Neurogenic Thoracic Outlet Syndrome due to the Compression at the Interscalene Triangle

İnterskalen Üçgendeki Sıkışmalara Bağlı Nörojenik Torasik Çıkış Sendromu

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Geliş Tarihi: 13.3.1998 ⇔ Kabul Tarihi: 6.8.1999

Abstract: The characteristics of neurogenic thorasic outlet syndrome due to compressions at the interscalene triangle were evaluated in 17 patients. Sixteen of the patients were female, and the mean age of the group was 34,6 years. Eight cases had only osseous anomalies (Group I). Another six had no bony variations, and the scalene muscles had caused the compression (Group II). The other 3 cases had both bony anomalies and muscular compression (Group III). The most common symptoms were painful myofascitis (88%) and paresthesia (77%), and the most frequent physical findings were motor deficits (82%) and positive Adson's tests (82%). In cases with osseous anomalies cervicocephalic symptoms were often seen but paresthesia was relatively rare ($p<0.05$). Also in these patients, a positive hyperadduction test was often accompanied by a fibrous band. Double crush or reverse double crush syndromes were detected in 7 of the 17 cases. Of the electrophysiological tests performed, electromyography gave the most information. Twenty-one extremities in 17 patients were operated via a supraclavicular appproach sparing the first rib, and no complications were encountered. Fibrous bands were found only in patients who had osseous anomalies ($p<0.05$). Satisfactory and tolerable results were achieved in nine (53%) and seven (41%) patients, respectively.

Key Words: Double crush syndrome, supraclavicular approach, thoracic outlet syndrome.

Özet: İnterskalen üçgendeki kompresyonlara bağlı nörojenik torasik çıkış sendromunun özellikleri 17 hastada değerlendirildi. Bunlardan 16'sı kadın olup ortalama yaş 34.6 idi. Sekiz olguda yalnız kemik anomalileri vardı (1.Grup). Diğer 6 olguda ise herhangi bir kemik varyasyon olmayıp sıkışıklıkların nedenleri skalen adelelerdi (2. Grup). Kalan 3 olguda ise hem kemik anomalileri hem de kas sıkışıklıkları mevcuttu (3. Grup). En sık izlenen semptomlar ağrılı myofasitis (%88) ve paresteziydi (%77). Motor defisitler (%82) ve pozitif Adson testleri (%82) de en sık gözlenen fizik bulgulardı. Kemik anomalili olgularda servikosefalik semptomlar sık olduğu halde parestezilerin göreceli olarak düşük oranda izlenmekteydi ($p<0.05$). Pozitif hiperadduksiyon testi de sıklıkla fibröz bandlara eşlik etmekteydi. İkili yada ters ikili sıkışma sendromları da 7 olgumuzda gözlendi. Elektrofizyolojik testler arasında ise elektromyografi, diğerlerine göre daha bilgilendirici göründü. Onyedi olguda 21 ekstremite supraklaviküler yolla birinci kaburga çıkarılmaksızın tedavi edildi ve herhangi bir komplikasyon ile karşılaşılmadı. Fibröz bandlar sadece kemik anomalili olgularda izlendi ($p<0.05$). Tatminkar ve tolere edilebilir sonuçlar ise sırasıyla dokuz (%53) ve yedi (%41) hastada elde edildi.

Anahtar Sözcükler: İkili sıkışma sendromu, supraklaviküler yaklaşım, torasik çıkış sendromu.

INTRODUCTION

Symptoms of upper extremity neurovascular compression can arise from changes or abnormalities in three spaces, namely, the interscalene triangle, the costoclavicular space and the subpectoral minor space (1, 13). Congenital fibromuscular (17, 18) and bony anatomic (10) variations in these spaces may

predispose individuals to thoracic outlet syndrome (TOS) after trauma, inflammation, or as a result of other factors, such as the dynamic and functional demands of the upper extremity, shoulder, and neck that cause postural changes (1, 21).

