Cureus
Part of SPRINGER NATURE

Open Access Case Report

Changes in Pain and Duplex Ultrasound Findings Following Four Months of Multimodal Physical Therapy for Thoracic Outlet Syndrome of Pectoralis Minor Etiology: A Case Report

Review began 10/15/2026
Review ended 10/22/2026
Published 10/26/2026

© **Copyright** 2026
Badr et al. This is an open access article distributed under the terms of the Creative Commons Attribution License CC-BY 4.0., which permits unrestricted use, distribution, and reproduction in any medium, provided the original author and source are credited.

DOI: 10.7759/cureus.118602

Mohamed Badr [1], Ahmed O. Mohamady [2], Hosny Elkhawaga [1]

1. Faculty of Physical Therapy, Cairo University, Giza, EGY 2. Faculty of Physical Therapy, October 6 University, Giza, EGY

Corresponding author: Ahmed O. Mohamady, ahmed.osama.mohamady@gmail.com

Abstract

Pectoralis minor syndrome (PMS) involves dynamic compression of the neurovascular bundle in the retropectoral space and can present with neurogenic thoracic outlet syndrome symptoms. This case report describes changes in pain and duplex ultrasound findings in a patient with suspected PMS after four months of multimodal physical therapy. A 28-year-old woman presented with a nine-month history of bilateral medial forearm and little finger pain and tingling. She also reported anterior chest pain, a sense of heaviness after prolonged overhead activity, and pain along the medial scapular border and axilla. She had no history of trauma. She had previously been diagnosed with cubital tunnel syndrome and did not improve with treatment. The Roos test, upper limb neural tension test for median nerve, and hyperabduction test were positive. Tinel's sign at the cubital tunnel and Adson's test were negative. Dynamic duplex ultrasound showed arterial velocity three to four times higher in the provocative position than at rest. She received four months of multimodal physical therapy. It consisted of electrophysical agents, manual therapy, and therapeutic exercises. Electrophysical agents included conventional transcutaneous electrical nerve stimulation, hot packs, and phonophoresis. Manual therapy included myofascial release and thoracic mobilization. Exercises addressed postural correction, cervical core stability, scapular strengthening, and rotator cuff strengthening. Outcomes were the numeric pain rating scale (NPRS) and arterial velocity on dynamic duplex ultrasound. At the end of treatment, NPRS decreased from 9/10 to 2/10, and arterial velocity decreased from 178 to 107 cm/s on the left and from 195 to 122 cm/s on the right in the provocative position. She returned to work without limitations. This case suggests that a criteria-based multimodal physical therapy program may be a useful option for patients with thoracic outlet syndrome. However, this is a single uncontrolled case with multiple interventions, so causality cannot be established. Prospective studies are needed.

Categories: Radiology, Physical Medicine & Rehabilitation, Orthopedics
Keywords: multimodal physical therapy, pectoralis minor syndrome, pms, thoracic outlet syndrome, tos

Introduction

Thoracic outlet syndrome (TOS) is underdiagnosed in patients presenting with chronic neck and shoulder pain, headaches, and upper limb neural manifestations [1,2]. TOS describes a heterogeneous group of symptoms resulting from dynamic compression of the neurovascular bundle at the thoracic outlet. The compression can be caused by muscles, bone, or other anomalies.

According to the Society for Vascular Surgery (SVS), three possible sites of compression are described. The first is the scalene triangle, which is bordered by the anterior and middle scalene muscles and the first rib. The second is the costoclavicular space between the clavicle and the first rib. The third is the pectoralis minor space, which lies beneath the pectoralis minor muscle near its attachment to the coracoid process [3].

TOS is classified into three types according to the affected structure: neurogenic TOS (nTOS) when the brachial plexus is affected, arterial TOS (aTOS) when the subclavian and/or axillary artery is involved, and venous TOS (vTOS) when the subclavian and/or axillary vein is affected [4].

TOS of pectoralis minor etiology results from dynamic compression of the neurovascular bundle in the retropectoral space and is often referred to as pectoralis minor syndrome (PMS) [5]. nTOS is the most common form of TOS [5]. PMS is considered either a separate diagnosis from nTOS or a main cause of it. In both scenarios, signs and symptoms are similar, including pain or tenderness in the anterior chest wall and axilla accompanied by upper extremity pain, weakness, and paresthesia, which are exacerbated by prolonged overhead activities [6-8].

The clinical diagnostic criteria proposed by the Consortium for Research and Education on Thoracic Outlet

Syndrome (CORE-TOS) are widely used to confirm the diagnosis of TOS [9]. Ultrasound-guided anesthetic injections into the pectoralis minor muscle can also confirm the diagnosis by relieving symptoms [8]. Other clinical findings include tenderness over the pectoralis minor muscle, and imaging studies such as dynamic ultrasound can detect the compression [1,10].

