Neurovascular Disorders About the Shoulder

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Thibault Lafosse, Jose Carlos Diaz-Miñarro, and Daniel Rojas

Thoracic Outlet Syndrome

Introduction

First described by Peet et al in 1956 [1], the Thoracic Outlet Syndrome (TOS) refers to the compression of the brachial plexus at the thoracic outlet. This disorder includes a great variety of symptoms, resulting most of the time in significant disability and negative effects on patients' health-related quality of life. Making an accurate diagnosis may be challenging, which explains the long-lasting diagnostic wavering that patients regularly experience before a treatment is given, despite which the symptoms may still persist over time

Epidemiology

Precisely establishing the incidence of TOS is challenging. Depending on the authors consulted, the numbers vary from one case in 100 to one in 100,000 people [2, 3]. This variability may be explained by the multiplicity of conditions that can mimic TOS (Table 96.1) and thus lead to misdiagnose this condition. The existing data suggest that this disorder typically affects adolescents to middle-age adults, especially females between the third and sixth decades of life [3, 4].

Table 96.1 Disorders that can be misdiagnosed as a TOS

Disorders that can be misdiagnosed as a TOS	
Other neurovascular disorders	Compressive tumoral conditions
Cervical radiculitis	Complex regional pain syndrome
Peripheral nerve entrapment	Brachial plexopathy

For instance, in our practice we face four main situations leading to TOS diagnosis:

- Patients complaining from shoulder pain, previously managed by shoulder surgeons, who conducted thorough investigations which failed to yield a diagnosis of shoulder pathology.
- Double crush syndromes, typically illustrated by patients suffering from peripheral nerve entrapment syndromes in the upper limb, who underwent previous surgeries and experience recurrence of the neurological symptoms or the early onset of new entrapment-like symptoms in another neurological territory of the upper limb.
- Patients presenting scapulothoracic abnormal motions (STAM) related to multiple etiologies including peripheral nerve impairment or muscular dyskinesia secondary to chronic pain or contracture.
- Finally, patients may be sent directly to our office with a TOS diagnosis made after complete clinical and paraclinical investigations. Occasionally, it can be revealed by a post-traumatic decompensation, mostly responsible for an acute deficit, both motor and sensory, in the territory of the inferior trunk and/or medial cord. The condition usually follows a cervical spine trauma and may spontaneously recover. Investigations eliminate cervical spine lesions and may reveal an unknown cervical rib or hypertrophic C7 transverse cervical process.

Pathophysiology

TOS can be caused by congenital, acquired or traumatic factors although most TOS cases are now thought to stem from an anatomic predisposition with a superimposed neck

T. Lafosse
Alps Surgery Institute, Hand, Upper Limb, Brachial Plexus, and Microsurgery Unit (PBMA), Clinique Générale, Annecy, France

J. C. Diaz-Miñarro
Shoulder and Elbow Department, University Hospital Reina Sofía, Córdoba, Spain

D. Rojas (✉)
Shoulder and Elbow Department, Hospital Regional de Talca, Talca, Chile

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Table 96.2 Abnormalities found in TOS

Soft tissue—70%	Bone abnormalities—30%
Variation in scalene muscle origin/insertion Hyper contracture of the scalene, subclavicular and pectoralis minor muscles secondary to repetitive traumas, and work-related injuries.	Cervical ribs (80% of the patients with TOS and cervical ribs show symptoms only after trauma) (Fig. 96.1).
Scalenus minimus (accessory muscle found in 30–50% of TOS cases)	Prominent C7 transverse processes
Congenital ligaments or bands	Exostoses or fracture callus
Scarring followed by trauma	Tumor

trauma, either from a single acute incident or from repetitive stress injuries [3, 5]. Nearly 70% of the cases are related to soft tissue etiologies (such as scalene hypertrophy, hypertonicity, regional tumors, or a muscular variation such as the scalenus minimus muscle). Most of the soft tissue impairments responsible for TOS are combined with an infraclavicular component of the compression particularly at the level of the subclavicular and pectoralis minor muscles. The remaining 30% are related to bone abnormalities such as cervical ribs or joint injury with resulting malunion [6] (Table 96.2).

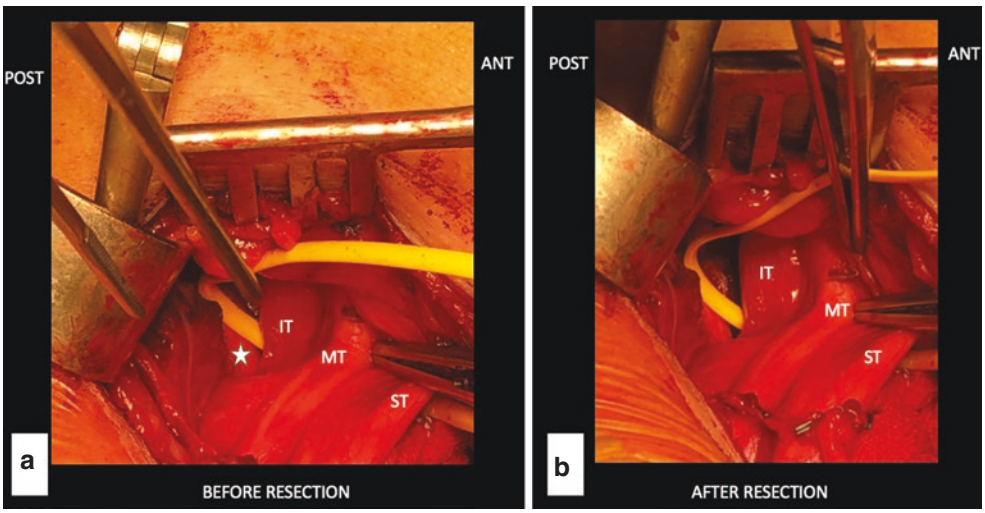

Fig. 96.1 Right side (**a**) Exposition of the interscalenic plexus before. (**b**) After the resection of the cervical process (star), the plexus is reclined anteriorly (st: superior trunk, mt: middle trunk, it: inferior trunk)

