Technical Note

Endoscopic Release of the Brachial Plexus

Diogo Bader, M.D., Thibault Lafosse, M.D., and Jose Carlos Garcia Jr., Ph.D.

Abstract: Thoracic outlet syndrome is a debilitating condition, impairing the function of the upper limb, and can be considered an entrapment of neurovascular structures dedicated to the upper limb. Its open treatment uses a large approach, and to date, only the structures under the clavicle have been endoscopically approached. The purpose of this Technical Note is to describe an endoscopic brachial plexus decompression at all possible entrapment areas between the neck and the arm.

Thoracic outlet syndrome (TOS) is a debilitating condition, impairing the function of the upper limb, and can be considered an entrapment of neurovascular structures dedicated to the upper limb.[1,2] The entrapment can be situated at different levels between the neck and the arm, including the interscalene triangle, the upper border of the first rib (by the rib itself or a hypertrophic transverse cervical process with or without fibrous bands), the costoclavicular space, the retro-coracoid, the pectoralis minor, and the penetration point of the neurovascular bundle at the level of the brachialis fascia.[1] The exact location of the entrapment, as well as the cause of the compression and the structures involved, such as the brachial plexus and subclavicular vein and artery, can be difficult to access.

The TOS pathophysiology is multifactorial, including anatomic variations, cervical ribs, fibrous bands, anomalous muscles, joint hypermobility, or biomechanical dysfunction of the neck and scapular girdle related to labor, sports, or trauma.[3] In this scenario, bony compression resulting from narrowing of the space between the clavicle and the first rib or a cervical rib, which was previously considered the main cause of entrapment, will be responsible for just 20% to 30% of the cases.[1,2]

The diagnosis of TOS remains difficult and controversial. No consensus has been reached to establish objective criteria proving the diagnosis of TOS. Indeed, the compression is mainly dynamic; therefore, dynamic assessments seem to be more likely to figure out this pathologic condition, even though these assessments may be difficult or even present high rates of false-negative results.[4]

Among the TOS types, the most common is neurogenic thoracic outlet syndrome (nTOS). Some of the clinical characteristics of nTOS are pain, paresthesia, and weakness.[4]

The pain is usually neuropathic, affecting the posterior cervical area, as well as trapezius and pectoral regions. It may also be felt in the entire upper limb. In addition, weakness may be described by these patients.[1,4,5] Reports of pain, weakness, and paresthesia associated with irritative maneuvers will strongly suggest the nTOS diagnosis.[4,6]

Complementary examinations can be performed, mainly to exclude other diagnoses (i.e., root compression at the cervical spine, peripheral nerve tumor, or distal entrapment syndrome). One of the main situations that would suggest nTOS is dynamic arterial subclavian duplex velocity assessment. This assessment compares the differences between arterial subclavian flux at rest and that during stress maneuvers. The proximity between the brachial plexus and subclavian artery can provide one with an indirect suggestion of brachial plexus entrapment.[6-8] This can be useful even in patients with no apparent vascular compromise. Trained radiologists are also able to evaluate this entrapment by analyzing the amount of fat tissue

From NAEON Institute, São Paulo, Brazil (D.B., J.C.G.); and Alps Surgery Institute, Hand, Upper Limb, Brachial Plexus, and Microsurgery Unit (PBMA), Clinique Générale, Annecy, France (T.L.).

The authors report the following potential conflicts of interest or sources of funding: J.C.G. receives grant support as speaker and consultant of Zimmer-Biomet and as a consultant for Razek. Full ICMJE author disclosure forms are available for this article online, as supplementary material.

Received April 11, 2020; accepted June 9, 2020.

Address correspondence to Jose Carlos Garcia Jr, Ph.D., NAEON Institute, Avenida Ibirapuera 2144, CJ 82, Sao Paulo (SP), Brazil, 04028-001. E-mail: josecarlos@especialistadoombro.com.br

2212-6287/20653

https://doi.org/10.1016/j.eats.2020.06.020

around the brachial plexus and comparing its size between the resting shoulder and the shoulder positioned in abduction and external rotation.

