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Case Report

Imaging features of the brachial plexus in neurogenic thoracic outlet syndrome: A case report☆,☆☆

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ABSTRACT

Neurogenic thoracic outlet syndrome (NTOS) is characterized by the compression of the brachial plexus in the thoracic outlet region, caused by various etiologies. We report a case with clinical symptoms and imaging findings from ultrasound and magnetic resonance imaging (MRI) of NTOS due to an elongated C7 transverse process and a fibrous band of the middle scalene muscle, which was confirmed in decompression surgery.

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Introduction

Neurogenic thoracic outlet syndrome is the most common form of thoracic outlet syndrome (TOS), a group of disorders characterized by the compression of the neurovascular structures at the thoracic outlet [1]. Approximately 3 per 100,000 people are diagnosed with NTOS annually [2]. The causes of this syndrome include congenital abnormalities, acquired functional causes, or trauma [3]. In the majority of TOS cases, nerve and vascular compression occurs within the interscalene triangle [1].

Patients with NTOS often present with symptoms such as pain, numbness, paresthesia, and weakness in the upper extremities [4]. Diagnosis is based on the medical history of the patient, clinical examination, electromyography (EMG), and imaging modalities [4]. Imaging can reveal swelling and enlargement of the brachial plexus, as well as identify abnormal structures, such as bone or fibrous bands, compressing the plexus [1]. The combination of ultrasound and MRI is particularly useful for the detailed assessment of neurovascular structures and soft tissue in the cervical region. Herein, we present a case of a patient with bilateral clinical symptoms suggestive of NTOS with typical imaging features, including the 'wedge-sickle sign' on ultrasound.

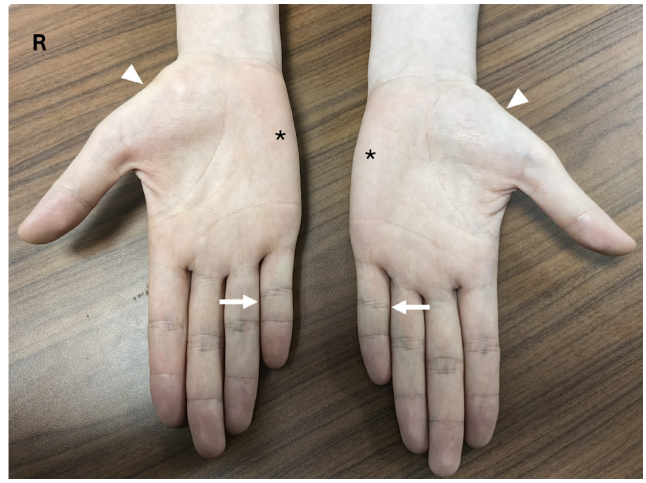

Fig. 1 – The patient's hand displayed the characteristic of muscle atrophy, primarily affecting the thenar eminence and the first interosseous muscle, with lesser involvement of the hypothenar eminence. Notably, there was an atrophy of the abductor pollicis brevis in the thenar eminence (arrowhead). Additionally, mild atrophy of the hypothenar muscles was observed (asterisk), Wartenberg's sign was absent (arrow).

Case presentation

A 29-year-old female patient, with no medical history, presented with pain and numbness along the medial aspect of both upper limbs, accompanied by bilateral hand weakness for approximately one year, with more severe on the right side. Upon examination, atrophy and weakness of the abductor pollicis brevis muscles in the thenar eminences on both sides and the first interosseous muscle on the right was observed, along with mild atrophy of the hypothenar muscles bilaterally and reduced superficial sensation along the medial upper limbs, particularly evident on the right side (Fig. 1). Furthermore, absence of involuntary abduction of the fifth finger (Wartenberg's sign). Based on these findings, the preliminary diagnosis was bilateral NTOS.

The cervical spine radiograph in anteroposterior and lateral views, along with bilateral brachial plexus ultrasound, were performed. The radiograph revealed bilateral elongated C7 transverse processes (Fig. 2). Ultrasound showed hypoechoic and enlarged lower trunks of the bilateral brachial plexus at the level of the elongated C7 transverse processes. Additionally, a hyperechoic structure at the medial border of the middle scalene muscle was seen compressing the right lower trunk, creating a 'wedge-sickle sign'. The absence of scalene minimus muscle or abnormal attachment of the scalene muscles was observed (Fig. 3).