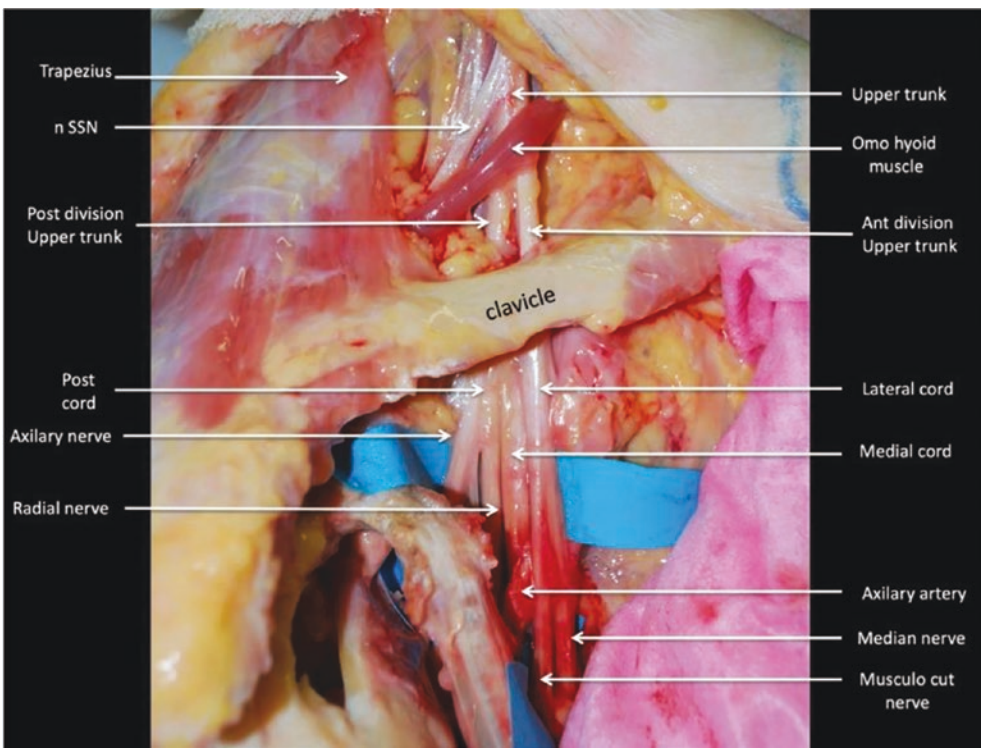

Fig. 96.2 Anatomy of the brachial plexus and the proximity to vascular and bony structures

Anatomy (Fig. 96.2)

The thoracic outlet is defined as a succession of intervals within which the neurovascular structures of the upper limb are entrapped at several levels that can be combined. Ranging from the emergence of the cervical roots and the trunks of the brachial plexus in the supraclavicular fossa, to the costoclavicular space, they then reach the axilla and the brachialis fascia. Despite the complexity of the anatomy, there are three main areas where the neurovascular structures of the upper limb can be compressed resulting in a TOS [7–9] (Fig. 96.2).

Interscalene triangle: It is the space bordered by the anterior scalene muscle, the middle scalene muscle, and the first rib. The scalene triangle contains the trunks of the brachial plexus and the subclavian artery. The subclavian vein passes anteriorly to the anterior scalene. Structures within the scalene triangle are often compressed by anatomic variations of the scalene muscles, the presence of the scalenus minimus muscle, fibrous bands, or osseous abnormalities such as the presence of a cervical rib [4] or hypertrophic cervical transverse processes. However, without anatomic variation, they can also suffer from permanent muscular contractures of the scalene muscles or post-traumatic fibrotic evolution of these structures.

Costoclavicular space: This space is made up anteriorly by the middle third of the clavicle, the subclavian muscle, and the costocoracoid ligament, and delimited posteriorly by the first rib and the scalene muscles. Compression within this compartment usually may result from positional disorders secondary to repetitive overhead movements, combined or not with hypertrophy of the subclavian muscle [10].

Subcoracoid space: It is the area anteriorly bounded by the pectoralis minor muscle, posteriorly by the 2–4 ribs and superiorly by the coracoid process. The subcoracoid space houses the cords of the brachial plexus, and the axillary artery and vein. These may be compressed by the clavipectoral fascia or by the hyperactivity of the pectoralis minor [6]. We often identify overdeveloped muscular bounds between the pectoralis minor and the coracobrachialis muscle, narrowing the space under the pectoralis minor through which the cords and axillary vessels exit. The entrapment is thus combined, resulting from a wide and bulky muscular tissue narrowing the space around the neurovascular bundle and the active contraction of those muscles, chronically and actively irritating the nerves they surround.

Classification

Depending on the structures involved, TOS can be divided into: Neurogenic TOS (nTOS), Venous TOS (vTOS), and Arterial TOS (aTOS). nTOS has been reported to represent more than 95% of all TOS cases, while vascular TOS is less frequent and accounts for roughly 4% and aTOS just 1% [11]. aTOS usually involves the compression of the subclavian artery (typically in the interscalene triangle associated with a cervical rib) and vTOS involves the subclavian vein (usually within the costoclavicular space) [4, 10]. Vascular TOS represents situations with a risk of evolution to complex situations such as venous thrombosis or arterial aneurisms, and it therefore requires surgical management more often than nTOS. The complexity of this condition usually makes it more easily and more comfortably managed by a team of vascular and peripheral nerve surgeons.

True and Disputed Thoracic Outlet Syndrome

In cases of objective findings of nerve impairments, both sensory or motor, the nTOS is considered as a true nTOS [12]. Most of the deficit reported in the literature involves the lower trunk territory. However, most of the patients suffering from nTOS do not present any objective signs of neurological impairment. They are rather complaining from subjective pain, discomfort, loss of strength in the hands, and paresthesia, influenced by the position of the arm, and the repetition of movements leading to an upper limb fatigue. Nonspecific pathological evidence of TOS is classified as disputed TOS [13]. True neurogenic TOS is a very rare disorder with a prevalence of one in a million [9]. The disputed or nonspecific TOS is a more controversial but frequent entity because of the lack of anatomical, clinical or electrophysiological objective evidence [14]. Most neurogenic TOS cases are known to be disputed TOS, but many other pathologies are unproperly considered disputed nTOS, as it remains a difficult clinical entity to diagnose in practice [9, 13].

Clinical Assessment

Presentation

In the situation of an acute decompensation of a chronic situation, history of neck trauma should raise suspicion of nTOS, with motor vehicle accidents being the most common inciting incident. It happens in a situation of pretraumatic discomfort of the upper limb caused by stress due to repetitive movement, especially in manual workers with an overhead activity, or athletes who practice overhead sports [15]. Patients are frequently young, active, and healthy and they often have seen multiple physicians with different diagnoses [3, 4].

In general, the symptoms associated with TOS are very variable depending on the structures involved and the severity of the compression. There can be found upper extremity weakness, numbness, paresthesia, pain in nonradicular distribution. Symptoms are present during daily activities as well as during sleep. Subjective sensation of upper limb heaviness and fatigue is common with overhead activities.