The interscalene triangle, which is bordered by the anterior scalene muscle anteriorly, the middle scalene muscle posteriorly, and the first rib inferiorly, is the most common site of compression by predisposing fibrosseous or fibromuscular anomalies (1). The brachial plexus and the subclavian artery pass through this triangle. Compression of the subclavian artery is rare, and its symptoms are usually caused by arterial insufficiency. They include extremity weakness, cold sensation, and pain caused by ischemic neuritis of the plexus. The finding of bruit in the supraclavicular area, in addition to an arteriogram that reveals a compressed area with poststenotic dilatation of the subclavian artery, may give the clinical impression of vascular TOS (5,6). However, 90% of all TOS cases are not vascular, but neurogenic in type. In these patients, the most common seen symptoms are pain and paresthesia (90-95%) distributed according to the level of the plexus involvement, weakness with an easily fatigued extremity, cold sensation, and cold intolerance and swelling (23).

Although a causative association between thoracic outlet compressions and arm symptoms is often suspected clinically, this is difficult to prove. Various electrophysiological tests has been evaluated, but all have a low level of sensitivity for TOS diagnosis and a negative finding does not exclude the condition (3, 9, 22). In patients who have no visible osseous anomaly on x-ray, magnetic resonance imaging (MRI) has recently been suggested to be of potential value in diagnosing TOS. Using MRI, it is possible to demonstrate deviation or distortion of nerves or blood vessels, findings that suggest the presence of radiologically invisible bands, and to reveal other causes of TOS (11). Currently, the combination of interpretation of the symptoms, physical examination findings, and provocative tests seems to be the most reliable way to identify the compression site and the affected structures. The traditional approach to decompression of the interscalene triangle has been transaxillary first rib resection (16), either with or without transcervical scalenectomy (1). Recently, a more selective method consisting of anterior scalenectomy and brachial plexus neurolysis via the supraclavicular approach has also been widely proposed, since it is a safe procedure and yields satisfactory results in certain patients (2, 20).

In this report, we present our experience with 17 patients who had neurogenic TOS due to compression at the interscalene triangle, and who underwent surgery via the supraclavicular route, with the first rib left intact.

PATIENTS and METHODS

During the 14-year period from 1984 through 1997, 16 female and 1 male ranging in age from 22 to 63 years (mean 34.6) underwent primary surgical decompression of the interscalene triangle (Table 1). The patients were subdivided into three groups according to the nature of the compressing structure, namely osseous (group I), muscular (grup II), and combined (group III). In all cases, the symptomatology, physical examination findings, and results of provocative tests were consistent with TOS. Osseous anomalies were investigated with x-ray studies. Electrophysiological tests and computerized tomography were used for either confirmation of TOS or differentiation of it from the clinics of other compressive neuropathies. Initally, all TOS cases were treated conservatively, and surgery was proposed only in cases where there was no improvement. In all of our patients, surgery was indicated due to brachial plexus compression at the interscalene triangle. The operations were done via the supraclavicular approach. As part of the protocol, patients were prescribed physical exercises postoperatively to minimize scar formation around the brachial plexus.

Surgical technique:

The supraclavicular approach is performed under general anesthesia. We placed the patient in the supine position and turned the neck toward the

Table I: Demographic and clinical characteristics of 17 patients with TOS.

Mean age (years)	34.7±9.6
Gender (Female/Male)	16/1 ◆
Mean duration of symptoms (months)	32.9±23.9
Patients with signs and/or symptoms	
Bilateral	4 (24%)
Unilateral right	4 (24%)
Unilateral left	9 (52%)
Mean duration of follow-up (months)	76.0±49.5

◆: P<0.05

nonoperative side. The surgery started with a 6-8 cm neck crease incision parallel to and 2 cm above the clavicle. We divided the platysma, and then identified and mobilized the supraclavicular nerves.The omohyoid and the lateral portion of the clavicular head of the sternocleidomastoid muscle were then divided. The supraclavicular fat pad was elevated proximally, the scalenus anticus muscle was approached, and the phrenic nerve was then identified on its anterior surface.Next, the upper, middle, and lower truncus of the brachial plexus were mobilized. Any muscular, fibrous, or osseous structure observed to be causing compression was resected at this stage, and varying degrees of neurolysis of the brachial plexus were performed in each case. In all patients, the first rib was left intact. The procedure was finished with repair of the sternocleidomastoid muscle and closure of the skin wound.

Clinical data was assessed using chi-square test, and Fisher's exact test was used when needed. P-values less than 0.05 were accepted significant during the statistical analysis.

