Technical Note

Comprehensive Endoscopic Brachial Plexus Release for Neurogenic Thoracic Outlet Syndrome Including Suprascapular Nerve Release and Scalenotomy

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Abstract: Thoracic outlet syndrome is characterized by compression of neurovascular structures including the brachial plexus. Endoscopic techniques for brachial plexus neurolysis are emerging as treatment options when properly indicated. This technical note presents an updated comprehensive endoscopic technique for infraclavicular and supraclavicular brachial plexus neurolysis, including release of the suprascapular nerve via the anterior approach and release of the brachial plexus at the level of the interscalene triangle.

Thoracic outlet syndrome (TOS) is a condition with compression of the neurovascular structures of the superior thoracic aperture, including the brachial plexus (BP).[1] Three major anatomic locations are common for such neurogenic entrapment of the BP owing to their congenital or acquired narrowing: the interscalene triangle, the costoclavicular space, and the space beneath the pectoralis minor (Pmin) muscle. Surgical treatment may be considered if conservative therapy has failed. Open and endoscopic techniques have been described.[2-7] For experienced endoscopic surgeons with expert knowledge of anatomy, endoscopic neurolysis of the infraclavicular BP appears to be safe and reproducible and to be associated with significant functional improvement in patients with neurogenic TOS.[4,5] In this report, we present an updated comprehensive endoscopic technique for infraclavicular and supraclavicular release of the BP, including release of the suprascapular nerve (SSN) following the anterior approach and release of the BP at the level of the interscalene triangle (Video 1).

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Surgical Technique

Patient Setup

The procedure is performed with the patient under general anesthesia in the beach-chair position, with the arm held in extension with optional longitudinal traction. The sterile field should be visible up to the sternum so that the medial portal can be created. Careful hemostasis is achieved by maintaining an adequate pump pressure of 50 mm Hg and a systolic blood pressure of less than 120 mm Hg at all times.

Endoscopic Portals

For this technique, standard arthroscopic and additional supraclavicular and infraclavicular portals are used. The endoscopic portals are shown in Figure 1. All portals are created under endoscopic control using a tracking needle.

Infraclavicular BP Release

Glenohumeral Exploration and Lateral Dissection. Glenohumeral assessment should be performed initially to detect intraarticular causes of pain (with portal A (posterior soft point portal) as the viewing portal and portal D (anterolateral portal) as the working portal). The rotator interval is opened using a radiofrequency device (VAPR TRIPOLAR 90; DePuy

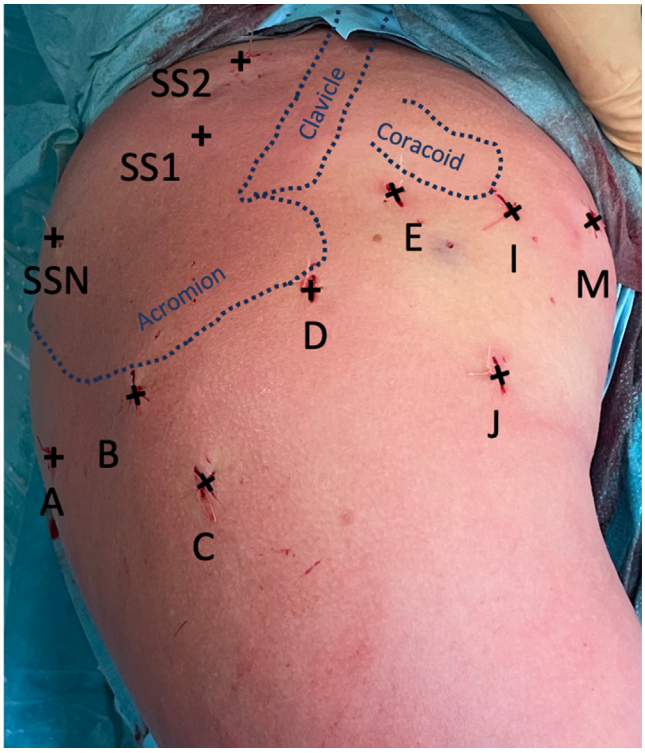

Fig 1. Portals for endoscopic brachial plexus release for neurogenic thoracic outlet syndrome including suprascapular nerve release and scalenotomy. A right shoulder is shown, with the patient in the beach-chair position under general anesthesia. Portal A is the posterior soft point portal; portal B is the posterolateral portal; portal C is the lateral portal; and portal D is the anterolateral portal, under the anterolateral angle of the acromion and parallel to the upper border of the subscapularis. In addition, for lateral visualization during anterior dissection, the following portals are used: portal E, anterolateral portal through the rotator interval; portal I, inferior and anterior portal, used for anterior visualization; portal J, portal between portals I and D, used for lateral dissection and manipulation; portal M, medial portal for medial dissection and manipulation; portal SSN, working portal for suprascapular nerve release, 4.5 cm medial to the posterolateral acromion; portal SC1, portal created above the clavicle, at the level of the transverse cervical vessels; and portal SC2, more proximal and medial cervical portal, at the level of the interscalene triangle, proximal to the division of the superior trunk into the suprascapular nerve.