The classical treatment in these patients is conservative,[6,7] consisting of pharmacologic measures, shoulder girdle rehabilitation, and ergonomic readjustment for working or exercising.[1,7] Surgery is indicated in cases refractory to conservative treatment, after a long period of rehabilitation.[8] Surgical techniques should be directed to the structures that cause entrapment. The most common procedures mention resection of the cervical rib, scalenectomy, and release of the pectoralis minor tendon next to the coracoid.[7-10]

Endoscopic soft-tissue decompression of the brachial plexus was initially performed in cadaveric models.[11] In vivo, until now, only subclavicular decompression of the brachial plexus has been performed. The suprascapular space has been released so far through the trans-trapezial portal, starting from a release of the suprascapular nerve and moving proximally to the interscalene area, without performing any scalenectomy or exposing the phrenic, long thoracic, and dorsal scapular nerves.[4] The purpose of this Technical Note is to describe an endoscopic brachial plexus decompression at all possible entrapment areas between the neck and the arm to manage patients with nTOS.

Surgical Technique

The procedure is performed with the patient in the lateral decubitus position under general anesthesia associated with an interscalene plexus block. The upper limb is set up with a traction device, allowing positioning of the shoulder in anterior elevation and slight abduction of 30° and 15°, respectively.

A standard bipolar radiofrequency device (VAPR; DePuy Synthes, Raynham, MA) is use. Saline solution infusion is used, just by gravity, through 4-way equipment with no pump.

Surgical Steps

The first step is the insertion of the video scope through the posterior portal for joint and subacromial space evaluation. In the bursal space, the lateral portal is created, followed by bursectomy. The coracoacromial ligament is identified and removed. The optic passes to the lateral portal, and the coracoid process and pectoralis minor tendon are identified. An anteroinferior portal is created in the axillary line, about 2 cm below the coracoid lateral to the conjoint tendon, with the help of a needle under visualization control.

The coracoid is exposed using the radiofrequency device through the anteroinferior portal, dissecting the space posterior to the pectoralis major and progressively moving medially until the pectoralis minor insertion can be visualized and released. The upper part of the pectoralis minor is exposed, along with the cords of the brachial plexus coming from lateral and medial areas. Under visualization control, the medial portal is made, 5 cm medial to the anteroinferior portal. The optic is moved to the anteroinferior portal (Fig 1); then, the radiofrequency device is inserted through the medial portal and is used to detach the pectoralis minor tendon, allowing visualization of the terminal branch of the musculocutaneous nerve and the neurovascular bundle.

At this step, 3 structures are visualized going from the brachial plexus toward the deltoid muscle: lateral pectoralis nerve, thoracoacromial artery branch, and cephalic vein. If fibroses or adhesions are found, they can be released in this region.

The costoclavicular space is then reached. By use of the lateral pectoralis nerve as a landmark, the plane between the brachial plexus and the subclavian muscle is identified. Anatomic variations of the subclavian muscle or the presence of the pectoralis minimus muscle may entrap the plexus in this area. Radiofrequency myotomy of the subclavius muscle can be performed until the clavicle is reached (Fig 2). Using a soft-tissue shaver (Razek, São Carlos, Brazil) with no aspiration will increase muscle resection and increase the cervical space view. In some selected cases (a distance between the plexus and clavicle < 1 cm), partial resection of the clavicle may also be performed by using a bony shaver.