Physical therapy is the first-line treatment for TOS, along with muscle relaxants, nonsteroidal anti-inflammatory drugs (NSAIDs), and opioids [11]. However, few published studies detail the physical therapy management of such cases. This case report aims to add to the existing literature by presenting a case of TOS of pectoralis minor etiology and proposing a multimodal physical therapy program.

Case Presentation

Patient history

A 28-year-old woman presented with a nine-month history of bilateral chest pain accompanied by upper limb pain, a "sense of heaviness," and numbness from the axilla to the little finger, worse on the left than the right. Her symptoms were provoked by prolonged overhead activities. She described the pain as starting in the anterior chest between the nipple and clavicle, then spreading to the anterior shoulder and down the medial forearm and hand, with paresthesia and heaviness. She also described pain along the medial border of the scapula and in the axilla.

The patient had previously been diagnosed with cubital tunnel syndrome and was treated with NSAIDs, transcutaneous electrical nerve stimulation (TENS), high-intensity laser therapy, therapeutic ultrasound, and corticosteroid injections, none of which relieved her symptoms. She had no history of trauma.

Clinical examination

On observation, the patient had forward head posture with rounded shoulders. Cervical spine examination showed intact sensation and reflexes, with mild grip weakness (4/5 on the Medical Research Council scale). Spurling, distraction, and shoulder abduction tests were negative. Palpation over the pectoralis region produced tenderness that radiated down the medial forearm and hand.

The Roos test, upper limb neural tension test 1 for the median nerve (ULNT1), and hyperabduction (Wright's) test were positive. Tinel's sign at the cubital tunnel and Adson's test were negative.

The patient met all five CORE-TOS clinical diagnostic criteria, raising suspicion for TOS. Principal symptoms: arm and hand pain with numbness and paresthesia. Symptom characteristics: symptoms provoked by prolonged overhead activity. Clinical history: symptom onset followed overuse. Physical examination: tenderness on palpation over the subcoracoid space. Provocative maneuvers: a positive ULNT1 and a positive Roos test.

Investigations

A cervical spine X-ray ruled out elongated transverse processes. Cervical spine magnetic resonance imaging (MRI) sagittal T1, T2, and axial T2 sequences showed no disc or structural abnormalities. Nerve conduction studies and electromyography showed normal ulnar motor conduction and F-waves bilaterally. Ulnar sensory conduction was also normal.

Finally, the patient was referred for dynamic duplex ultrasound to localize the site of compression. Blood flow velocity was measured first with the arm in the neutral position, then at 90° abduction and external rotation (ABER). Hemodynamically significant impingement of the artery at the ABER position was established if the blood flow velocity increased more than two-fold. Arterial velocity increased three to four times from rest to the dynamic position (left side: 45 cm/s at rest, 178 cm/s dynamic; right side: 50 cm/s at rest, 195 cm/s dynamic). The pulse was also severely damped, and the axillary vessels were compressed in the provocative position and when the patient took a deep breath (Figure *1*). Based on the clinical and imaging findings, the diagnosis was TOS of pectoralis minor etiology.

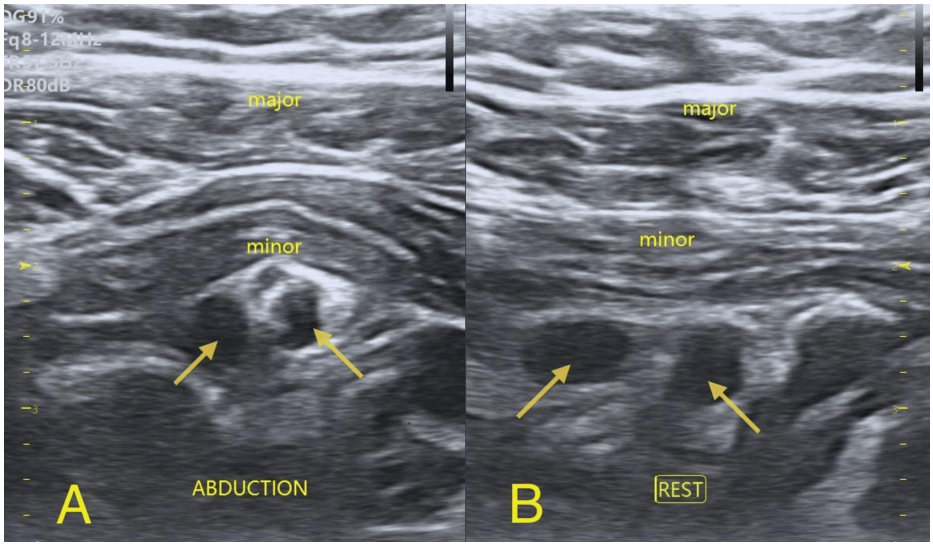


FIGURE 1: Dynamic duplex ultrasound of the retropectoral space.