The EMG examination revealed a reduction in the amplitude of the motor nerve response of the right ulnar and median nerves while the amplitude of the motor nerve response of the left ulnar and median nerves was normal. Additionally, the amplitude of the sensory nerve response of the medial antebrachial cutaneous nerves was reduced bilaterally, indicating a partial injury of the medial cord of the brachial plexus on both sides, with more prominent on the right.

Due to the suspicion of brachial plexus injury on ultrasound and EMG, an MRI of the bilateral brachial plexus was performed, which showed bilateral enlargement and hyperintensity STIR of the lower trunks at the level of the elongated C7 transverse processes, more predominant on the right. Additionally, a band-like hypointense structure was seen crossing the bilateral lower trunk of the brachial plexus (Fig. 4).

Based on the clinical examination, EMG, and imaging findings, a diagnosis of bilateral neurogenic thoracic outlet syndrome (NTOS) was established, with greater severity on the right side. This condition was likely attributed to elongated C7 transverse processes and a fibrous band of the middle scalene muscle.

The patient had undergone 2 months of conservative treatment with NSAIDs, but the symptoms did not improve. Subsequently, the patient underwent right-sided brachial plexus decompressive surgery via a supraclavicular approach. Intraoperatively, the thoracic outlet within the interscalene triangle was found to be narrowed, with a fibrous band of the middle scalene muscle and an elongated C7 transverse process compressing the right lower trunk of the brachial plexus (Fig. 5). These findings confirmed the diagnosis of NTOS in this patient.

Discussion

TOS encompasses a group of disorders characterized by the neurovascular compression of the upper extremity at the thoracic outlet, including the scalene triangle, the costoclavicular

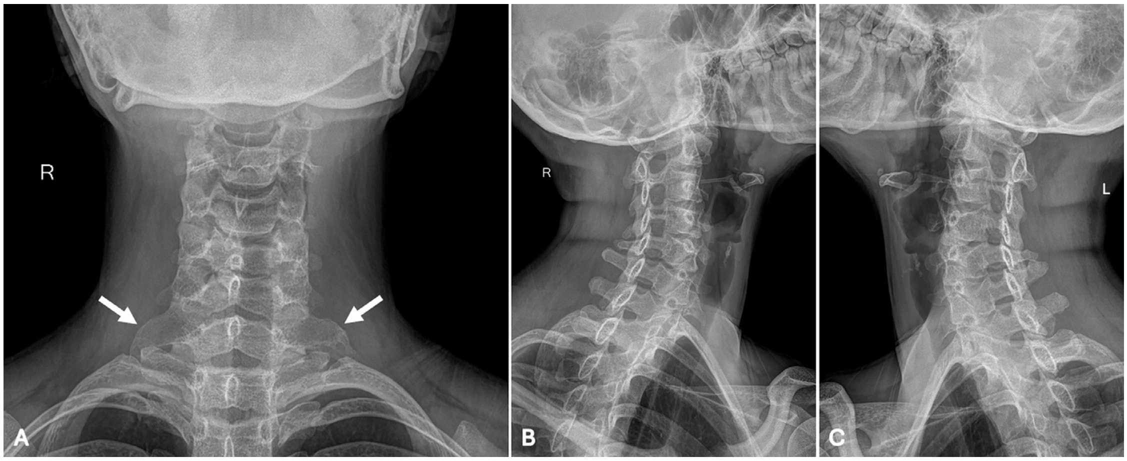

Fig. 2 – The cervical spine radiograph in anteroposterior views (A) showed elongated C7 transverse processes on both sides (arrow). No foramen stenosis on bilateral oblique cervical spine radiographs (B: right side, C: left side).