Synthes Mitek, Raynham, MA) (Fig 2). The clavipectoral fascia is opened, and the coracoid process and the lateral edge of the conjoint tendon (CT) are exposed.

Retrocoracoid Space. The space between the subscapularis (SSC) muscle and the CT is dissected and the inferior border of the coracoid is exposed (with portal D as the viewing portal and portal E [anterolateral portal through the rotator interval] as the working portal). The retrocoracoid fascia is identified and opened, and the retrocoracoid bursa is resected. At the inferior border of

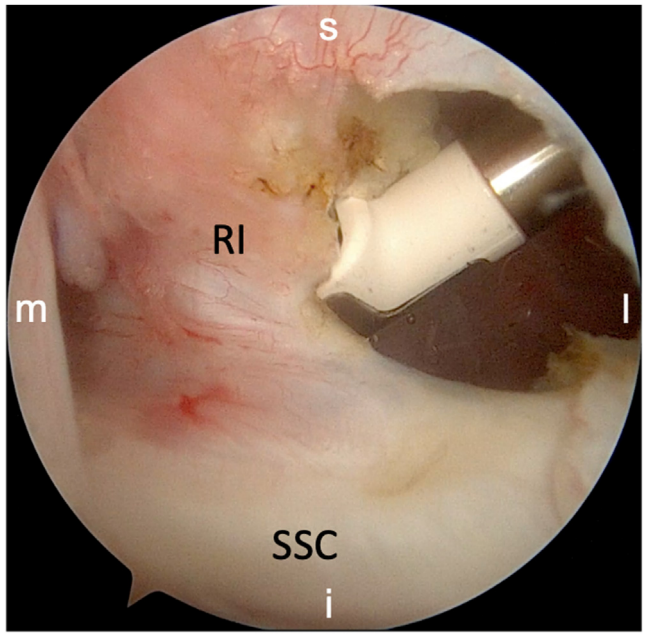

Fig 2. Arthroscopic opening of rotator interval (RI) superior to subscapularis tendon (SSC) (with portal A [posterior soft point portal] as viewing portal and portal E [anterolateral portal] as working portal). Right shoulder. (i, inferior; l, lateral; m, medial; s, superior.)

the SSC muscle, the axillary nerve is identified (Fig 3). The cords and branches are dissected and released from any fibrous bands using the radiofrequency device or any blunt instrument (e.g., trocar). Medially to the axillary nerve, the SSC nerve and artery can be identified. In our experience, better visualization of the BP can be achieved by internal rotation and elevation of the shoulder because this reduces the bulky SSC muscle belly.

Retropectoral Exploration. The endoscope is moved into the retropectoral space, and portals I (inferior and anterior portal) and J (portal between portal I and D) are created. The endoscope is introduced in portal J, which is in midline to the coracoid to allow good visualization of the coracoid process, Pmin, and CT. Portal M (medial portal for medial dissection and manipulation) is created to allow further proximal dissection in the costoclavicular space and retropectoral minor space.

Retropectoral Minor Space. The upper edge of the Pmin is exposed. A thick coraco-subclavius fibrotic band is often identified at its superior edge. At its inferior edge, it can be difficult to differentiate the Pmin from the CT because there is typically a thick fascia between the Pmin and CT (Fig 4). Once the musculocutaneous nerve is identified, the Pmin can be detached from the coracoid process.

