Surgery for suspected neurogenic thoracic outlet syndromes: a follow up study

Michael Donaghy, Zelko Matkovic, Peter Morris

Abstract

Objectives—To assess the outcome of surgical treatment for thoracic outlet syndrome (TOS), and to compare the outcome in patients with and without an underlying cervical rib.

Methods—a heterogeneous group of 40 patients (33 women, seven men; aged 22–62 years) were evaluated 3 months to 20 years after surgery for suspected neurogenic TOS. Forty nine operations had been performed: cervical ribs were removed in 23 patients, together with fibrous band excision in nine. In the 17 without a cervical rib the thoracic outlet was decompressed by resection of the first thoracic rib in nine, and by other operations in eight.

Results—After surgery patients reported improved pain (33/36), sensory disturbance (30/35), hand muscle strength (14/27), and hand function (23/34). Postoperatively TOS recurred in two, and symptoms continued to progress in three patients in whom other diagnoses eventually emerged. Surgical complications were recorded in 10 patients, but were transient and did not result in permanent symptomatic sequelae.

Conclusions—Surgical treatment of suspected neurogenic TOS relieves pain and sensory disturbance predominantly in the thenar eminence; a radiographic cervical rib; and neurophysiological studies confirming chronic postganglionic axonal loss, and excluding focal mononeuropathy.

The diagnosis of neurogenic TOS is relatively straightforward in the patient with pain and sensory disturbance predominantly in the ulnar forearm and hand, aggravated by use of the affected limb; associated with weakness and wasting of the small hand muscles particularly in the thenar eminence; a radiographic cervical rib; and neurophysiological studies confirming chronic postganglionic axonal loss, and excluding focal mononeuropathy. Many patients with suspected neurogenic TOS, however, fail to exhibit such a clear cut clinical, neurophysiological and radiological picture. Indeed it is self evident that the full blown syndrome must go through a long stage of evolution when such features are only partially present and insufficient for a definite diagnosis of TOS. Further, although soft tissue anomalies, including various fibrous bands and less commonly scalenus anterior/medius anomalies may be responsible for TOS, only the bony abnormalities (cervical rib, malunited clavicular fracture, abnormal first thoracic rib) are clearly demonstrated by preoperative radiography. Unfortunately, there is no single criterion upon which to base a diagnosis. Currently this depends on collating the symptoms, examination findings, and results of electrophysiological and radiological studies. However, dynamic factors related to posture are of importance in TOS for even the findings at surgical exploration or brachial plexus imaging, when gravity no longer depresses the shoulder girdle, may not provide a diagnostic gold standard.

Keywords: cervical rib; thoracic outlet; surgery

Controversy surrounds the diagnosis and management of thoracic outlet syndromes. The term “thoracic outlet syndrome” (TOS) refers to the clinical disturbance resulting from compromise of the neurovascular bundle (brachial plexus, subclavian artery, or vein) by bony or soft tissue anomalies during its course between the neck and axilla. Most patients present with a neurogenic TOS with symptoms of brachial plexus compression. Syndromes due to subclavian arterial or venous compromise are relatively uncommon and do not usually present a problem in diagnosis.
To enhance our understanding of how to manage suspected neurogenic TOS we have analysed the postoperative neurological outcome in a heterogeneous group of patients who underwent surgery in Oxford for suspected neurogenic thoracic outlet syndrome. In particular, we were interested to discover if the outcome differed significantly between those with and those without radiographic cervical ribs, thereby comparing a group likely to have definite TOS with a group in whom that diagnosis can only be inferred.

**Methods**

**PATIENT POPULATION**

From surgical department records we were able to contact 41 patients, only one of whom refused to take part, who had undergone surgery for suspected neurogenic thoracic outlet syndrome since 1973.

**PREOPERATIVE FEATURES**

Medical records were reviewed for details of the patient’s presentation and the findings on general, vascular, and neurological examination. Plain cervical x-rays had been performed in all, thoracic outlet and/or cervical spine MRI in 15, cervical myelography in four, and subclavian angiography in 11. Routine diagnostic neurophysiological studies had been conducted preoperatively in 29 patients by various clinical neurophysiologists: concentric needle EMG of small hand muscles, median and ulnar motor conduction, and median and ulnar sensory nerve action potentials (SNAPs) had been carried out in all; F response and deep tendon reflex latencies had been determined in 25.

