	27 (27%)	8 (42%)	12 (40%)
Tendon reflexes diminished	8 (8%)	1 (5%)	7 (23%)
Hypalgesia posterior cord	5 (5%)	0 (0%)	0 (0%)
Muscle weakness	3 (3%)	0 (0%)	3 (10%)
Swelling hand	3 (3%)	0 (0%)	3 (10%)
Hyperesthesia median cord	3 (3%)	0 (0%)	0 (0%)

[a] TOS, thoracic outlet syndrome.

[b] The first number in parenthesis after the number of patients with positive provocation tests indicates the number of patients in whom the radial pulse disappeared with this test.

TABLE 30.9. Radiographic findings in 149 patients with possible thoracic outlet syndrome [a]

	TOS (n=100)	Mild/partly TOS (n=19)	No TOS (n=30)
Bilateral cervical ribs	6	0	0
Unilateral cervical rib	4	0	0
bilateral large transverse process C7	3	0	0
Unilateral large transverse process C7	5	0	0
Degenerative disc disease	3	1	6
Normal myelogram or MRI	15	2	3
Abnormal myelogram or MRI	2	1	5
Normal venogram	2	0	0
Occlusion A Subclavia with provocation	2	0	0
Atherosclerotic occlusion A Subclavia	0	0	1

[a] TOS, thoracic outlet syndrome.

TABLE 30.1. Diagnoses based on electromyography and nerve conduction studies in 77 of 149 patients with possible thoracic outlet syndrome who underwent these studies [a]

	TOS (n=100)	Mild/partly TOS (n=19)	No TOS (n=30)
Normal	32	8	7
Carpal tunnel syndrome	9	3	9
Ulnar neuropathy	2	1	0
plexopathy	3	0	1
Other	3	2	4

[a] TOS, thoracic outlet syndrome.

TABLE 30.11. Outcome of 59 operations in 50 patients related to intraoperative findings [a]

	Normal	Cervical rib	Fibrous bands	Other
Good (75%)	25	9	9	1
Fair (17%)	6	1	3	1
Poor (8%)	5	0	0	0

[a] Good, return to former job and no narcotics; Fair, no return to former job or still using narcotics; Poor, no return to work and still using narcotics

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Fig. 30.1 Establishing the diagnosis of TOS.