Upper extremity paresthesia occurs in 98% of the patients such as numbness or tingling. The appearance of pain is also

frequent over the trapezius in 92% of patients but they can also suffer from pain over the neck, shoulder or arm (88%), supraclavicular pain (76%) or chest pain (72%). Occipital headaches are another common complaint, occurring in 76% of TOS patients [16].

Compression of the lower plexus (C7–T1 roots) manifests as pain of the ulnar forearm and hand, paresthesia of the fourth and fifth digits, and hand weakness or loss of dexterity. Similarly, compression of the upper plexus (C5–C7 roots) results in pain in the supraclavicular region that may radiate into the ipsilateral head, face, upper chest, and periscapular region, along with arm weakness and paresthesia of the first three digits [16, 17]. TOS must be differentiated from other compression syndromes, such as carpal or cubital tunnel syndrome and cervical nerve compression. Such a distinction may be made by the wide anatomic distribution and the nonradicular nature of the symptoms in TOS [4].

In our experience, most patients with TOS have a history of vague symptoms that are difficult to differentiate from other causes of shoulder pain. Diagnosis depends upon both knowledge of the patient's existing risk factors and their clinical presentation, and it may be confirmed with physical exam maneuvers, radiographic imaging, or vascular studies.

Pectoralis Minor Syndrome

The Pectoralis minor syndrome (PMS) is a neurovascular disorder which causes brachial plexus compression under the pectoralis minor. Presentation is often similar to TOS: Many patients have a history of traumatic incident, such as a motor vehicle accident or a fall down the stairs. In the absence of history of an injury, patients should be asked about their occupation, exercise habits, and sports participation, looking for a cause of repetitive stress injury (RSI). RSI occurs in many forms. Working on assembly lines or keyboards are well-recognized causes of RSI [18]. Some sports have been seen to cause PMS, such as swimming, baseball (especially pitchers), volleyball, or weightlifting [19].

Paresthesia is common in both TOS and PMS in over 90% of the patients. However, neck pain and occipital headaches are much common in TOS. Pain or tenderness in the axilla and the anterior chest wall just below the clavicle strongly suggest PMS. Pain in the shoulder, upper arm, and forearm is frequent in both of these conditions [18].

In most of our patients suffering from TOS, we tend to assume they also suffer from PMS as well.

Diagnosis

An exhaustive exam of the entire upper limb must be done in order to exclude other causes of pain and to identify muscle weakness, wasting or atrophy or signs of neuropathy in order to locate the site of impingement and the nerve roots involved [20]. It is, however, important to note that there are often overlaps in symptomatology when multiple structures are compressed [4].

Like peripheral nerve entrapment, TOS has several provocative maneuvers and tests that can guide us to determine the site of impingement and the structures involved. However, the authors advice that there is no maneuver that is pathognomonic for TOS, and the results found after the physical examination should be interpreted with caution. There is a high rate of false positives for many of these tests and even 91% of the asymptomatic population will develop positive symptoms from at least one of the tests used to detect TOS [21].

To our experience, the typical clinical presentation is the triad of pain, paresthesia, and weakness in the neck and upper limb, associated with positive provocative maneuvers [14]. Only a thorough history and physical exam with an emphasis on detecting neurovascular compromise, in combination with additional diagnostic tests and imaging, can accurately diagnose TOS and help make an effective treatment plan.

Physical Examination

The examination consists of careful observation, followed by palpation and various provocative maneuvers. Atrophy should be ruled out; therefore the patient is examined topless, inspected from the front and from the back.

Active movements should be asked to the patient in order to check for any scapulothoracic abnormal motion (STAM). As the interrogation may have led to suspecting a TOS, the clinical examination may focus on confirming that diagnosis; however, both a shoulder and cervical spine clinical examination should be performed in order to eliminate other causes for upper limb pain. Only then can the clinical exam focus on the TOS and PM diagnosis.

Palpation

- Around the coracoid, where the PM is attached, it can reproduce both a standard local pain and an irradiation in the usually painful territory. A gentle percussion above the tendon may increase the neurological discomfort. This sign is called a Pseudo Tinel sign and corresponds to a peripheral nerve irritating symptom.
- The same symptoms can be highlighted at the suprascapular level, with the scalene muscles. The palpation of their insertion on the first rib can be painful, and also trigger neurological discomfort.

– The pain created by the palpation of the muscles responsible for the symptoms corresponds to their permanent contracture

Suprascapular Nerve Test

In most of the cases, the suprascapular nerve is also entrapped. This can be explained by the position of the scapula which is permanently positioned in a pathological way, creating a traction on the SSN which can impinge under the transverse ligament at the coracoid notch [22]. We asses this condition by compressing the SSN at the coracoid notch from the back of the shoulder, through the upper trapezius and supraspinatus, creating the usual pain, and reproducing that pain by an SSN stretch test maneuver as described by Lafosse [23, 24].

Brachial Plexus Stretch Test

The compression and permanent traction of the brachial plexus is enhanced during physical examination by looking for impingement under the subcoracoid and interscalene spaces placing the patient in abduction, external rotation, and retropulsion of the shoulder with the head rotated in a contralateral direction. It is important to highlight the difference with cervical spine pathology, and root compression, by looking for spine stiffness and pain, gently mobilizing the cervical spine, and looking for pain triggering while coughing, and cervical spine compression with Spurling or Davidson maneuvers. The cervical spine-related pain is rather improved by decompression maneuvers including contralateral rotation of the head. Central neurological signs such as positive Babinski or Hoffman signs should not be found in TOS.

Pectoralis Minor Stretch Test

It is an evolution of the Brachial plexus stretch test which focuses on the motion of the scapula on the thorax. The PM prevents the retropulsion of the scapula when hypercontracted. With the shoulder and arm in a resting position, a retropulsion of the shoulder should trigger the pain and discomfort, independently to the position of the arm. In cases of vascular compression, the pulse may also be fading. A positive PM stretch test orientated to the PM tenotomy. However, we tend to systematically perform this step during surgery, therefore, a positive PM stretch test has more value when positive while brachial plexus stretch test is negative, suggesting an absence of supraclavicular impingement.

Roos Maneuver

The patient is placed in bilateral abduction external rotation and is asked to open and close his hands. Each open-close movement is called a cycle. The patient must count the number of cycles after which the symptoms start. We evaluate the severity of the symptoms with this number. The lower the number of cycles triggering the symptoms, the more severe the suffering is. In our practice, we consider this test positive below 20 cycles.