**SURGERY**

Surgery had been performed by eight different consultant surgeons; 36 of the 49 thoracic outlet operations were carried out by one (PM). Surgery was performed by the supraclavicular approach in 34 patients. The scalene anterior was divided to expose the subclavian artery and lower trunks of the brachial plexus. Fibrous bands, if present, were divided, and cervical ribs or the first thoracic rib removed piecemeal with bone nibblers as far posteriorly as possible to leave the brachial plexus and subclavian artery “free” in the thoracic outlet.

The infraclavicular approach for first rib resection and the brachial plexus were retracted upwards in six patients exposing the first rib, which was excised with bone nibblers to a point well behind the brachial plexus.

**POSTOPERATIVE NEUROLOGICAL ASSESSMENT**

The postoperative review at 3 months to 20 years (median 2 years) after surgery was by a neurologist who had not been involved in their preoperative management except in three cases. A full history was obtained including details of the presenting features: presence of arm pain, paraesthesia, numbness, weakness, wasting, vascular symptoms and loss of hand function; duration of symptoms; relieving and aggravating factors; and the effect on activities of daily living, employment, and leisure. The peroperative course, the nature and effect of complications, and the progress after discharge from hospital were ascertained. A full neurological examination of the limbs was undertaken.

The vascular assessment involved palpation of upper limb pulses, checking for positional radial pulse obliteration, sphygmomanometer measurement of blood pressure in both arms, and auscultation for supraclavicular bruits. The outcome after surgery was judged according to the presence of postoperative complications, symptomatic relief, alteration in examination findings, and significant changes in disability.

**Results**

**PREOPERATIVE FINDINGS**

Table 1 shows preoperative findings. Presenting symptoms were similar in the two groups, exclusively or predominantly unilateral and left sided in 23 patients, right sided in 15, and bilateral in two; 32 were right handed. Each patient complained of arm pain, pain in the shoulder, forearm, or hand or sensory disturbance generally, paraesthesia, in the ulnar aspect of the forearm or hand, or both. These sensory symptoms were typically intermittent and aggravated by use of the affected limb. A combination of these symptoms led to the frequent complaint (34) of impaired hand function interfering with manual tasks; in nine this restricted leisure activities or interfered with employment. Vascular symptoms such as changes in hand colour were never the dominant complaint.

The principle preoperative clinical features suggestive of TOS were pain or sensory disturbance in the ulnar forearm, with weakness of intrinsic hand muscles or flexor digitorum profundus.

Electrophysiology was abnormal in 26 out of 29 patients. Most commonly a reduced fifth digit sensory nerve action potential was associated with chronic partial denervation of small hand muscles. Plain cervical spine x-rays demonstrated bilateral cervical ribs in 16 patients, unilateral cervical ribs in five, elongated C7

<table>
<thead>
<tr>
<th>Preoperative features in suspected neurogenic thoracic outlet syndrome</th>
<th>With cervical rib (n=23)</th>
<th>Without cervical rib (n=17)</th>
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<tbody>
<tr>
<td>Presenting symptoms:</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Age at symptom onset (y (median))</td>
<td>10–57 (35)</td>
<td>21–58 (31)</td>
</tr>
<tr>
<td>Duration of symptoms (median)</td>
<td>Weeks–20 y (11 months)</td>
<td>3 months–10 y (2 y)</td>
</tr>
<tr>
<td>Arm pain</td>
<td>21</td>
<td>15</td>
</tr>
<tr>
<td>Arm sensory disturbance</td>
<td>20</td>
<td>15</td>
</tr>
<tr>
<td>Hand weakness</td>
<td>15</td>
<td>12</td>
</tr>
<tr>
<td>Impaired hand function</td>
<td>20</td>
<td>14</td>
</tr>
<tr>
<td>Vascular symptoms</td>
<td>14</td>
<td>5</td>
</tr>
<tr>
<td>Preoperative examination findings:</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Decreased sensation</td>
<td>14/23</td>
<td>10/17</td>
</tr>
<tr>
<td>Reduced muscle strength</td>
<td>14/23</td>
<td>11/17</td>
</tr>
<tr>
<td>Muscle wasting</td>
<td>10/23</td>
<td>7/17</td>
</tr>
<tr>
<td>Reproduction of sensory disturbance by rolling the brachial plexus</td>
<td>7/7</td>
<td>5/5</td>
</tr>
<tr>
<td>Positional obliteration of radial pulse</td>
<td>12/22</td>
<td>12/15</td>
</tr>
<tr>
<td>Subclavian bruit</td>
<td>4</td>
<td>3</td>
</tr>
<tr>
<td>Neurophysiological studies:</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Normal results</td>
<td>1/15</td>
<td>2/14</td>
</tr>
<tr>
<td>Decreased F5 SNAP</td>
<td>9/15</td>
<td>10/14</td>
</tr>
<tr>
<td>Denervation of APB or FD10</td>
<td>14/15</td>
<td>10/14</td>
</tr>
<tr>
<td>Denervation of forearm flexor muscles</td>
<td>2/6</td>
<td>1/3</td>
</tr>
<tr>
<td>Prolonged wrist reflex latency</td>
<td>6/13</td>
<td>7/12</td>
</tr>
<tr>
<td>Prolonged F waves</td>
<td>2/4</td>
<td>6/11</td>
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SNAP=Sensory nerve action potential; APB=abductor pollicis brevis; FD10=first dorsal interosseous muscle.
transverse process in five, and a large anomalous first thoracic rib in one. Magnetic resonance imaging of the brachial plexus, carried out in 14 patients, showed distortion of the lower brachial plexus and cervical spine or C8-T1 nerve roots in 10 and, additionally, helped to exclude compressive cervical radiculopathy. Myelography and cervical spinal canal MRI in five patients were normal. Poststenotic subclavian artery dilatation or occlusion of the subclavian artery on abduction of the arm was detected in nine of the 11 patients who underwent angiography.