Through this same portal, the optic advances proximally to the cervical region between the plexus and the clavicle. By use of a blunt dissector, the first cervical portal, named the supraclavicular portal, is created, just cranial to the superior aspect of the clavicle, over the brachial plexus (Fig 3). Particular attention should be paid to the transverse cervical vessels, which are left in a more superficial plane. One can insert the optic through the medial portal and devices through the supraclavicular portal. Identification of the upper plexus trunk, as well as emergence of the suprascapular

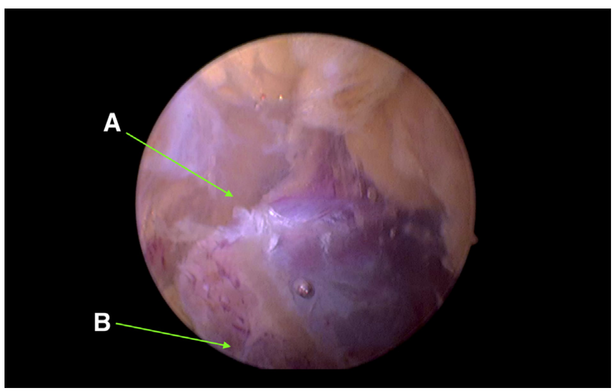

Fig 1. Fat over brachial plexus (A) and released pectoralis minor tendon (B) with scope through anteroinferior portal. Right side.

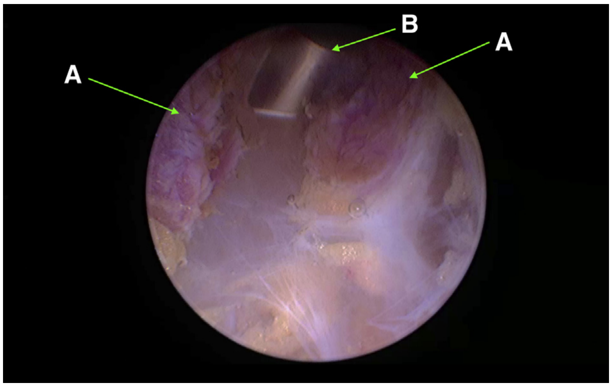

Fig 2. Subclavius muscle release (A) and electrocautery device (B) with scope through anteroinferior portal. Right side.

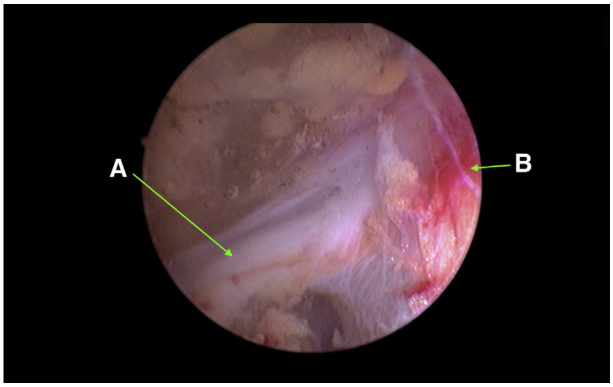

Fig 4. Suprascapular nerve (A) and upper trunk (B) with scope through medial portal. Right side.

nerve (Fig 4) rising laterally and posteriorly toward the coracoid notch, is performed. At this anatomic location, the suprascapular artery can cross the plexus over the upper trunk or between the upper trunk and middle trunk. 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. Suprascapular nerve neurolysis can also be performed at this point.

A 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 scalene and anterior scalene. The optic is moved to the supraclavicular portal. Release of the sheath to the scalene hiatus is continued using the radiofrequency device through the cervical portal (Fig 5). Regarding the phrenic nerve whose course is on the anterior border of the anterior scalene muscle, it is not easy or necessary to visualize this nerve by endoscopy; however, if visualized, it needs to be protected. The middle scalene is dissected (Fig 6), and the dorsal scapular nerve and/or the long thoracic nerve can be identified. These nerves actually have a very similar origin, but their directions are different: The dorsal scapular nerve goes posteriorly and medially, whereas the long thoracic nerve proceeds inferiorly, more anteriorly, and above the first rib.

These nerves usually present an intramuscular path; middle scalene myotomy can be performed by direct visualization to release them. One can use a nerve stimulator to better understand which nerve is going to be released.

The subclavian artery can be visualized after complete release of the anterior and middle scalenus muscles (Fig 7, Video 1); the portals developed for this technique are shown in Fig 8. Thereafter, revision of hemostasis and additional scalene myotomies may be performed with the radiofrequency device. A needle is positioned between the 2 cervical portals for infiltration of a solution containing betamethasone, tramadol, tranexamic acid, and magnesium sulfate. Extubation requires additional care because infused fluid can sometimes compress the airways.