Adson, Allen, and Wright Test

Those maneuvers position the arm in the different positions which were previously described (i.e., respectively abduction and external rotation, traction and retropulsion of the arm combined with a contralateral rotation and traction of the head), and focus on the impact is on the radial pulse, looking for an arterial symptom. When positive, they orientate to vascular components of the TOS [25].

Imaging

The combination of both clinical history and physical examination often leads to suspicion of TOS. Nevertheless, imaging is always necessary to rule out differential diagnosis, and helps to identify the TOS subtype and exact anatomical site of compression.

Obtaining plain radiographs of the chest and cervical spine is always recommended in order to identify bony anomalies such as cervical rib, prominent C7 transverse processes, low-lying shoulder girdles, or old fractures, all of which may contribute to TOS [4, 16].

CT scan and MRI have specific indications and can be effective in the setting of an identifiable congenital anomaly or a space-occupying lesion (e.g., Pancoast tumor or metastatic disease). An MRI of the brachial plexus is mandatory in order to look for a peripheral nerve tumor. In the event of a suspected case of vascular TOS, doppler ultrasound and angio-CT scan are necessary to accurately identify the compression. The ultrasound enables both the detection of the compression and the amount of reduction of the vascular flow. The angio-CT scan may highlight the vessel damage, such as venous thrombosis or arterial aneurisms. Therefore, their use is systematic in our practice [26].

The EMG test is usually normal; therefore, it is often used in conjunction with other diagnostic tests to rule out other etiologies of neuropathic pain and it is rarely used alone due to frequently negative, nonspecific, and varying results. What can be found in initial stages of TOS are abnormal nerve conduction in T1 and C8 distribution (medial antebrachial cuta-

neous nerve and median motor nerve to the abductor pollicis brevis) [27]. Thus, a negative EMG does not mean there is no TOS, but it may probably be a dynamic entrapment not detectable by a test that is done statically [15].

Conservative Treatment

The primary goal with medical treatment for neurologic TOS is mainly nonoperative unless significant vascular compromise, muscle atrophy leading to diagnosis of an objective TOS, or an important disability is found. Modifications in daily life activities, pain control, and physical therapy will be the first line of treatment [3]. The Proost protocol is the physiotherapy program that we foster in our practice.

It is important to avoid all activities that trigger the symptoms, even to change sports or employment when necessary. Physical therapy will be aimed at improving core and back strength, correct body postures, and relax muscle contractures. Primary targeted muscles are usually the scalenes and the pectoralis minor, with stretching exercises for both [14, 28]. Nerve gliding exercises and fascia therapy are part of the therapeutic arsenal.

The psychological impact of the pathology is high and may be prevailing in the subjective forms of nTOS for different reasons [29]. First, the chronic pain may lead to depression and anxiety. Then, the condition preventing the patients from working tends to isolate them from their social life. And last, the absence of diagnosis and treatment options that patients often face when they meet healthcare professionals who are not familiar with their problem leads to living this condition as an incurable disease they will never be able to overcome. Hence, psychological management is one of the major issues in the treatment of TOS, related to both the support of mood disorders and the teaching of self-management of the psychological aspect of chronic pain.

A socioprofessional adaptation should surround the medical treatment and may affect the psychological management as it will ease the social pressure often felt by the patients. They should be provided temporary or permanent work reorganization in order not to trigger their symptoms anymore, helping them to be back to work as soon as possible without maintaining the mechanism of their pathology.

Usually, a high percentage of patients find an important relieve of their symptoms after conservative treatment. However, a higher rate of failure has been described in obese population, in patients that search a worker's compensation and those who have an associated neurologic pathology involving carpal or cubital tunnels [3, 4].

Anterior scalene blocks with lidocaine or even botulinum toxin have proven to be temporally effective in reducing symptomatic TOS, as well as a positive surgical prognostic factor [30–32].

Conservative treatment is beyond the scope of this chapter, so we will not further describe it [33].

Surgical Treatment

Surgical treatment is indicated when conservative treatment has failed, usually after a minimum of 6 months. It can be scheduled earlier in several situations [4, 12]:

- If there is an obvious anatomical modification responsible for compression (i.e., cervical rib, hypertrophic transverse cervical process, fibrotic band)
- In case of acute neurological deficit (i.e., motor or sensory deficit in the lower trunk or medial cord)
- In vascular etiologies with a severe impact highlighted by doppler ultrasound

The objective of surgery combines different options and is, as in any other nerve entrapment surgery, to decompress the structures involved [4, 6, 14]. In our practice, the procedure is performed either arthroscopically or with open surgery, and the indication for each one of the approaches depends on several factors. The principles remain the same regardless of the selected method:

1. Interscalenic debridement, performing a suprascapular nerve release at the coracoid notch, and/or a scalenectomy
2. Costoclavicular space increasement by first rib resection and/or subclavicular muscle resection
3. Retrocoracoid space release with systematic pectoralis minor tenotomy and subcoracoid bursa debridement

Open Surgery

The surgical procedure for patients suffering from TOS has been described by many teams and combines several techniques and approaches, including the transaxillary or supra-infraclavicular approaches, isolated or combined. The aim of the surgical approach is to provide a safe exposure of the brachial plexus, the first rib, and the vessels. These approaches provide a direct view of certain parts of the rib. Depending on whether a vascular or neurologic etiology is suspected, some teams choose to selectively dissect either the medial or posterior portion of the rib.

In neurogenic TOS, reconstructive surgeons prefer the supraclavicular approach to achieve a thorough neurolysis of the brachial plexus. However, an incomplete resection of the anterior portion of the first rib as well as the costoclavicular ligament and the subclavius tendon can be difficult when using this approach.

Endoscopic Surgery

Some studies highlight that hyperactivity of the pectoralis minor, known as neurogenic pectoralis minor syndrome (NPMS), is a major factor in TOS, and even isolated pectoralis minor tenotomy can achieve similar results than scalenectomy and first rib resection for selected patients with TOS due to NPMS [6].

Recent progress in shoulder arthroscopy has led us to operate outside the glenohumeral joint cavity, around the terminal branches of both the infraclavicular and the supraclavicular brachial plexus. This allows us to perform endoscopic procedures such as Latarjet, suprascapular nerve release, latissimus dorsi transfer or far retracted subscapularis tendon repair. Endoscopic surgery in this area requires a perfect visualization of brachial plexus branches due to their proximity.

Our daily practice for TOS surgical treatment includes an all-endoscopic technique for infra- and supraclavicular plexus neurolysis. This plexus dissection is safe and allows us to, starting distally from the glenohumeral joint, dissect the plexus widely and perform an efficient decompression in TOS [14].