SURGICAL FINDINGS
In patients with a radiographic cervical rib, the thoracic outlet was explored by the supraclavicular route. Brachial plexus distortion or stretching was evident at operation in 17 out of 23 patients. In nine patients, a fibrous band extended from the tip of the cervical rib to the region of the scalene tubercle of the first thoracic rib; this was excised along with the cervical rib. To obtain adequate plexus decompression in two patients, a portion of the first thoracic rib as well as the cervical rib had to be removed. In two patients with bilateral symptoms both cervical ribs were excised during a single operation. In two patients the other cervical rib was removed 2 and 4 years later when symptoms had developed in the other arm.

In the 17 patients without a cervical rib a variable portion of the first thoracic rib was removed in nine, scalenotomy performed in five, elongated C7 transverse process excised in two, and a fibrous band extending from the scalenus medius to the first thoracic rib excised in one. In the nine patients who underwent first thoracic rib resection anatomical anomalies responsible for neural distortion were noted in five: anomalous scalenus muscles in three, a very large anomalous first thoracic rib in one, and an abnormally long T1 nerve root angulated over the first thoracic rib in one. In one of the two patients in whom a prominent C7 transverse process was excised, a fibrous band running from the scalenus medius to Sibson’s fascia was also divided. In five patients in whom no plexus distortion was evident at operation surgery was limited to scalenotomy (division of scalenus anterior).

SURGICAL COMPLICATIONS
Table 2 shows surgical complications. Thirty five patients underwent 43 operations by the supraclavicular approach. Asymptomatic right phrenic nerve injury occurred in two but none had damage to the long thoracic nerve. Transient increase in hand weakness, in two patients, was attributed to traction injury of the brachial plexus. Three patients experienced severe postoperative shoulder girdle pain which was controlled by oral analgesics and resolved after 1–3 months. All patients regarded the scar as cosmetically acceptable. Thoracic outlet decompression by first thoracic rib resection was performed through an infracavicular approach in six patients with complications in two: severe but transient shoulder girdle pain in one and bronchitis in the other.

POSTOPERATIVE SYMPTOMS
Table 3 shows postoperative symptoms. At the neurological follow up assessment patients most often reported a favourable postoperative outcome. Appreciable symptom amelioration occurred a few days to 1 year (median, 1 month) after surgery. Arm pain had significantly diminished or disappeared in 33 of 36 patients. Thirty of 35 patients reported significant improvement of other sensory disturbance. Twenty three patients reported an improvement in hand function, including eight of the patients with muscle wasting. Reports of improved muscle strength or a clear cut improvement in power on examination occurred in about 50% of patients with preoperative muscle weakness. Established muscle wasting never improved.