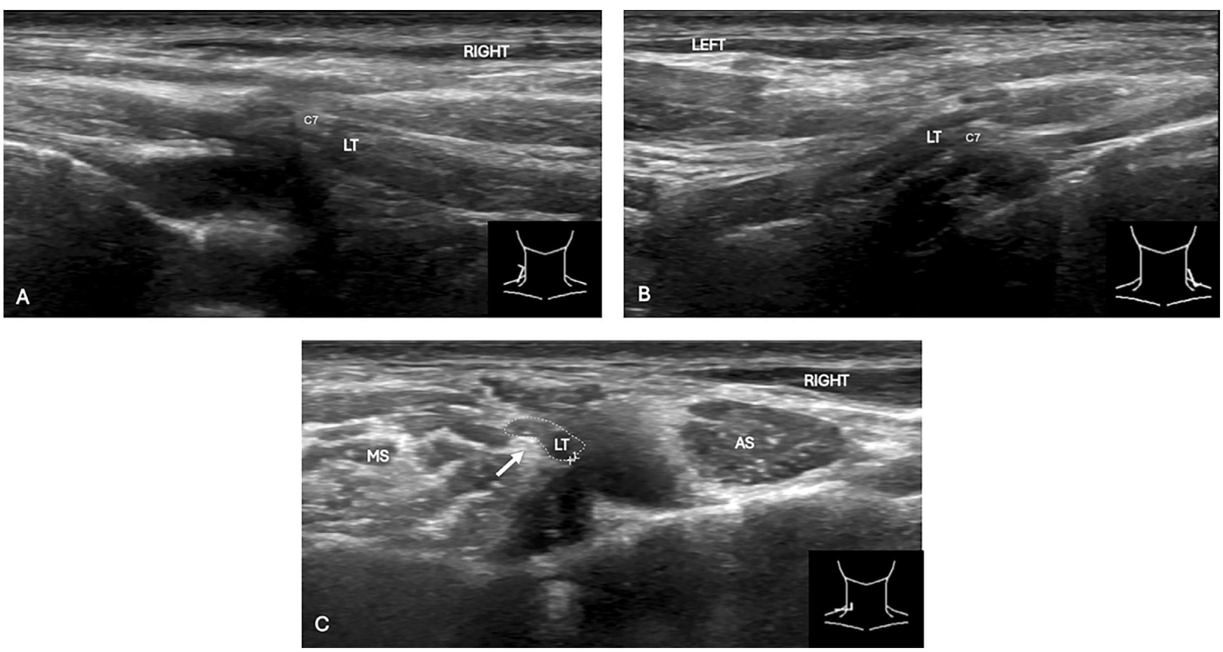

Fig. 3 – (A, B) Long-axis ultrasound imaging revealed bilateral elongated C7 transverse processes compressing the lower trunk of the brachial plexus (A: right side, B: left side). (C) On short-axis imaging, the lower trunk of the right brachial plexus (dotted line) was indented by a hyperechoic structure (arrow) at the medial border of the middle scalene muscle, called the 'wedge-sickle sign'. LT: lower trunk; C7: C7 transverse process; MS: middle scalene muscle; AS: anterior scalene muscle.

space, and the retropectoralis minor space [1]. TOS is divided into 3 types: neurogenic, arterial, and venous, corresponding to compression of the brachial plexus, subclavian artery, and subclavian vein, respectively. Among these types, NTOS accounts for the majority of cases, estimated at approximately 90-95% [3,5]. In most cases of TOS, neurovascular compression occurs within the interscalene triangle [1]. Epidemiologically, NTOS is more common in females (3-4:1) and typically presents between the ages of 20 and 40 [1]. Our patient's age and gender were consistent with the typical demographic for this syndrome.