Author's Preference for Surgical Technique

Open Approach

The patients are set up in the supine position and placed under general anesthesia. In case of neurologic deficit, the use of paralyzing drugs is strictly limited to the induction phase of general anesthesia.

The entire upper limb is draped. The head is rotated toward the opposite direction of the operated side.

In our practice, at least two incisions are systematically performed, a transverse supraclavicular incision and a short deltopectoral approach. In addition, when necessary, a transverse subclavicular incision is made for better control the anterior third of the first rib and the subclavicular vein.

The basic principles of the procedures are as follows.

The supraclavicular approach is made 2 cm proximal to the clavicle, in the Langer's lines. The platysma is incised, hemostasis is made layers after layers. The supraclavicular fat pad is incised posterior to the sternocleidomastoid muscle and the superior border of the clavicle. It is then reclined posterior and superior to expose the plane of the omohyoid muscle, brachial plexus, and scalene muscles.

The omohyoid muscle is incised, and the brachial plexus exposed at the level of the trunks. They are exposed between the middle and anterior scalene muscles (Fig. 96.3).

Both those muscles are inserted on the first rib. They must be isolated from the surrounding structure (i.e., brachial plexus, phrenic, and long thoracic nerve, subclavicular vessels) and detached from the first rib.

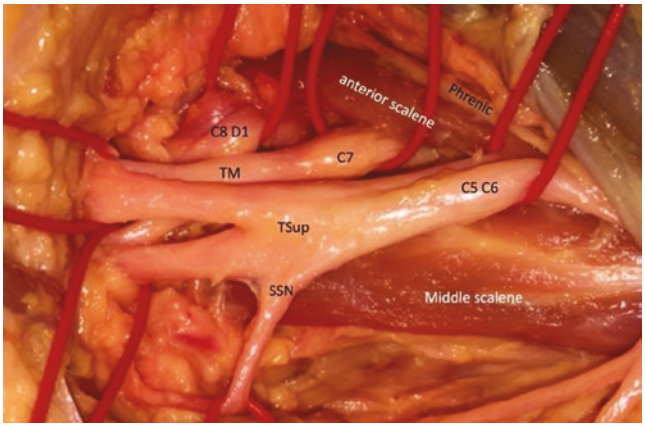

Fig. 96.3 Exposition of the three trunks of the brachial plexus prepared on silicon loops

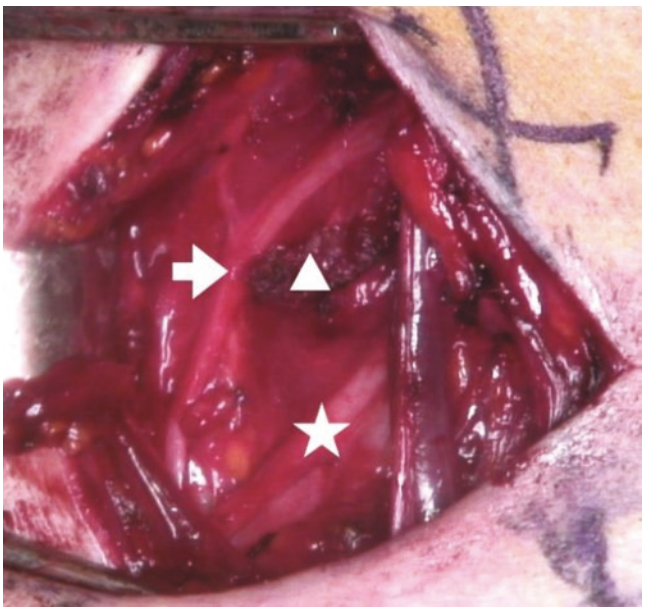

Fig. 96.4 Long thoracic nerve and middle scale section. With the patient in supine position, by means of a simple incision at the supraclavicular space, the important structures are identified. The middle scalene muscle and any adhesions can then be resected. Middle scalene muscle resected (triangle), long thoracic nerve (arrow), and suprascapular nerve (star)

The anterior scalene muscle is isolated by dissecting the phrenic nerve, and the subscapular artery. The anterior scalene is cut above the artery, to provide a good exposition of the artery. Some of the muscle therefore remains attached on the anterior arch of the rib and must be removed to expose the bone.

The middle scalene is isolated from the long thoracic and the dorsal scapular nerves. It must be followed to its insertion on the posterior arch of the first rib (Fig. 96.4).

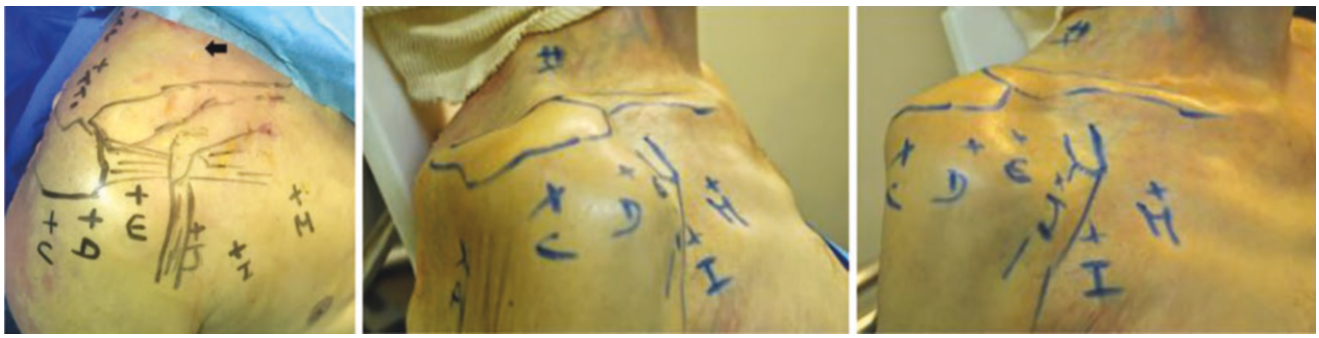

Fig. 96.5 We use a minimum of eight endoscopic portals, including four supraclavicular portals and four infraclavicular portals

Once both the scalene muscles are exposed and isolated, the whole interscalene brachial plexus is isolated from the superior to inferior trunks. It is then mobilized from its adhesions above the superficial face of the first rib. The following step is to perfectly identify the anterior and posterior arches of the first rib, which requires to expose the subclavian artery and its branches. The more the artery is released and isolated from the surrounding tissues, the safer its mobilization will be.

Once the artery can be mobilized, the anterior arch or the first rib can be sufficiently exposed on its superficial face. The deep dissection should be performed to detach the pleura from the deep face of the first rib.