The neurological examination was normal in 18 patients. Variable combinations of residual weakness or wasting of the small hand muscles or the forearm finger flexors were found in 17. Notably, involvement of the flexor digitorum

<table>
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<th>Complications of surgery</th>
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<tr>
<td>Patient age,sex</td>
<td>Operation</td>
</tr>
<tr>
<td>45, F</td>
<td>Bilateral cervical rib resection and partial left first rib resection</td>
</tr>
<tr>
<td>25, F</td>
<td>Bilateral cervical rib resection</td>
</tr>
<tr>
<td>54, F</td>
<td>Right cervical rib and fibrous band resection</td>
</tr>
<tr>
<td>45, F</td>
<td>Left cervical rib resection</td>
</tr>
<tr>
<td>19, F</td>
<td>Left cervical rib resection</td>
</tr>
<tr>
<td>47, F</td>
<td>Left cervical rib resection</td>
</tr>
<tr>
<td>36, F</td>
<td>Right first thoracic rib resection</td>
</tr>
<tr>
<td>49, M</td>
<td>Right first thoracic rib resection</td>
</tr>
<tr>
<td>24, F</td>
<td>Division of left fibrous band</td>
</tr>
<tr>
<td>32, M</td>
<td>Scalenotomy.</td>
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</tbody>
</table>

<table>
<thead>
<tr>
<th>Table 3</th>
<th>Outcome after surgery</th>
</tr>
</thead>
<tbody>
<tr>
<td>Change in symptoms:</td>
<td>With cervical rib (n=23)</td>
</tr>
<tr>
<td>Improved pain</td>
<td>7/21</td>
</tr>
<tr>
<td>Complete resolution of pain</td>
<td>13/21</td>
</tr>
<tr>
<td>Improved sensory disturbance</td>
<td>17/20</td>
</tr>
<tr>
<td>Improved muscle strength</td>
<td>8/15</td>
</tr>
<tr>
<td>Improved function</td>
<td>15/20</td>
</tr>
<tr>
<td>Improved power (on examination)</td>
<td>8/14</td>
</tr>
</tbody>
</table>

Neurological examination:

<table>
<thead>
<tr>
<th>No motor or sensory abnormalities</th>
<th>With cervical rib (n=23)</th>
<th>Without cervical rib (n=17)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Reduced sensation in the ulnar hand or forearm</td>
<td>7</td>
<td>5</td>
</tr>
<tr>
<td>Other sensory abnormalities</td>
<td>4</td>
<td>2</td>
</tr>
</tbody>
</table>

Weakness or (wasting) of:

<table>
<thead>
<tr>
<th>APB</th>
<th>With cervical rib (n=23)</th>
<th>Without cervical rib (n=17)</th>
</tr>
</thead>
<tbody>
<tr>
<td>FDI0 or ADM</td>
<td>8 (6)</td>
<td>6 (5)</td>
</tr>
<tr>
<td>Finger flexors</td>
<td>8 (6)</td>
<td>7 (3)</td>
</tr>
<tr>
<td>Positive Wright’s or Adson’s manoeuvre</td>
<td>5</td>
<td>2</td>
</tr>
</tbody>
</table>

APB=Abductor pollicis brevis; ADM=abductor digiti minimi; FDI0=first dorsal interosseous muscle.
Surgery for thoracic outlet syndromes

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genic TOS is debated.14 15

Discussion
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another patient; symptoms recurred 10 years
after cervical rib resection and resolved after
excision of the fibrous tissue. In three other
patients recurrence of symptoms occurred at 3
months, and 2 and 3 years after surgery: despite
MRI studies in all three and neurophysiological
testing in one a clear cause for the symptoms was
not established; however, these “new” symp-
toms were less troublesome and produced less
disability than the preoperative disturbance.

NEUROLOGICAL PROGRESSION OR RECURRENT
POSTOPERATIVELY
Weakness and wasting of the small hand muscles
continued to progress after surgery in three
patients. In two without cervical ribs a diagnosis
of chronic asymmetric spinal muscular atrophy
emerged several years after first thoracic rib
resection. In retrospect neither patient had
experienced arm pain, and their modest sensory
disturbance was overshadowed by prominent
muscle weakness. In the third patient a foramen
magnum decompression was carried out 15
months after cervical rib resection when the
presence of syringomyelia and an Arnold-Chiari
malformation was established.

Five patients developed recurrent neurologi-
cal symptoms in the previously affected arm 3
months to 10 years after operation. Multiple
recurrences of TOS occurred in a patient with
Meltkerson-Rosenthal-Miescher syndrome,
which includes a tendency to fibrosis in the
affected regions: a periosteal regrowth of the first
thoracic rib was resected a year after the initial
surgery and, on two further reoperations for
recurrence of symptoms and signs, fibrous tissue
which was distorting the brachial plexus was
removed. Distortion of the brachial plexus by
scar tissue was the cause of recurrence of TOS in
another patient; symptoms occurred 10 years
after cervical rib resection and resolved after
excision of the fibrous tissue. In three other
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toms were less troublesome and produced less
disability than the preoperative disturbance.