The causes of TOS are categorized into 3 main groups: congenital abnormalities, acquired functional causes, and trauma [1,3]. Congenital abnormalities include elongated C7 transverse processes, cervical ribs, or other structural anomalies such as fibromuscular bands or abnormal attachment of the scalene muscles to the first rib [1,3]. Notably, about two-thirds of these abnormalities detected during surgery are fibromuscular bands [3]. Acquired functional causes can result from repetitive arm movements in individuals with specific activities [1]. Traumatic causes include either isolated trauma or repeated trauma, often re-

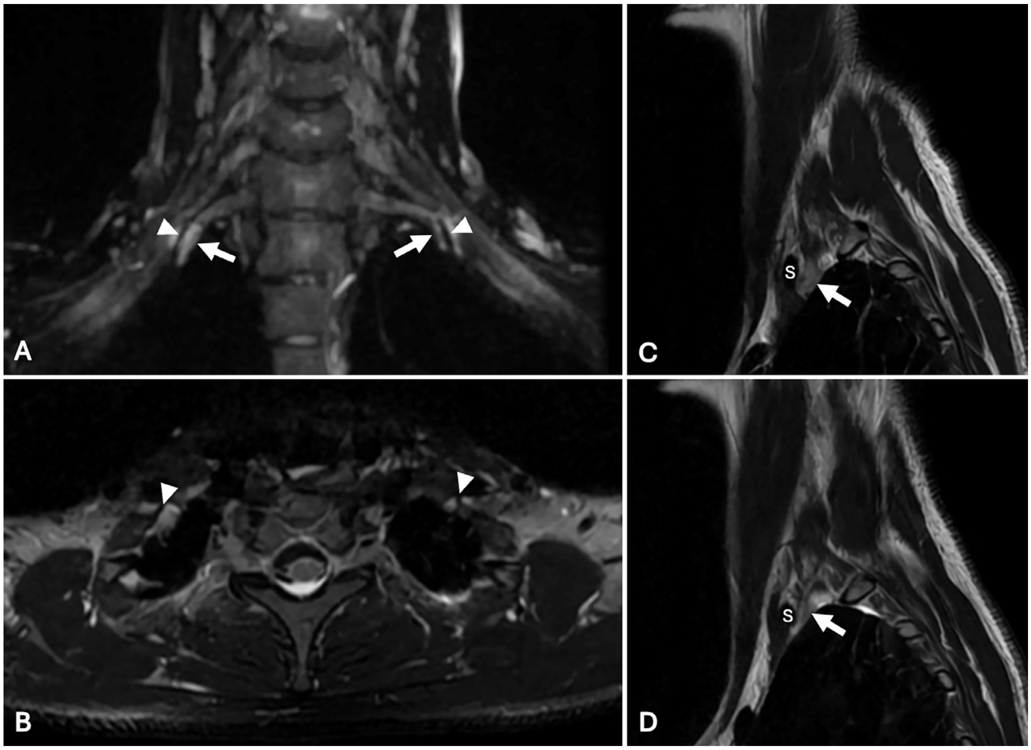

Fig. 4 – (A) The coronal 3D STIR MIP image revealed an enlargement and hyperintensity STIR of the lower trunk of the brachial plexus (arrow), accompanied by a band-like hypointense structure (arrowhead) crossing the lower trunk on both sides. (B) The band-like structure (arrowhead) is likewise observed crossing the lower trunk bilaterally on axial T2W imaging. (C and D) Sagittal T2W imaging reveals enlargement of the lower of the brachial plexus (arrow), with a predominance on the right side. (C: right side, D: left side, S: subclavian artery).

lated to neck and shoulder injuries, particularly whiplash injuries [3].

Clinically, NTOS can present with a variety of symptoms including pain, paresthesia, numbness, and weakness of the upper limbs [1]. Classic NTOS is characterized by the atrophy of the thenar and hypothenar eminence, interossei muscles, and the abductor pollicis brevis muscles, commonly referred to as the 'Gilliatt-Sumner hand' [1]. Moreover, provocative tests including the elevated arm stress test (Roos test) and the upper limb tension test (Elvey test) are useful for diagnosing NTOS with relatively high sensitivity [6,7]. However, other conditions such as rotator cuff injuries, cervical radiculopathy, and peripheral neuropathy can present with similar symptoms. Therefore, a detailed medical record and thorough clinical examination are essential. Illig et al. [6] define NTOS as the presence of 3 of the following 4 criteria: (1) local symptoms in a compression area (e.g., chest wall, trapezius, neck) with pain on palpation; (2) arm or hand symptoms confirmed by history and exacerbated by provocative maneuvers; (3) exclusion of other likely diagnoses such as cervical, shoulder, or peripheral nerve pathology; (4) positive response to a scalene injection (typically local anesthetic). Our patient exhibited clinical features consistent with classic NTOS, including numbness in the medial part of the upper limbs corresponding to the C8-T1 nerve root distribution, as well as atrophy and weakness of the interosseous muscles and abductor pollicis brevis bilaterally.