In some anatomical forms, the vein should be further dissected in order to properly and safely expose the anterior portion of the rib before resecting it.

In such situation, we prefer to perform a complementary subclavian approach through the pectoralis major. It allows the exposure of the subclavicular vein, the medial portion of the subclavian artery, and the anterior arch of the rib.

The rib is then transected using either an oscillating saw or Kerrison grasper. The subclavicular anterior transversal approach also helps to perform a complete subclavian muscle resection, thus widely opening the subclavicular space.

In some cases of severe chronic veinous compression, we have had to perform a reconstruction of the vein through a bypass, during which the above-mentioned incision was mandatory.

In our practice, a complementary deltopectoral approach is systematically performed in order to detach the pectoralis minor from the coracoid process and release the subcoracoid bursa and the cords.

When the surgery is finished, the skin is closed in layers on a drain and the patients are discharged after a two-day surveillance.

The main complication found in this procedure is pneumothorax, which occurs mainly due to severe adhesions between the pleura and the rib.

Endoscopic Approach

NB: The description of the endoscopic technique of brachial plexus release is included in various publications from the author and is thus briefly reviewed in the following paragraph.

The patients are set up in a beach chair position and operated on under general anesthesia combined with interscalene locoregional anesthesia. The whole upper extremity is included in the field and simple traction, a robotic arm holder or an assistant can be used to hold and manipulate the arm. We also have the experience of the lateral decubitus position, which was used at the beginning of our practice. However, we now favor the low beach chair position. The lateral part of the neck should be draped as well, paying particular attention to allow the conversion to an open approach, thus draping the sternocleidomastoid and trapezius muscles and exposing the interscalene triangle all the way up to the ear. The endoscopic portals are described below (Fig. 96.5).

Supraclavicular Portals

There are two subacromial and two transtrapezial portals. The C portal is a subacromial portal. It is located at the level of the middle of the acromion and 2 cm distal to its lateral border.

The D portal is a subacromial portal. D is anterolateral, 2 cm distal to the anterior angle of the acromion.

The lateral transtrapezial (LT) (TT1) and the medial transtrapezial (MT) (TT2) portals are both located 2.5 cm distally from the upper border of the trapezius. They are used for the release of the suprascapular nerve at the coracoid notch

The LT portal is at the level of the suprascapular notch, it is created under endoscopic control from the C and D portals.

The MT portal is at the level of the middle of the clavicle. It is created under endoscopic control from the D and LT portals.

Additional can be created to perform the scalenectomy as described by Bader, Lafosse, and Garcia JC Jr [34].

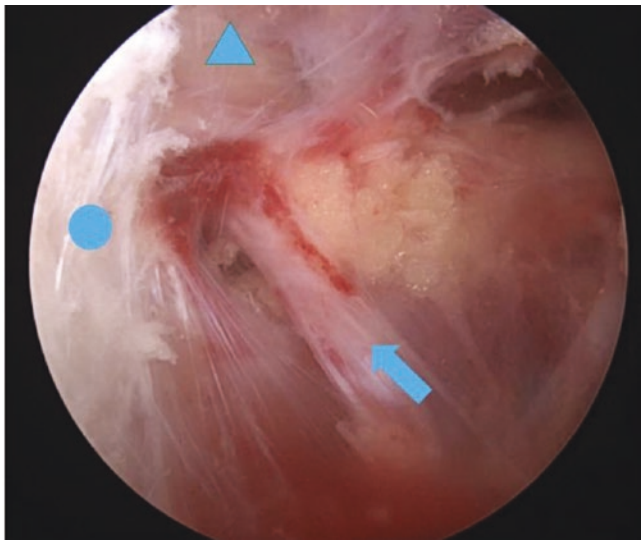

Fig. 96.6 Suprascapular nerve (arrow) lies underneath the transverse ligament (triangle) and on the left of the image we can see the base of the coracoid process (circle)

Infraclavicular Portals

The E portal is anterior and lateral, 2 cm distal to the acromioclavicular joint, facing the rotator interval.

The I portal is in the axis of the coracoid process and faces it 2–3 cm below.

The J portal is at mid distance from the I and D portals.

The M portal is 4 cm distal to the clavicle and 3 cm medial to the coracoid process and the conjoint tendon.

SSN Release

The first step is to release the SSN. We use the technique previously described by Lafosse et al. [23]. We use the C portal as a visualization portal and the D portal for instrumentation along with the two transtrapezial portals for instrumentation. We follow the anterior border of the supraspinatus muscle until we reach the coracoclavicular ligaments. At this point, we look for the transverse ligament, perpendicular to the coracoclavicular ligament under which lies the suprascapular nerve (Fig. 96.6).

The LT portal is created under endoscopic control, introducing a needle before incising through the trapezius muscle, as previously described. An endoscopic cutting device is introduced in this portal toward the suprascapular notch, and the ligament is cut, freeing the suprascapular nerve.

The MT portal is created as previously described, and under endoscopic control, introducing a needle as with the lateral transtrapezial portal.

The scope can switch to the LT and the instrumentation through the MT.

The dissection of the suprascapular nerve can be completed by proximally reaching the upper trunk.

Interscalenic Trunk Release

The second step is to start the release of the trunks through the two transtrapezial portals.

After releasing the suprascapular nerve, we follow it proximally until it reaches the superior trunk. At this level, we release the fibrous bands found around the nerves between the scalene muscles and perform an intraneurodissection using a smooth trocar. We do not perform the scalenectomy through this portal. However, the long thoracic nerve can be exposed and released during this step.

Exposure of the Infraclavicular Plexus Area

The dissection is started from the subacromial area with the scope through the C portal, and the instruments through the D portal. The E portal is created, as previously described and under endoscopic control, with a needle before incising the skin. After opening the clavipectoral fascia, the conjoint tendon (CT) and coracoid process are dissected, and the retropectoral space is enlarged anteriorly between the coracoid process and the pectoralis major. The retropectoral space is limited anteriorly by the posterior face of the pectoralis major muscle, and posteriorly by the coracoid process and the anterior face of the PM muscle. This space is an anatomical plane that must be found during dissection and enlarged using a smooth trocar and the help of the water flow. Hemostasis is often needed and achieved with the radiofrequency.

The I portal is created with endoscopic control, introducing a needle. The J portal is created at mid distance from the D and I portals, and the scope is introduced in it. The scope is directly facing the coracoid process, and the operator can see the PM muscle and the conjoint tendon very clearly. The limit between the conjoint tendon and the PM muscle bellies is sometimes difficult to visualize. However, it is an important area to identify and dissect because it is the only way to safely expose the musculocutaneous nerve, which lies just below.