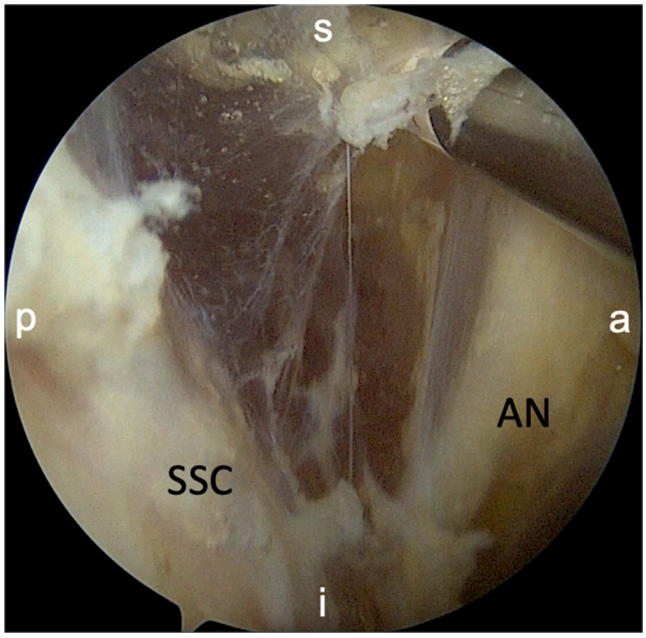

Fig 3. Endoscopic dissection of space between conjoint tendon and subscapularis muscle (SSC) with dissection of axillary nerve (AN) (with portal D [anterolateral portal] as viewing portal and portal E [anterolateral portal] as working portal). Right shoulder. (a, anterior; i, inferior; p, posterior; s, superior.)

Costoclavicular Space. During proximal BP release, the costoclavicular space is opened and widened by cutting the subclavius muscle so that the cords of the BP can be visualized and released. Because the subclavian muscle is close to the thoracoacromial trunk, it should be exposed to avoid accidental damage and severe bleeding. The artery is ligated with a vascular clamping device (Endo Clip; Covidien, Dublin, Ireland) and then transected. The subclavian muscle is cut with the radiofrequency device and a shaver (Fig 5).

After this release, it is important to abduct and externally rotate the patient's shoulder with the BP under direct visualization. When the BP is considered free, the surgeon proceeds to the supraclavicular BP release. However, if more space is needed for the BP, enlargement of the costoclavicular space by careful clavicular drilling through portal SC1 can be an option.

The retropectoral minor space and the costoclavicular space are now opened, and the BP can be released using the radiofrequency device and blunt instruments. The cords and nerves should be dissected with careful movements from proximal to distal.

Supraclavicular BP Release

SSN Release. To identify the SSN, the BP is followed from distal to proximal. As the second branch of the upper trunk, the SSN follows to the suprascapular notch (with portal J as the viewing portal and portal M as the working portal). Once the superior transverse suprascapular ligament (STSL) has been identified, the SSN portal is created (Fig 6). The space superior and inferior to the STSL is opened with gentle, repetitive vertical and horizontal movements along the coracoclavicular ligaments, the STSL, and the lateral bony borders (with portals M and SSN [portal 4.5 cm medial of posterolateral acromion] as the working portals). Sufficient release is achieved when the SSN and STSL are clearly exposed. In the present case, the suprascapular vein passes with the SSN through the suprascapular notch. Arthroscopic nerve scissors (DePuy Synthes Mitek) are inserted from the portal SSN into the suprascapular notch lateral to the SSN. The STSL is detached under endoscopic control, and the SSN is released from fibrotic tissue.

Scalenotomy (With Portal SC1 as Viewing Portal and Portal SC2 as Working Portal). First, to develop the cervical space around the supraclavicular BP, the portal

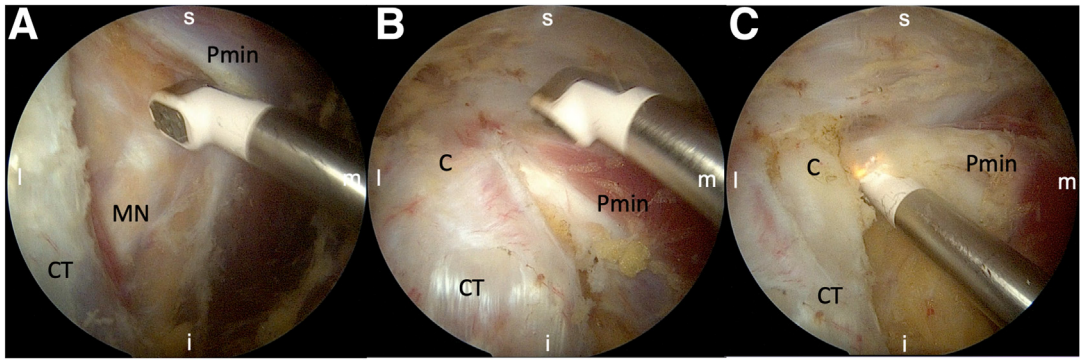

Fig 4. Endoscopic opening of retropectoral minor space (with portal J [anteroinferior portal] as viewing portal and portal M [medial portal] as working portal). (A) Visualization of musculocutaneous nerve (MN) after opening interval between pectoralis minor (Pmin) and conjoint tendon (CT). (B) Release of upper edge of Pmin medial to the coracoid (C). (C) Pmin tenotomy. Right shoulder. (i, inferior; l, lateral; m, medial; s, superior.)