EMG can detect conduction abnormalities in the medial antebrachial cutaneous nerve and the motor branch of the median nerve that innervates the abductor pollicis brevis [8]. These nerves originate from the C8-T1 roots. In a study by Tsao et al., [8] abnormalities of both motor and sensory nerves in EMG were detected in 89% of NTOS patients. In our patient, EMG revealed abnormalities in both the amplitude of the motor nerve response of the right ulnar and median nerves and the amplitude of the sensory nerve response of the bilateral medial antebrachial cutaneous nerves.

Imaging techniques are not only used to identify symptomatic abnormalities but also assist in surgical planning and assessment of anatomical structures of the thoracic outlet, including the scalene muscles, as well as fibrous or bony structures. Radiographs can reveal elongated C7 transverse processes or cervical ribs, while computed tomography can assess both bony abnormalities and detect masses in the neck region [1]. However, these methods have limitations in directly assessing brachial plexus injuries compared to ultrasound and MRI.

Ultrasound is effective in evaluating the interscalene triangle, the site where the brachial plexus is predominantly compressed in NTOS cases [1]. According to Dollinger et al., ultrasound has a sensitivity of 48% and specificity of 84% for diagnosing NTOS [9]. Ultrasound findings in NTOS are similar to those in other nerve compression syndromes, including enlargement and hypoechogenicity of the nerve, loss of

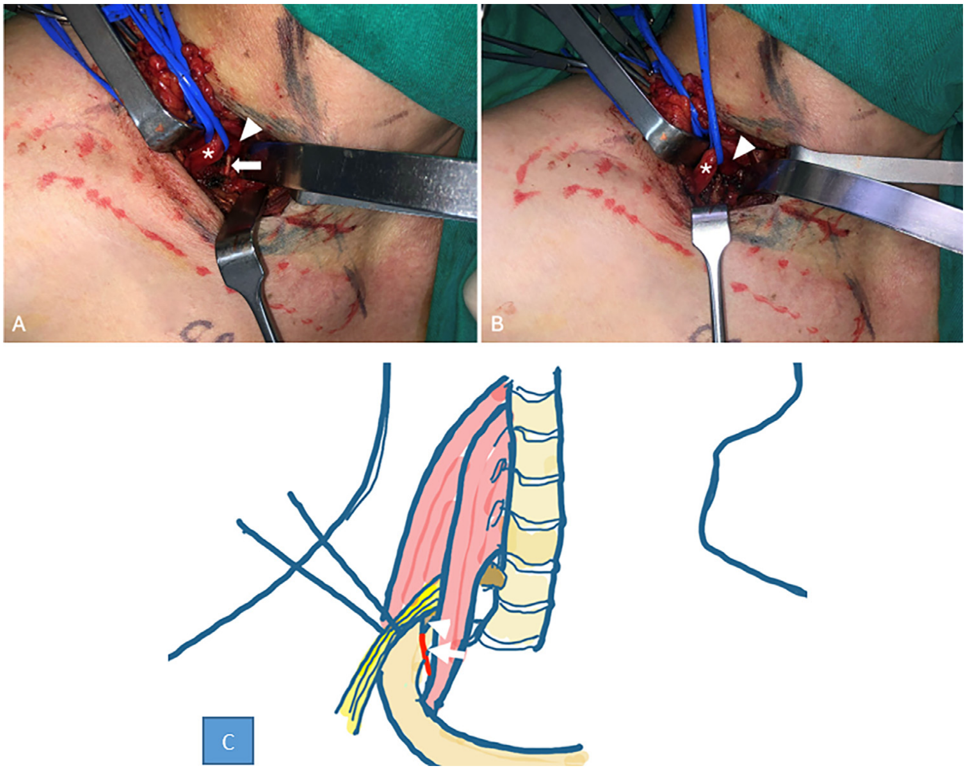

Fig. 5 – (A) Surgery revealed the presence of a fibrous band (arrow) of the middle scalene muscle attached to the elongated C7 transverse process (arrowhead), contributing to the compression of the lower trunk (asterisk) of the brachial plexus. (B) Following resection of the fibrous band, the thoracic outlet was successfully released. (C) surgery diagram (arrow: the fibrous band, arrowhead: the elongated C7 transverse process).