Subclavian Muscle Section, Costoclavicular Space Release

The M portal is created as previously described. It allows the dissection of the retropectoral space, the CT, PM, and the medial border of the coracoid process. The axillary artery is reaching the BP medially at the level of the cords, which are visualized at the upper border of the PM tendon, in the space under the clavicle bone (Fig. 96.7). The space under the clavicle is increased and the subclavian muscle is detached from under the clavicle at a distance as large as the width of the three cords. The lateral, posterior, and medial cords can thus be exposed and followed toward the supraclavicular space. We then reach to the trunks, which have previously been dissected. The BP can be followed until the interscalene area, requiring the creation of additional supraclavicular portals.

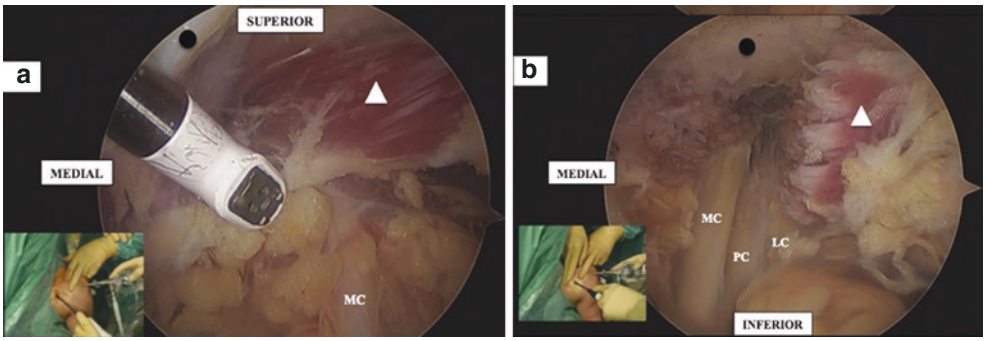

Fig. 96.7 Endoscopic release of brachial plexus (cords) through costoclavicular space. The three cords—medial cord (MC), posterior cord (PC), and lateral cord (LC)—are lying underneath the subclavian muscle (white triangles) and the clavicle (black circles) (**a**) and are freed released once the subclavian muscle is detached from the clavicle (**b**). A left shoulder is shown through portal J

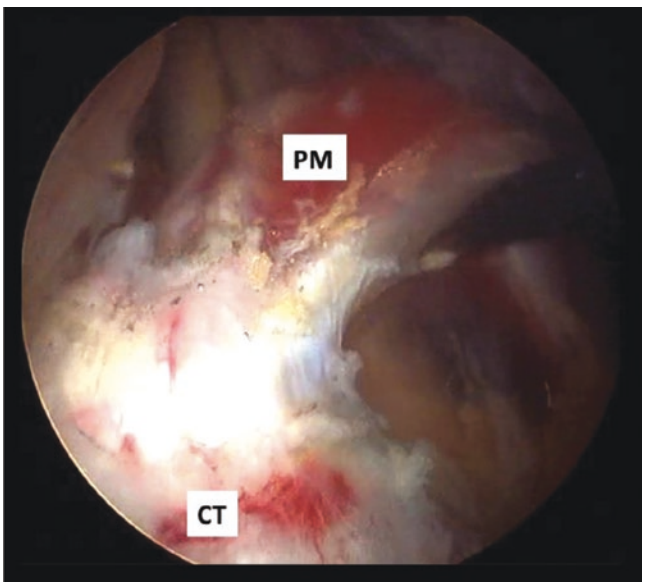

Fig. 96.8 Visualization from portal I. We observe the coracoid process, conjoint tendon (CT), and pectoralis minor (PM) free of adhesions prior to being disinserted

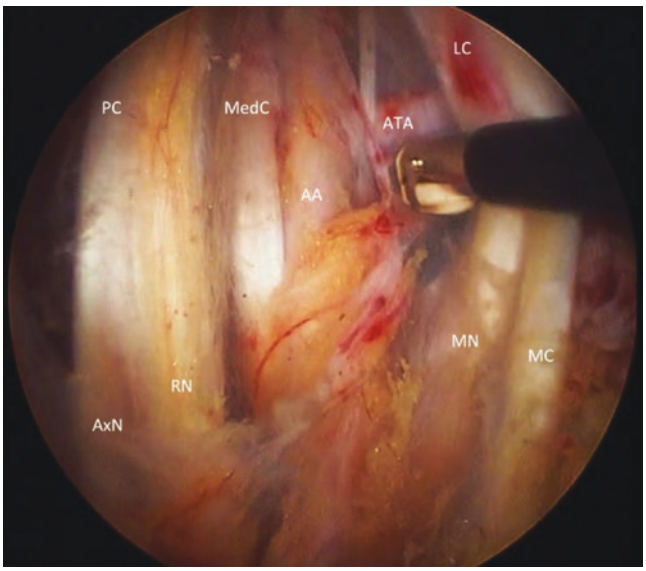

Fig. 96.9 View from portal I after detachment of the pectoralis minor with direct visualization of the cords and terminal branches of the brachial plexus

Pectoralis Minor Section, Terminal Branches Release (Figures)

The space between the conjoint tendon and the PM is opened and dissected to visualize the musculocutaneous nerve and the terminal branches (Fig. 96.8).

Only then, the PM tendon is detached from the coracoid process, and the dissection continued. The three chords are followed from proximal to distal. The plexus branches and the axillary artery, which reach the cords from medially at the level of the coracoid process, are dissected by carefully cutting the fibrous bands often surrounding (Fig. 96.9).

The lateral chord gives the musculocutaneous nerve and the lateral branch of the median nerve, which are the first terminal branches to be visualized.

Laterally and behind those two nerves, the axillary and radial nerves come from the posterior chord. They are exposed reclining the axillary artery, the musculocutaneous, and median nerves medially. They are also exposed and dissected from an approach posterior to the coracoid process, following the anterior border of the subscapularis muscle (SSC). It leads to the division of the posterior cord into the radial nerve, and the axillary nerve, separating at this level to reach for the quadrilateral space (Fig. 96.10).

The Ulnar nerve comes from the medial chord. It is seen behind the artery, and more medial to the rest of the plexus.

The dissection is stopped after the branches are identified and released from any adhesions and fibrous bands.