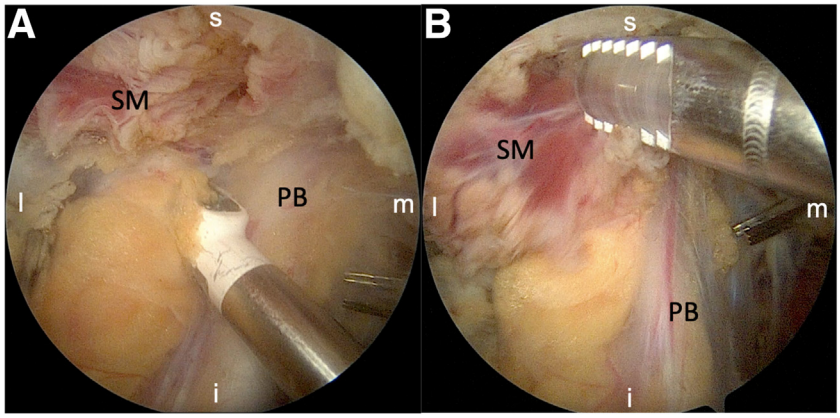

Fig 5. Endoscopic opening of costoclavicular space (with portal J [anteroinferior portal] as viewing portal and portal M [medial portal] as working portal). (A) Exposure of subclavius muscle (SM) at level of brachial plexus (PB) via portal M. (B) Resection of lateral aspect of SM. Right shoulder. (i, inferior; l, lateral; m, medial; s, superior.)

SC1 (portal created above the clavicle, at the level of the transverse cervical vessels) is created at the level of the midclavicular shaft, proximally, in the supraclavicular area. Care must be taken not to damage the transverse cervical vessels, which may bleed and should be ligated when necessary. The interscalene space is developed through this portal until the emergence of the SSN from the upper trunk is identified. The portal SC2 (more proximal and medial cervical portal, at the level of the interscalenic triangle, proximal to the division of the superior trunk into SSN) is then created facing the BP proximally at the level of the upper trunk.

The endoscope is switched to portal SC1. The portal SC2 is used as a working portal. The upper trunk is released, and the middle and inferior trunks are exposed (Fig 7). By guiding the endoscopic and radiofrequency device anteriorly to the BP, the anterior scalene muscle can be identified (Fig 8). The phrenic nerve (oblique), the subclavian artery and vein (horizontal), and the carotid artery are located posteriorly to the anterior scalene muscle. Between the anterior scalene muscle and the middle scalene muscle, the roots and trunks of the cervical plexus are identified and dissected. To avoid bleeding, the dorsal scapular artery can be ligated. Vascular branches at risk can be ligated to reduce the postoperative hemorrhage risk. The long thoracic nerve passes through the middle scalene muscle and must be tagged and protected before middle scalenectomy is performed.

Discussion

With increasing arthroscopic and endoscopic skills and development, we have been able to upgrade our 2017 technique for endoscopic BP release.[4,5] The current technique comprises 2 major endoscopic innovations: anterior approach to the SSN and tenotomy of both the anterior and middle scalene muscles, enabling release of the long thoracic nerve. There exist several endoscopic techniques for SSN release via a lateral approach with a lateral viewing portal and lateral and superior working portals.[6-8] The endoscopic lateral approach is reproducible, but in some cases with substantial soft tissue and adhesions, exposure can be challenging. An open anterior approach for the