fascicular structure, and nerve compression or indentation. An important sign on ultrasound is the 'wedge-sickle sign', characterized by the presence of a hyperechoic, wedge-shaped structure (fibromuscular or bony) along the medial edge of the middle scalene muscle, indenting the lower trunk, which thus transforms into the shape of a 'sickle' and becomes swollen and hypoechoic. In the study of Dollinger et al., [9] the 'wedge-sickle sign' caused by a fibrous band had the highest specificity (100%) but relatively low sensitivity (23%), while the sign caused by bone had a sensitivity of 19% and occasionally appeared in control groups. In another study of 49 arms diagnosed with NTOS in 36 patients, the 'wedge-sickle sign' was seen in 4 cases, with 3 of these confirmed to have fibrous bands during surgery [10]. In our patient, the radiograph showed elongated C7 transverse processes, and ultrasound revealed a hyperechoic structure compressing the lower trunk of the brachial plexus, creating the 'wedge-sickle sign'. Subsequent surgical decompression confirmed this structure to be a fibrous band.

MRI plays an important role in providing detailed information about the complex anatomical structures involved in NTOS, facilitating precise identification of compression sites, and assessment of the severity of nerve damage [11]. Baumer et al. [12] conducted high-resolution MR neurography on patients suspected of NTOS, with subsequent surgical confirmation in all cases, indicating a high positive predictive value for this method. Baumer proposed 2 MRI criteria for diagnosing NTOS: (1) the detection of anatomical structures compressing the lower part of the brachial plexus and (2) the presence of signal abnormality in T2-weighted within the compressed plexus portions but sparing the upper plexus [12]. MRI can also detect subtle anatomical abnormalities causing NTOS, such as fibrous bands. Furthermore, diffusion tensor imaging is emerging as a promising method, providing images of nerve fiber tracts and enabling a more comprehensive assessment of peripheral nerve injuries [13]. In our case, MRI revealed both diagnostic signs of NTOS: increased signal intensity of the lower trunk of the brachial plexus on STIR and the presence of fibrous bands compressing the lower trunk bilaterally.

Treatment for NTOS typically begins with conservative management, which may include lifestyle modifications, physical therapy, muscle relaxants, NSAIDs, opioids, and botulinum toxin injections into the cervicothoracic musculature [1,14]. Surgery is considered after the failure of conservative management, which may involve resection of the cervical rib, first rib, or removal of other compressive abnormalities such as fibrous bands, depending on the underlying cause [3]. In our patient, symptoms persisted for about a year, resulting in significant muscle atrophy and a notable impact on quality of life. The patient had also undergone treatment with NSAIDs for approximately 2 months by the time of diagnosis. Therefore, the indication for brachial plexus decompression surgery was entirely appropriate in this case.

Conclusion

Neurogenic thoracic outlet syndrome is characterized by compression of the brachial plexus at the thoracic outlet, most commonly within the scalene triangle. Imaging plays a crucial role in identifying the underlying causes of this syndrome and providing essential information for surgical planning. The 'wedge-sickle sign' observed on ultrasound is a specific finding indicating brachial plexus compression by bony or fibrous structures. Additionally, MRI serves as a valuable tool in supporting diagnosis by detecting signal abnormalities suggestive of brachial plexus injury and identifying adjacent abnormal structures.

Patient consent

Informed consent for patient information to be published in this article was obtained.

Author's contributions

Hoang TM and Nguyen MD: Case file retrieval and case summary preparation. Hoang TM and Nguyen MD: preparation of manuscript and editing. All authors read and approved the final manuscript.

Availability of data and materials

Data and materials used and/or analyzed during the current study are available from the corresponding author on reasonable request.