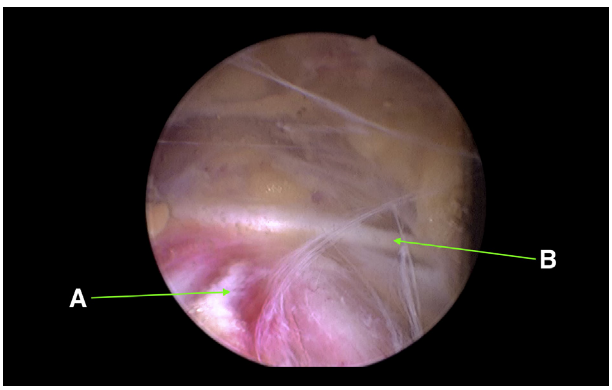

Fig 3. Upper trunk (A) and suprascapular artery (B) with scope through medial portal. Right side.

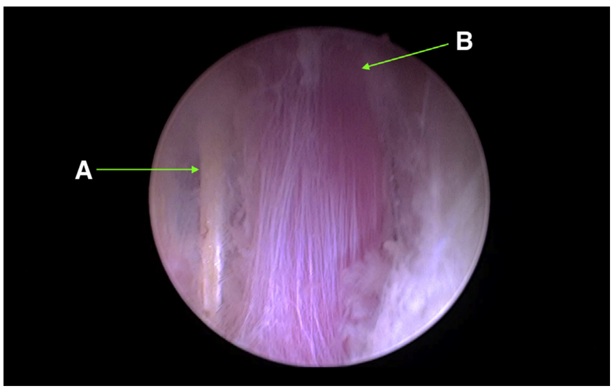

Fig 5. Fibrous adhesion (A) and anterior scalene muscle (B) with scope through supraclavicular portal. Right side.

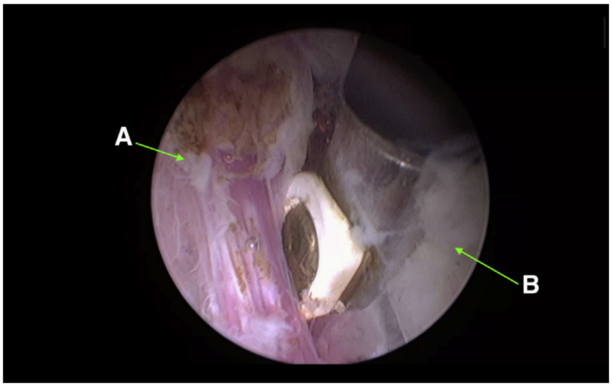

Fig 6. Scalene muscle (A) and brachial plexus (B) with scope through supraclavicular portal. Right side.

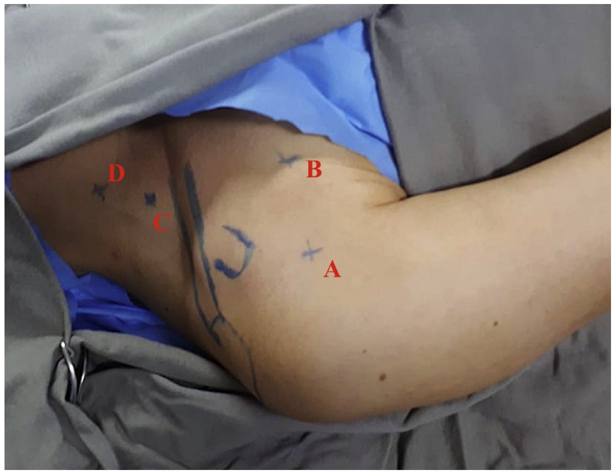

Fig 8. Special portals designed for procedure: anteroinferior (A), medial (B), supraclavicular (C), and cervical (D).