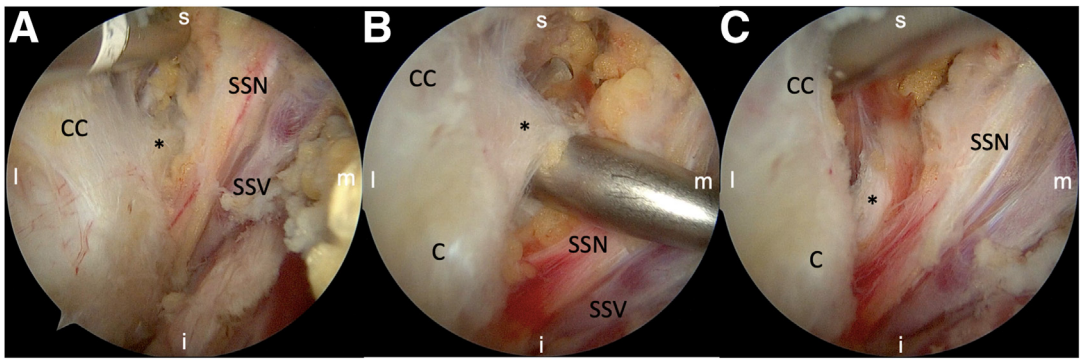

Fig 6. Endoscopic suprascapular nerve (SSN) release via anteroinferior viewing portal (portal J). (A) Exposure of SSN, suprascapular vein (SSV), superior transverse suprascapular ligament (asterisk), suprascapular notch, and coracoclavicular ligaments (CC) via anterolateral working portal (portal E). (B) Endoscopic transection of superior transverse suprascapular ligament (asterisk) medial to the coracoid (C) with arthroscopic nerve scissors via portal SSN. (C) Visualization after SSN release. Right shoulder. (i, inferior; l, lateral; m, medial; s, superior.)

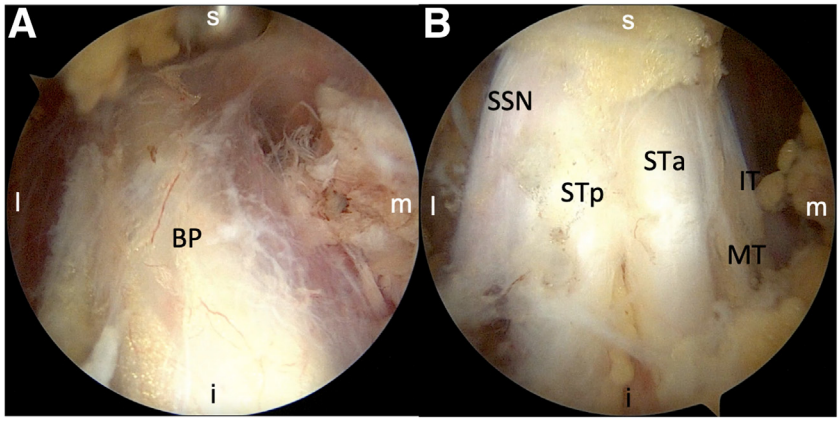

Fig 7. Endoscopic visualization of brachial plexus (BP) (with portal SC1 [lateral supraclavicular portal] as viewing portal and portal SC2 [medial supraclavicular portal] as working portal). (A) Before BP release. (B) After BP release. Right shoulder. (i, inferior; IT, inferior trunk; l, lateral; m, medial; MT, middle trunk; s, superior; SSN, suprascapular nerve; STa, anterior division of superior trunk; STp, posterior division of superior trunk.)

treatment of SSN entrapment has already been shown to be feasible in anatomic cadaveric studies and technical reports.[9,10] Endoscopic release of the SSN after visualization of the BP via an anterior approach may be advantageous because the SSN can be dissected further distal to the suprascapular notch and the risk of incomplete neurolysis of the SSN can be reduced. This seems to be a very efficient method of SSN neurolysis that can be performed safely and might be less time-consuming.

Moreover, the described technique includes a comprehensive supraclavicular BP release with tenotomy of the scalene muscle for compression due to muscle hypertrophy and/or hyperactivity. Excellent anatomic knowledge and thorough technical skills are essential to perform the dissection of the interscalene region close to the nerve roots. When performing a scalenectomy, the surgeon must pay special attention to the surrounding tissue when working with the shaver. In general, this technique is still very demanding. In