The first nerve identified during dissection changes with the approach and the portal. From an aspect anterior to the coracoid process, the first nerve to be found is the musculo-

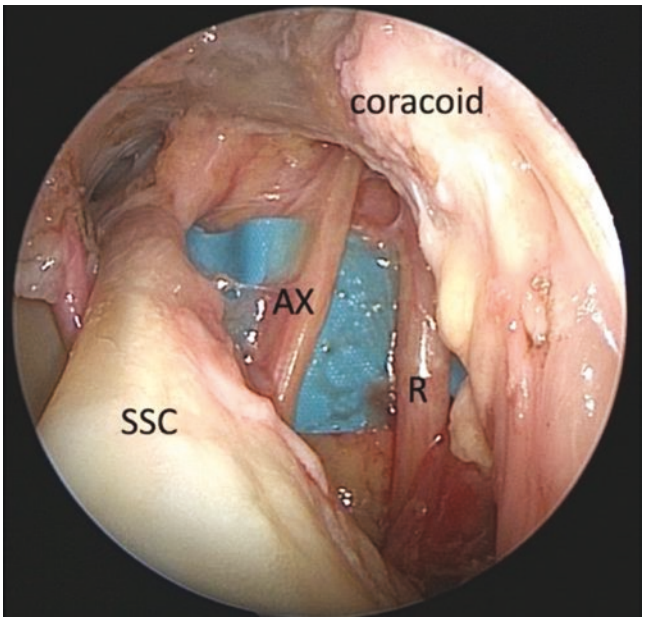

Fig. 96.10 Visualization from the D portal of the axillary nerve and radial nerve

cutaneous nerve, but from approach posterior to the coracoid process, the first nerve to be found is the axillary nerve.

Supraclavicular Plexus Release

The costoclavicular space is reached after exposing the subclavian muscle. Using the lateral pectoralis nerve as a landmark, the plane between the brachial plexus and the subclavian muscle is identified. Anatomical variations of the subclavian muscle or the presence of the pectoralis minimus muscle may entrap the plexus in this area. Radiofrequency myotomy of the subclavicular muscle can be performed until the clavicle is reached. Using the soft tissue shaver with no aspiration will increase muscle resection and increase the cervical space view. In some selected cases (distance between the plexus clavicle of less than 1 cm), partial resection of the clavicle may also be performed using a bony shaver.

Through this same portal, the optics advances proximally to the cervical region between the plexus and the clavicle. Using a needle, the first cervical portal is located just above the clavicle, following the brachial plexus. A careful dissection through the cervical portal is performed, paying particular attention to the transverse cervical vessels, which are left in a more superficial plane, thanks to the hydrodissection starting from the plexus structures. The upper plexus trunk is identified, and the suprascapular nerves emerge, raising laterally and posteriorly toward the coracoid notch. At this anatomical location, the suprascapular artery crosses the plexus over the upper trunk or between the upper and middle trunks. More inferiorly, the dorsal scapular artery can be found at the level of the middle trunk.

Adhesions and/or a thickened fascia can be visualized between the scalene muscles and the brachial plexus. This fascia must be released, allowing visualization of the scalene muscles. Then, suprascapular nerve neurolysis can also be performed at this point.

The cervical portal is made about 2.5 cm from the supraclavicular portal and the radiofrequency device is inserted and used to increase the space around the entry point. Distance parameters may vary, but as usual, the portal is created under visualization control with the aim to create access between the middle and anterior scalenes. The optics is moved to the supraclavicular portal. The release of the sheath to the scalene hiatus is continued using radiofrequency through the cervical portal. The phrenic nerve which courses on the anterior border of the anterior scalene muscle needs to be visualized and protected. The middle scalene is dissected and the surgeon can identify the dorsal scapular nerve and/or the long thoracic nerve. They actually have a very similar origin, but their directions are different: the dorsal scapular nerve passes posteriorly and medially and the long thoracic nerve passes inferiorly, more anteriorly, and above the first rib.

These nerves usually present an intramuscular path. The middle scalene myotomy can be performed by direct visualization in order to release them. The surgeon can use the nerve stimulator in order to better understand which nerve is going to be released.

Patients are usually kept in observation for 24 h and discharged from the ward after the surgeon checked on them and no early complication occurred.

Complication/Prognosis

The main complication is the failure of an efficient relieve of the symptoms.

Patients must be informed that the procedures performed are putting their lives at risk whereas the objectives are functional improvements. Indeed, a real vascular and neurological risk exists with the extensive dissections of the neck and subclavicular area.

After endoscopic braquial plexus release, there was no complication reported. This technique seems to be safe and reproducible and provides significant functional improvements in the selected patients with nonspecific NTOS, with an average postoperative DASH score improvement of 36% [14].

This procedure must be limited to neurogenic cases, as well as to cases in which no anatomic variations or modifications are identified and this technique should not be applied to cases in which symptomatic vascular compression occurs, and it is not a technique that enables first-rib resection [13–34].

In conclusion, the main problem remains in the management of chronic painful upper limbs in patients with a presentation of subjective neurological symptoms. They are indeed for most of them extremely handicapped, with a wide impact on their personal, social, and professional lives. In our practice they are the type of patients to which we propose endoscopic release of the brachial plexus, in order to remain as minimally invasive as possible, still proposing a thorough release of the potential compression factors (i.e., pectoralis minor, subclavian muscle, and suprascapular nerve).

Finally, anatomic knowledge of the area by the surgeon, in addition to the ability to work in the region while performing open surgery, as well as anesthesiology cooperation, is mandatory.

Summary

- The thoracic outlet syndrome (TOS) refers to the compression of the brachial plexus at the thoracic outlet.
- Nearly 70% of cases are related to soft tissue etiologies (such as scalene hypertrophy, hypertonicity, regional tumors, or a muscular variation such as the scalenus minimus muscle).
- Our daily practice for TOS surgical treatment includes an all-endoscopic technique for infra- and supraclavicular plexus neurolysis. This plexus dissection allows us to, starting distally from the glenohumeral joint, dissect the plexus widely and perform an efficient decompression in TOS.
- We believe that diagnostic suspicion is essential, and we must always keep in mind our difference diagnosis.
- Knowledge of the anatomy and training with experienced surgeons in this technique allow the procedure to be safe and reproducible.

Key Points

- A detailed clinical examination of the patient is the most important point to define the necessary complementary studies and the best treatment for each particular case.
- The anatomy of the brachial plexus must be well understood before performing an open or endoscopic release.
- The endoscopic technique should not be applied to cases in which symptomatic vascular compression occurs, and it is not a technique that enables first-rib resection.
- The learning curve is the main limitation, but training with experienced surgeons, practice on cadaveric specimens, and knowledge of anatomy make the procedure reproducible and with a low rate of complications.

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