The efficacy of surgical treatment for neuro-
genic TOS is debated.14 15 In advanced forms
of neurogenic TOS, resection of the underlying
cervical rib and/or fibrous band relieves pain
and paraesthesia in most patients, but usually
does not alter the motor deficit significantly.4
Thus, surgery in such patients will not allow a
useful recovery of muscle function and merely
prevents further progression of the weakness
and wasting. On the other hand, studies of
patients without the “classic” full blown or
advanced form of TOS have reported surgical
success rates as high as 80%-90% without clear
definition of the criteria on which a “good” or
“excellent” outcome is based.9 11 12 Moreover,
some patients who had been described by their
surgeon as having “improved” were subse-
sequently judged not to have benefited from sur-
gery when reviewed by a different observer.15
Thus, there was a clear need for a study of sur-
gical outcome conducted by independent neu-
rologists which would also evaluate the influ-
ence of preoperative severity and the presence of
features such as a radiographic cervical rib
on that outcome.

We found a generally satisfactory outcome
after surgical treatment in this heterogeneous
group of patients with suspected neurogenic
TOS. In particular, we were surprised to find
near identical surgical outcomes in the patients
with and without cervical ribs, given that this
anatomical variation might be regarded as con-
siderably strengthening the likelihood of defi-
nite TOS. Pain and sensory disturbance
improved in 90% of the patients, whereas
improved muscle strength and hand function
were reported by half. Muscle wasting never
resolved, which suggests that early surgery may
prevent irreversible denervation of hand mus-
cles. Postoperative recurrence of TOS has been
previously described17 and special circum-
stances prevailed in our two patients. The con-
tinued progression of upper limb symptoms in
three patients was due to an alternative
diagnosis from TOS. The postoperative out-
come in our patients was not obviously
influenced by the surgical approach (either
supraclavicular or infraclavicular); the type of
underlying anomaly (cervical rib, prominent
C7 transverse process, anomalous first thoracic
rib, fibrous bands, or abnormal insertion of
scalenus muscles); or by the presence of visible
brachial plexus distortion at operation.

We regard the anterior supraclavicular
approach10 as the operation of choice in
patients with suspected neurogenic TOS who
require surgical treatment. It provides the best
exposure of the neurovascular bundle, cervical
ribs, and fibrous bands and can be used for first
rib resection. Its disadvantages include the risk
of damage to the long thoracic or phrenic
nerves and the presence of a cosmetically
undesirable scar.18 19 The transaxillary route20
is the most popular approach to the thoracic
outlet in the United States: it leaves a small
hidden scar, requires little dissection, but
involves strenuous abduction of the arm, leav-
ing the brachial plexus vulnerable to traction
injury, and haemostasis may prove difficult if
there is intraoperative damage to the subcla-
vian vessels. Although the infraclavicular
approach21 provides excellent access to the
anterior two thirds of the first rib it does not in,
general, allow visualisation of the anatomical
abnormality and is not commonly practised.
We recorded surgical complications in 10 of 40
patients but these did not give rise to long term
or permanent symptoms or disability.

No single diagnostic criterion for TOS can be
used in making the decision to offer a patient
surgical exploration with a view to decompres-
sion of the thoracic outlet, and even the intraop-
errative findings may not be diagnostic. Helpful
diagnostic symptoms include sensory distur-
bance in the C8 and T1 dermatomes, aggravation
of pain, and paraesthesia by use of the
affected arm, absence of nocturnal symptoms,
and the presence of vascular symptoms when the
subclavian artery is also involved. We regard the
typical motor features of TOS to consist of
The results of a retrospective study must by definition be regarded with caution. Unfortunately, the outcome remains unknown in a similar group of asymptomatic patients with TOS who have not undergone surgical treatment. Nevertheless, the results of our study do suggest that surgical decompression is highly likely to alleviate what can be disabling upper limb symptoms in patients with a wide range of abnormalities at the thoracic outlet. Although in patients with suspected neurogenic TOS who lack objective neurological findings, progression to muscle weakness and wasting has not been definitely established, it does seem likely that such progression will eventually occur in many as part of the natural evolution of TOS. Further, given that established motor abnormalities respond poorly to surgery for TOS, exploration should be considered in such patients before the irreversible denervation occurs, providing that conservative methods have failed, and the symptoms are disabling. The patient must recognise the possibility of complications and, particularly if there is no cervical rib, the exploratory nature of such an operation.

We thank Mrs Anne Richardson and Mrs Joanna Wilkinson for their patient and expert secretarial assistance, and Mrs Jackie Walton for help in identifying patients.

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doi: 10.1136/jnnp.67.5.602

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