Rehabilitation

For neuropathic analgesia, drugs are administered according to the patient's needs, including pregabalin, nortriptyline, vitamin C, prednisone, opioids, and anti-inflammatory drugs. Ten days after surgery, the stitches are removed and the patient is able to remove the sling. Tips and tricks of the described technique are shown in Table 1, and a comparison with open surgery is presented in Table 2.

Discussion

Endoscopic release of the brachial plexus as suggested in this Technical note offers advantages compared with an open technique or previously described endoscopic techniques. It indeed provides better visualization of the neurologic structures with magnification thanks to the arthroscope, almost equivalent to a microscope. It allows a 3-level release, that is, supraclavicular, retroclavicular in the costoclavicular outlet, and infraclavicular. It allows a multiple-level release without multiple approaches as required in the case of an open scalenectomy and pectoralis minor tenotomy[11] and thus yields less scar tissue formation because of its minimal invasiveness.

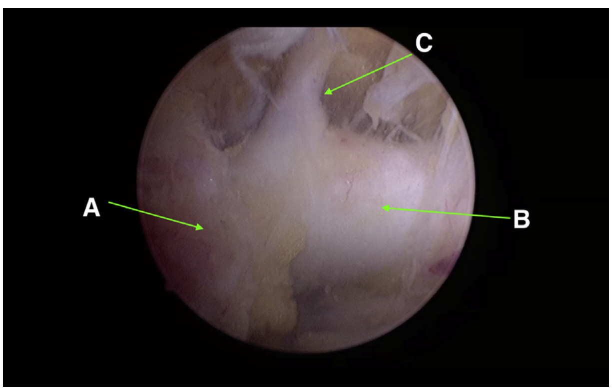

Fig 7. Scalene muscle release (A), subclavian artery (B), and dorsal scapular artery (C) with scope through supraclavicular portal. Right side.

Endoscopic techniques have been described before[4]; however, they were mainly used to manage retroclavicular and infraclavicular decompression. Supraclavicular decompression was addressed in those techniques through a different approach starting from the subacromial space, reaching the suprascapular nerve and the interscalene area, up to the upper trunk, and managing a local fibrous band section, as well as neurolysis, but lacking 2 main aspects that are capital to TOS management: scalenectomy and exposure of the middle and inferior trunks. As described in previous articles,[4,12] a safe approach to the middle and inferior trunks, as well as correct exposition of the subclavicular artery and phrenic, long thoracic, and dorsal scapular nerves, was not achievable. Meanwhile, Garcia et al.[11] in 2012 described an anatomic exposition of the previously cited structures, using a different technique and mainly a different surgical strategy. The procedure presented in this Technical Note has shown an improvement in the clinical scores that was greater than that in the previously published series.[4] It seems obvious that the release addressed in this Technical

Table 1. Tips and Tricks

	Tips and Tricks
Saline solution infusion	Saline solution infusion is used, just by gravity, through 4-way equipment with no pump; this will avoid extreme distension at the cervical area.
Shaver	Aspiration should not be performed near the nerves; the flow can just be left to run through the shaver.
Electrocautery	Only bipolar electrocautery should be used.
Doubt in structure identification	When in doubt, the surgeon should use a nerve stimulator to ensure that a nerve is not going to be cut.

Table 2. Comparison Between Endoscopic and Open Procedures

	Endoscopic	Open
Duration	Longer	Faster
Exposition	Small	Huge
Approach	Minimally invasive	Open
Scar formation	Low	High
Cosmetic result	Yes	No
Price	More expensive	Cheaper

Note is more exhaustive, but the thorough release of the whole brachial plexus affords better clinical results. The main difference as well as benefit brought by this technique is the ability to perform a scalenectomy. The scalene muscles are clearly identified as compressors in this pathology. Scalenectomy is indeed a mandatory step of the open surgical procedure.[13]

However, limitations can be raised regarding this technique. The first and most obvious limitation involves the importance of the learning curve. The interscalene area is an anatomic region that must be well known before one adventures around it endoscopically. Before performing the scalenectomy, the surgeon must identify and preserve the nerves and vessels around it. When doubt regarding the identification of those structures exists, the surgeon should never hesitate to convert to an open approach. The technique, therefore, is one that must be managed by surgeons trained in brachial plexus and peripheral nerve surgery.