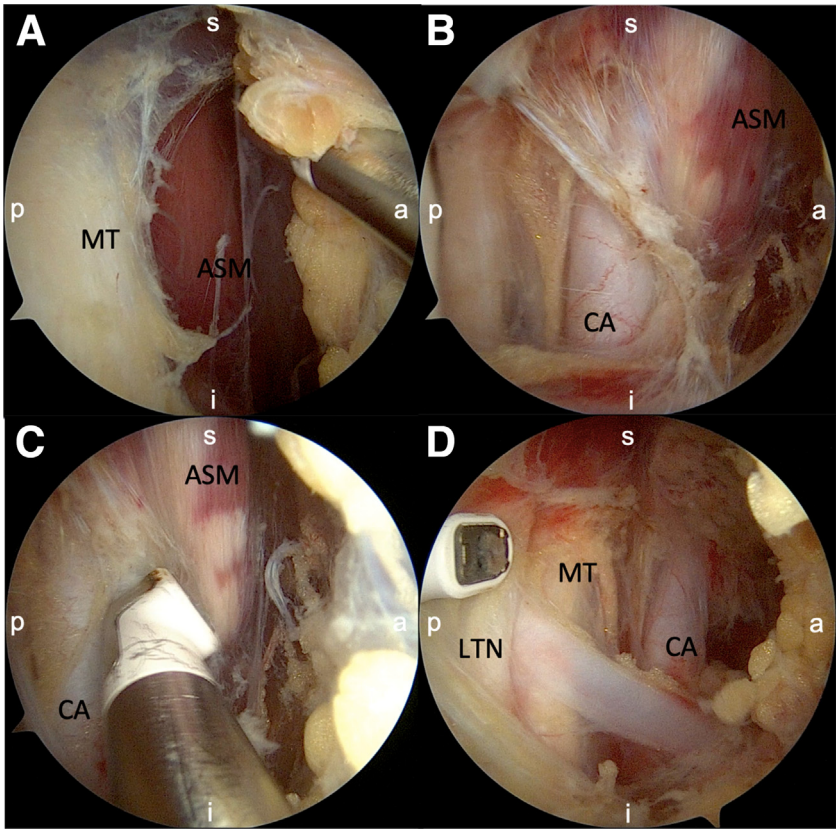

Fig 8. Endoscopic scalenotomy (with portal SC1 [lateral supraclavicular portal] as viewing portal and portal SC2 [medial supraclavicular portal] as working portal). (A) Anterior of the inferior trunk of brachial plexus dissection to the medial side and visualization of the anterior scalene muscle (ASM). (B) Visualization of the carotid artery (CA) posterior to ASM. (C) ASM tenotomy. (D) Visualization after ASM tenotomy showing middle trunk (MT) and long thoracic nerve (LTN). Right shoulder. (a, anterior; i, inferior; p, posterior; s, superior.)

Table 1. Advantages and Downsides of Endoscopic Infraclavicular and Supraclavicular Brachial Plexus Release Including Suprascapular Nerve Release and Scalenotomy

Advantages
Complete dissection with minimal scar tissue
Low risk of infection
Illumination and magnified view
Treatment of glenohumeral lesions
Cosmetic
Downsides
Need to suture vessels in case of neurovascular injury
Risk of subtotal release
Rib resection not possible
Resection of hypertrochic, elongated C7 transverse process not feasible

Table 2. Pearls and Pitfalls of Endoscopic Infraclavicular and Supraclavicular Brachial Plexus Release Including Suprascapular Nerve Release and Scalenotomy

Pearls
Dissection should be started from retrocoracoid space to free posterior cord
Improved view of axillary nerve in elevation and internal rotation to retract voluminous muscle belly of subscapularis
Axillary artery is more medial than cords under clavicle, so risk is low when surgeon stays high
Surgeon should avoid dissection between veins and watch out for cephalic vein, which is upper limit of dissection
Vascular clipping of transverse cervical veins is suggested to avoid bleeding
SSN release with good visibility with careful clipping of small veins and arteries
Pitfalls
Steep learning curve
High level of anatomic knowledge needed
No increased risk of iatrogenic nerve injury
High risk of bleeding and death in event of injury to high-caliber vessels
Sparing of subclavian vein during scalenectomy
Attention must be paid to anatomic variants of neurovascular and muscular structures during scalenectomy

SSN, suprascapular nerve.

addition to the benefits of our technique, there are several risks (Table 1). Paying attention to the pearls and pitfalls can help to avoid serious complications (Table 2).

This technical note presents an endoscopic BP release with anterior SSN release and supraclavicular scalenectomy. The anterior release of the SSN is a feasible alternative to the lateral approach. By modifying the technique with a scalenotomy, the range of indications for endoscopic treatment of neurogenic TOS can be extended.

Disclosures

The authors declare the following financial interests/personal relationships which may be considered as potential competing interests: T.L. reports a consulting or advisory relationship with DePuy Synthes Mitek Sports Medicine, Stryker Orthopaedics, Smith & Nephew, and Zimmer Biomet Holdings. J.C.G. receives speaker grants from General Electric, Zimmer Biomet, and Stryker. L.L. owns equity or stock in DePuy Synthes. M.K. receives funding grants from DePuy Synthes Mitek Sports Medicine.

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