Ethics approval and consent to participate

Our institution does not require ethical approval for reporting individual cases or case series. Written informed consent was obtained from the patient(s) for their anonymized information to be published in this article.

Consent for publication

Not applicable.

REFERENCES

[1] Lim C, Kavousi Y, Lum YW, Christo PJ. Evaluation and management of neurogenic thoracic outlet syndrome with an overview of surgical approaches: a comprehensive review. JPR 2021;14:3085–95. doi:10.2147/JPR.S282578.
[2] Illig KA, Rodriguez-Zoppi E. How common is thoracic outlet syndrome? Thorac Surg Clin 2021;31(1):11–17. doi:10.1016/j.thorsurg.2020.09.001.
[3] Laulan J, Fouquet B, Rodaix C, Jauffret P, Roquelaure Y, Descatha A. Thoracic outlet syndrome: definition, aetiological factors, diagnosis, management and occupational impact. J Occup Rehabil 2011;21(3):366–73. doi:10.1007/s10926-010-9278-9.
[4] Chen D, Gong W, Wang J, Hao J, Zhao R, Zheng M. Diagnosis of thoracic outlet syndrome with the lower trunk compression of brachial plexus by high-frequency ultrasonography. BMC Musculoskelet Disord 2023;24(1):690. doi:10.1186/s12891-023-06762-7.
[5] Freischlag J, Orion K. Understanding thoracic outlet syndrome. Scientifica 2014;2014:e248163. doi:10.1155/2014/248163.
[6] Illig KA, Donahue D, Duncan A, Freischlag J, Gelabert H, Johansen K, et al. Reporting standards of the Society for Vascular Surgery for thoracic outlet syndrome. J Vasc Surg 2016;64(3):e23–35. doi:10.1016/j.jvs.2016.04.039.
[7] Jones MR, Prabhakar A, Viswanath O, Urits I, Green JB, Kendrick JB, et al. Thoracic outlet syndrome: a comprehensive review of pathophysiology, diagnosis, and treatment. Pain Ther 2019;8(1):5–18. doi:10.1007/s40122-019-0124-2.
[8] Tsao BE, Ferrante MA, Wilbourn AJ, Shields RW. Electrodiagnostic features of true neurogenic thoracic outlet syndrome. Muscle Nerve 2014;49(5):724–7. doi:10.1002/mus.24066.
[9] Dollinger P, Böhm J, Arányi Z. Combined nerve and vascular ultrasound in thoracic outlet syndrome: a sensitive method in identifying the site of neurovascular compression. PLoS One 2022;17(5):e0268842. doi:10.1371/journal.pone.0268842.
[10] Pesser N, Teijink JAW, Vervaart K, Goeteyn J, Gons RAR, van Sambeek MRHM, et al. Value of ultrasound in the diagnosis of neurogenic thoracic outlet syndrome. Eur J Vasc Endovasc Surg 2020;59(5):852–3. doi:10.1016/j.ejvs.2020.02.016.
[11] Szaro P, Suresh R, Molokwu B, Sibala DR, Mendiratta D, Chu A, et al. Magnetic resonance imaging for diagnosis of suspected neurogenic thoracic outlet syndrome-a systematic scoping review. Front Physiol 2023;14:1198165. doi:10.3389/fphys.2023.1198165.
[12] Baumer P, Kele H, Kretschmer T, Koenig R, Pedro M, Bendszus M, et al. Thoracic outlet syndrome in 3T MR neurography-fibrous bands causing discernible lesions of the lower brachial plexus. Eur Radiol 2014;24(3):756–61. doi:10.1007/s00330-013-3060-2.
[13] Magill ST, Brus-Ramer M, Weinstein PR, Chin CT, Jacques L. Neurogenic thoracic outlet syndrome: current diagnostic criteria and advances in MRI diagnostics. Neurosurgical Focus 2015;39(3):E7. doi:10.3171/2015.6.FOCUS15219.
[14] Christo PJ, McGreevy K. Updated perspectives on neurogenic thoracic outlet syndrome. Curr Pain Headache Rep 2011;15(1):14–21. doi:10.1007/s11916-010-0163-1.