RESULTS

Group I included eight patients, six who had cervical ribs and two had enlarged transverse processes. Fibrous bands were present in six of these patients. Grup II consisted of six patients, and no fibrous bands were found during these operations. In Group III included three patients, two with cervical ribs and one with enlarged transverse process. An associated fibrous band was also excised in one case.

The duration of symptoms varied from 1 month to 6 years (mean 33 months). The most common symptoms in all groups were pain and paresthesia. Painful myofascitis and radicular pain were present in 88% and 71% of patients, respectively. Paresthesias (77%) and weakness of the upper extremity (53%) were also frequently reported (Table 2). Complaints of easily fatigued extremity, especially while carrying objects, nocturnal aggrevation of paresthesias, and cervicocephalic symptoms were relatively rare (below 30%). Prior to surgery, one of the patients had previously undergone a bilateral sympathectomy and first rib resection, and another had undergone

Table II: Summary of the symptomatology and physical findings in patients with TOS.

	GroupI (N=8)	GroupII (N=6)	GroupIII (N=3)	Total (N=17)
SYMPTOMS				
Pain				
Myofascitis	7	6	2	15 (88%)
Radicular pain	6	3	3	12 (71%)
Paresthesia	4 ◆	6	3	13 (77%)
Weakness	4	3	2	9 (53%)
Easily fatigued limb	3	2	0	5 (29%)
Aggravation with carrying	3	2	0	5 (29%)
Nocturnal aggravation	2	1	0	3 (18%)
Cervicocephalic symptoms	4 ◆	0	0	4 (24%)
PHYSICAL EXAMINATION				
Motor deficits	7	4	3	14 (82%)
Sensorial deficits	6	3	2	11 (65%)
Bruit	1	1	1	3 (18%)
Absence of DTRs	1	0	1	2 (12%)
Atrophy	1	1	0	2 (12%)
PROVOCATIVE TESTS				
Adson's	6	5	3	14 (82%)
Neck tilting	5	1	1	7 (41%)
Hyperabduction	2	1	1	4 (24%)
Hyperadduction	3 ●	0	1 ●	4 (24%)
PLEXUS INVOLVEMENT				
Upper	1	1	0	2 (12%)
Lower	3	1	1	5 (29%)
Combined	4	4	2	10 (59%)

Abbr: DTR: deep tendon reflexes◆: P<0.05; ●: hyperadduction test was positive only in cases with fibrous bands (p<0.05).

ipsilateral carpal tunnel release. Associated inflammatory conditions, such as radial epicondylitis, and bicipital and rotator cuff tendonitis secondary to disuse of the affected extremity, were observed in four patients.

Physical examination showed motor and sensory deficits in 82% and 65% of the patients, respectively, and neck tilting was painful in 41%. Of the provocative tests, Adson's test was positive in 82% of the cases (Table 2). Atrophy, aggravation of symptoms on percussion of the supraclavicular area and on hyperabduction or hyperadduction, and bruit in the supraclavicular region were not commonly observed (below 25%).

When we considered both the symptomatology and physical examination, lower (C8-Th1) and combined (C5-Th1) types of brachial plexus involvement were identified in 5 and 10 patients, respectively. Bilaterality of the osseous anomaly did not seem to affect the symptomatology. Although x-rays revealed bilateral osseous anomaly in four patients from group I, three from group II, and two from group III, these were symptomatic in only half of these patients, and were excised unilaterally on the affected side. Computed tomography showed various intensities of disc herniation in five patients, but only one of the five underwent similtaneous cervical discectomy and thorasic outlet decompression procedures. Electrophysiological tests, including electromyography (EMG), somatosensory evoked potential study (SEP) and electroneurography (ENG), were also used in seven of the 17 patients. Five of the seven exhibited specific findings of thoracic outlet compression. EMG was the most informative, and yielded these specific findings for four of six cases (Table 3). Findings associated with another type of compression, suggesting double crush or reverse double crush syndrome, were also recorded in five of the six who underwent EMG, and in one case severe carpal tunnel compression was released during the same surgery, immediately after the brachial plexus was decompressed.