Short-axis view of the retropectoral space of the patient's left arm during abduction and external rotation (ABER) (A) and at rest (B). During ABER, the pectoralis minor muscle bows and compresses the neurovascular bundle. Arrows indicate the axillary artery and vein.

minor: pectoralis minor; major: pectoralis major

Multimodal physical therapy intervention

The patient received an individualized and supervised multimodal physical therapy program over four months, with three sessions per week. A muscle relaxant was also given for the first two weeks. Adherence to the exercise protocol was monitored using the clinic's paper-based diaries. The treatments were delivered by an experienced orthopedic physical therapist at a private clinic in Cairo, Egypt. The program consisted of electrophysical agents, manual therapy, education, and therapeutic exercise. It was delivered in three phases, with progression based on patient irritability and on the radial pulse and neurological symptoms assessed using Wright's test. The radial pulse was used as a clinical safety signal for positional vascular compression. Details of the protocol are described in the following sections. Figure *2* shows the criteria for progression.

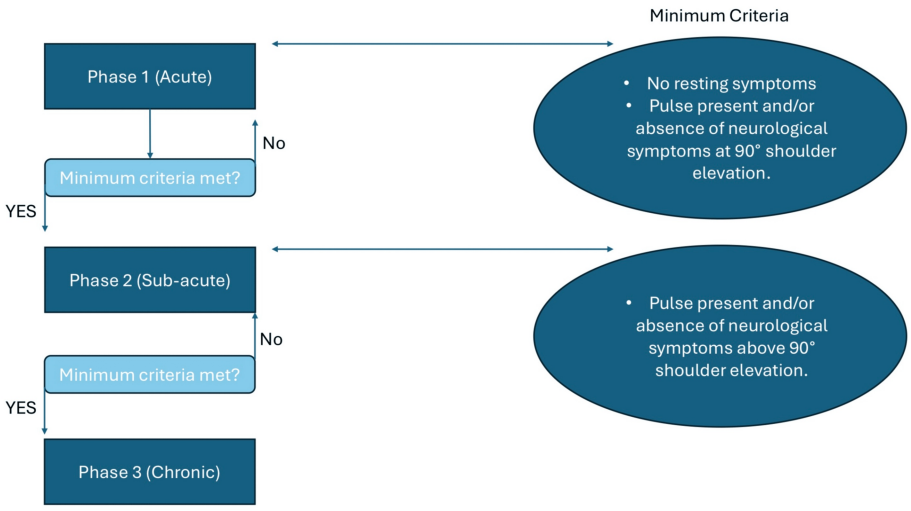


FIGURE 2: Criteria-based progression.

Diagram created using Microsoft PowerPoint (Microsoft Corp., Redmond, WA, USA).

Phase 1 (Acute)

The first phase focused on pain relief and symptom modification. The patient received conventional TENS, hot packs, and phonophoresis. Manual therapy consisted of myofascial release of the pectoralis major and minor, subscapularis, upper trapezius, interscapular muscles, neck muscles, and both arms. The patient also performed diaphragmatic breathing exercises. Details are shown in Table *1*. In this phase, the patient also received education on work ergonomics, which included avoiding overhead activities that provoked her symptoms and avoiding carrying heavy objects on the affected side [2].

Electrophysical agents	
Description	*Dose and progression*
Conventional transcutaneous electrical nerve stimulation (TENS), from supine, adjacent electrodes on both upper traps	Pulse Frequency: 100 Hz. Pulse duration: 80 μs. Intensity: Sensory level “strong but comfortable.” Duration: 20 minutes
Hot pack, under the cervicothoracic and over the pectoral regions, at the same time with the TENS	Duration: 20 minutes
Low-intensity pulsed ultrasound phonophoresis with 2 mL diclofenac and 2 mL dexamethasone, on the pectoral area	Intensity: 0.3 W/cm². Duty cycle: Pulsed, 20%. Frequency: 1 MHz. Duration: 5 minutes
Manual therapy	
Description	*Dose and progression*
Myofascial release for pectoralis major and minor, subscapularis, upper trapezius, interscapular muscles, neck muscles, and both arms	Very gentle 2–3 minutes each muscle
Therapeutic exercises	
Description	*Dose and progression*
Diaphragmatic breathing	3 × 5 repetitions (supine) 3 × 5 repetitions (sitting) 3 × 5 repetitions (standing) 3 × 5 repetitions (walking)
Shoulder external rotation below 30° abduction starting from full internal rotation till neutral, from supine	3 × 7 repetitions 3 × 10 repetitions 3 × 12 repetitions 3 × 15 repetitions

TABLE 1: Detailed multimodal physical therapy program: phase 1 acute.