The area is also sensitive to pressure variation. Indeed, a balance between low blood pressure and high inflow pressure must be reached. The surgeon needs perfect bleeding management to obtain good visualization, and the anesthesiologist must manage the blood and water inflow pressure to prevent neurologic complications. Indeed, compressions not only to the pneumogastric nerve and the carotid body but also to the spinal cord can occur.

Overall, the described technique clearly brings many advantages to the management of nTOS, and we recommend that it become the reference technique compared with open techniques or previously described endoscopic techniques.[14] However, we acknowledge that its use must be limited to neurogenic cases, as well as to cases in which no anatomic variations or modifications[3] are identified. 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. As a matter of fact, we have not yet studied or proved that the results obtained with neurogenic syndromes are applicable to vascular syndromes. 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.

References

1. Illig K, Donahue D, Duncan A, et al. Reporting standards of the society for vascular surgery for thoracic outlet syndrome. *J Vasc Surg* 2016;64:e23-e35.
2. Levine N, Rigby B. Thoracic outlet syndrome: Biomechanical and exercise considerations. *Healthcare (Basel)* 2018;6:68.
3. Ferrante M, Ferrante N. The thoracic outlet syndromes: Part 1. The arterial, venous, neurovascular, and disputed thoracic outlet syndromes. *Muscle Nerve* 2017;55:782-793.
4. Lafosse T, Hanneur M, Lafosse L. All-endoscopic brachial plexus complete neurolysis for idiopathic neurogenic thoracic outlet syndrome: Surgical technique. *Arthrosc Tech* 2017;6:e967-e971.
5. Kuhn JE, Lebus GFV, Bible JE. Thoracic outlet syndrome. *J Am Acad Orthop Surg* 2015;23:222-232.
6. Doneddu P, Coraci D, De Franco P, Paolasso I, Caliandro P, Padua L. Thoracic outlet syndrome: Wide literature for few cases. Status of the art. *Neurol Sci* 2016;38:383-388.
7. Altobelli GG, Kudo T, Haas BT, Chandra FA, Moy JL, Ahn SS. Thoracic outlet syndrome: Pattern of clinical success after operative decompression. *J Vasc Surg* 2005;42:122-128.
8. Chang DC, Rotellini-Coltvet LA, Mukherjee D, De Leon R, Freischlag LA. Surgical intervention for thoracic outlet syndrome improves patient's quality of life. *J Vasc Surg* 2009;49:630-635.
9. Soukiasian H, Shouhed D, Serna-Gallgos D, McKenna R III, Bairamian B, McKenna R Jr. A video-assisted thoracoscopic approach to transaxillary first rib resection. *Innovations (Phila)* 2015;10:21-26.
10. Balderman J, Holzem K, Field B, et al. Associations between clinical diagnostic criteria and pretreatment patient-reported outcomes measures in a prospective observational cohort of patients with neurogenic thoracic outlet syndrome. *J Vasc Surg* 2017;66:533-544.e2.
11. Garcia JC, Mantovani G, Livernaux P. Brachial plexus endoscopy: Feasibility study on cadavers. *Chir Main* 2012;31:7-12.
12. Lafosse T, Masmejean E, Bihel T, Lafosse L. Brachial plexus endoscopic dissection and correlation with open dissection. *Chir Main* 2015;34:286-293.
13. Cheng SWK, Reilly LM, Nelken NA, Ellis WV, Stoney RJ. Neurogenic thoracic outlet decompression: Rationale for sparing the first rib. *Cardiovasc Surg* 1995;3:617-623.
14. Ferrante M, Ferrante N. The thoracic outlet syndromes: Part 2. The arterial, venous, neurovascular, and disputed thoracic outlet syndromes. *Muscle Nerve* 2017;56:663-673.