Seventeen patients underwent 21 surgical procedures involving the supraclavicular approaches. Four of the patients had bilateral procedures, with the intervals between the operations for the two sides varying from 1 month to 4 years. In nine of the group I and III patients, we were able to totally resect the osseous anomaly. In one case the resection was subtotal, and in another patient, who had undergone previous surgery on the contrlateral side, we found no compression at the interscalene triangle. Likely, this individual's symptoms were caused by overuse of the extremity due to disease in the contrlateral arm. Fibrous bands, which were encountered in 7 of the 11 patients with osseous anomalies, were also excised. We found no fibrous bands in the patients with muscular compression. In group II and III patients, we eliminated muscular compression via anterior scalenectomy, and performed middle scalenectomy when indicated (Table 4). Five cases were operated bilaterally, and the scalene muscles were identified as causing the compression in three of these patients.

Table III: Results of the diagnostic laboratory studies.

X-RAY	
Cervical rib	
Unilateral	5 (29%)
Bilateral	7 (41%)
Enlarged transverse process	
Unilateral	1 (6%)
Bilateral	2 (12%)
Combined	1 (6%)
ELECTRODIAGNOSTIC TESTS (S/NS)	5/7 (71%)
Electromyography	4/6 (67%)
F-wave	-
SEP	1/1 (100%)
ENG	3/6 (50%)
DOUBLE CRUSH SYNDROME	7 (41%)
CT (CDH)	5 (29%)
Electrodiagnostic tests (CTS)	2 (12%)

Abbr: S/N:specific/nonspecific findings confirming TOS; SEP:somatosensory evoked potential study; ENG:electroneurography; CDH:cervical disc herniation; CTS:carpal tunnel syndrome.

The mean follow-up period was 76 months. Improvement of neurogenic TOS symptoms was satisfactory in nine (53%) cases. Seven of the other cases were left with persistent minor symptoms that could be tolerated well during daily life, but one patient experienced no improvement postoperatively (Table 4).

Statistical analysis:

All but one of our patients was female, which indicates a gender bias toward woman in TOS ($p<0.05$). In patients with TOS, only the complaints of paresthesia and cervicocephalic symptoms were statistically significant ($p<0.05$). In patients with

Table IV: Summary of the surgical findings, procedures and their effects on the complaints of the patients with TOS.

	GroupI (N=8)	GroupII (N=6)	GroupIII (N=3)	Total (N=17)
Cervical rib resection	6 (75%)	-	2 (66%)	8 (47%)
Enlarged transverse process excision	2 (25%)	-	1 (34%)	3 (18%)
Fibrous band excision	6(75%) ◆	-	1(34%) ◆	7 (41%)
Scalenectomy	-	6 (100%)	3 (100%)	9 (53%)
Bilateral approaches	2 (25%)	2 (34%)	1 (34%)	5 (29%)
Surgery for a second compression	2 (25%)	1 (17%)	-	3 (18%)
Negative exploration	1 (12%)	-	-	1 (6%)
Postoperative results				
Satisfactory	5 (63%)	3 (50%)	1 (34%)	9 (53%)
Tolerable	2 (25%)	3 (50%)	2 (66%)	7 (41%)
No improvement	1 (12%)	-	-	1 (6%)

◆: Fibrous bands were observed only in cases with osseos anomalies ($p<0.05$).

osseous anomalies, cervicocephalic smyptoms were common, but paresthesia was relatively rare ($p<0.05$). Also, compression due to fibrous bands was statistically significant in this patient group ($p<0.05$). In analyzing physical findings, with regarding to diagnosing the cause of compression, we found a positive hyperadduction test to be more meaningful than a positive hyperabduction test. All four of the patients whose symptoms were aggravated by hyperadduction had fibrous bands ($p<0.05$). There was no statistical association between postoperative results and cause of compression at the interscalen triangle or applied surgical technique.

DISCUSSION

The reported incidence of TOS in the general population is approximately 0.3% to 0.7% (1, 22). The affected typically range from 25 to 40 years in age (mean 34,6) and a higher incidence (4:1) has been reported in females (1, 19). In our patients, the age range was similar to that reported by other investigators, but the bias toward females was more extreme (16:1).

Apart from the detection of radiologically visible osseous anomalies, the combination of clinical examination and provocative testing seems the best way to determine which of the three outlets of thorax is the site of interest. Symptoms and findings due to compression of all three structures in the neurovascular bundle can be aggravated either by hyperabduction, when the pectoralis minor space is narrowed (24), or by costoclavicular compression, when the costoclavicular space is diminished (7).

Although combined upper and lower plexus involvement occurs in 85-90% of all TOS cases (19), the symptoms and neurological findings of the involved plexus level and the response to hyperabduction and hyperadduction tests may vary according to the specific compression problem at the interscalene triangle. The indication for scalenectomy requires careful interpretation of the symptoms and physical findings, provocative tests, electrophysiologic tests, and probably MRI (11) for patients with x-rays that show no visible osseous anomaly. In addition, the anterior scalene muscle injection test may be used as a diagnostic and confirmatory test for thoracic outlet compression caused by the scalene muscles (21). This type of compression usually affects the upper plexus (C5,6,7) and relief of symptoms occurs during adduction (19). In contrast, since cervical ribs and associated ligaments act as a fulcrum beneath the plexus, exerting pressure upward against the nerves, complaints in these cases relate to the lower plexus involvement (C8, Th1), and thus increase during adduction, and resolve during hyperabduction (1). We also noted positive hyperadduction tests in our patients with fibrous bands.

Electrophysiologic studies may help either confirm the existence of compression at interscalene triangle or predict a possible cause. Of our seven patients who were examined with EMG, SEP and

ENG, we observed specific findings of TOS in five. Of the three tests done, EMG was most informative. This may be explained by the very low incidence of severe atrophy and longstanding disease in our patients. Since EMG is able to detect the early changes (12), it was most helpful in our patients. Others forms of electrodiagnostic testing are usually accepted as complementary (12, 22). In the two patients who registered normal electrodiagnostic test results, severe compression was revealed intraoperatively. Thus, a negative finding should never exclude the presence of TOS when the clinical picture is highly suggestive of thoracic outlet compression (12, 22). We have no experience with the utility of MRI for diagnosing TOS, but, this technique may also be helpful for confirming the diagnosis. Panegyres. et al, demonstrated the deviation of the brachial plexus in 19 out of the 24 symptomatic sides in affected patients, and detected a band-like structure in 25 out of 33 sides (11).

Sometimes, it is difficult to differentiate TOS from carpal tunnel syndrome (CTS). It is noteworthy that the symptoms, especially the parestesia, are not usually nocturnal in TOS, but are very frequently so in CTS (22). We also found that nocturnal aggravation of symptoms was rare in our patients (18%), and the three patients with this complaint had no carpal tunnel compression. Double-crush or reverse double-crush syndrome is more common in TOS patients (22). The treatment of another compression distal or proximal to the thorasic outlet may delay the intensity of the symptoms of thorasic outlet compression, as well as the surgery (4). The best results are achieved when coexisting compressions are investigated and treated simultaneously (1). Seven of our cases exhibited varying degrees of a separate typeof neural compression. In three of these patients, both compressed areas were treated, and we achieved excellent results in these cases. Of the other four, only one patient had no complaints postsurgery.

Most series report some relief of symptoms in the 70% to 80% range, regardless of the operative approach used (2, 14, 16, 20). Currently, resection of the first rib is the most popular surgical approach (16). This is suitable for cases with signs of lower plexus involvement, and can be performed via either a transaxillar or the supraclavicular route. However, this is limited in that it can only treat problems associated with the lower plexus, and it is also associated with considerable risks. In contrast, the supraclavicular approach offers better visualization and resection of the compressing structures in the interscalene triangle, thus, a scalenectomy can be performed when compression on the upper plexus is identified. Recent reports have demonstrated that significant relief of neurogenic symptoms can be achieved with decompressive operations that leave the first rib intact, and that this also minimizes complications (2, 8, 14, 15). Resection of the first rib has been recommended only for vascular TOS (8). For our patients, we used a more selective approach, consisting of excision of the osseous and fibrous anomalies, anterior scalenectomy and brachial plexus neurolysis via the supraclavicular route, sparing the first rib in all cases. Direct visualization of neurovascular and bony structures was excellent, and allowed to a precise anatomic decompression. Fortunately, we did not encounter any significant postoperative complications, and our results were comparable to those reported with other traditional techniques.

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