Phase 2 (Sub-acute)

Phase 2 was the early exercise stage, which introduced light exercises that did not provoke the patient’s symptoms. The criteria for progressing to this stage were a palpable radial pulse and/or absence of symptoms at 90° of shoulder elevation (Figure *2*). Symptoms were monitored during exercise. A symptom change of less than 2 points on the numeric pain rating scale (NPRS) with exercise was accepted, while a change of 2 points or greater, or the inability to recover to baseline symptoms within the session, warranted exercise regression.

The electrophysical agents were the same as in Phase 1, without phonophoresis. Thoracic and rib mobilizations were added to the myofascial release. Dry needling was used as needed for the pectoralis minor (needle size: 0.30 × 50 mm, deep approach). Patient consent was obtained. Ultrasound guidance was not available; however, there were no adverse events.

Scapular muscle strengthening, rotator cuff strengthening, and cervical core stability exercises were introduced [12]. Cyclic stretching of the pectoralis minor and scalene muscles was also added. Details are shown in Table *2*.

Electrophysical agents	
Description	*Dose and progression*
Conventional transcutaneous electrical nerve stimulation (TENS), from supine, adjacent electrodes on both upper traps	Pulse frequency: 100 Hz. Pulse duration: 80 μs. Intensity: sensory level “strong but comfortable.” Duration: 20 minutes
Hot pack, under the cervicothoracic and over the pectoral regions, at the same time with the TENS	Duration: 20 minutes
Manual therapy	
Description	*Dose and progression*
Myofascial release for pectoralis major and minor, subscapularis, upper trapezius, interscapular muscles, neck muscles, and both arms	2–3 minutes each muscle
Thoracic and ribs mobilization	2 minutes
Trigger point dry needling for pectoralis minor	Intensity: one needle manipulated using fishing technique 3–5 times. Duration: 5–10 seconds. Frequency: Every other session for 3 sessions
Therapeutic exercises	
Description	*Dose and progression*
Diaphragmatic breathing	3 x 5 repetitions (supine) 3 x 5 repetitions (sitting) 3 x 5 repetitions (standing) 3 x 5 repetitions (walking)
Cyclic stretching of scalene and pectoralis minor, from supine, done by the therapist, hold 3–5 seconds, repeat on each side	3–5 repetitions
Shoulder extension with TheraBand from supine and standing	3 x 10 repetitions very light band 3 x 10 repetitions light band 3 x 10 repetitions medium band
Prone extension, prone horizontal abduction with external rotation	3 x 7 repetitions 3 x 10 repetitions 3 x 12 repetitions 3 x 12 repetitions 1 kg dumbbell 3 x 12 repetitions 1.5 kg 3 x 12 repetitions 2 kg 3 x 12 repetitions 2.5 kg
Craniocervical flexor muscles	5 repetitions 5 seconds hold 5 repetitions 10 seconds hold 5 repetitions 15 seconds hold 5 repetitions 20 seconds hold 5 repetitions 25 seconds hold 5 repetitions 30 seconds hold
Neck isometric for side bending. 10 seconds hold	3 x 10 repetitions manual resistance 3 x 10 repetitions, light band 3 x 10 repetitions, medium band 3 x 10 repetitions, heavy band

TABLE 2: Detailed multimodal physical therapy program: phase 2 sub-acute.

Phase 3 (Chronic)

Phase 3 was the strengthening stage. The criteria for progressing to this stage were a palpable radial pulse and/or absence of symptoms above 90° of shoulder elevation (Figure *2*). Progressive strengthening exercises were delivered, electrophysical agents were discontinued, and myofascial release was used only as needed. Neurodynamic mobilization of the median nerve was also added in this phase. Exercise progressions are shown in Table *3*.

Manual therapy	
Description	*Dose and progression*
Thoracic and ribs mobilization.	2 minutes
Neural mobilization of median nerve, Sliding technique	3 x 7 repetitions
Therapeutic exercises	
Description	*Dose and progression*
Diaphragmatic breathing	3 x 5 repetitions (supine) 3 x 5 repetitions (sitting) 3 x 5 repetitions (standing) 3 x 5 repetitions (walking)
Pectoralis minor self-stretch, from standing shoulder flexed and abducted 90 on wall and leaning with the chest, repeat on each side	3 x 3 repetitions, 30 seconds hold 3 x 3 repetitions, 1 minute hold
Shoulder extension with TheraBand from supine and standing	3 x 10 repetitions very light band 3 x 10 repetitions light band 3 x 10 repetitions medium band
Prone extension, prone horizontal abduction with external rotation	3 x 7 repetitions 3 x 10 repetitions 3 x 12 repetitions 3 x 12 repetitions 1 kg dumbbell 3 x 12 repetitions 1.5 kg 3 x 12 repetitions 2 kg 3 x 12 repetitions 2.5 kg
Craniocervical flexor muscles	5 repetitions 5 seconds hold 5 repetitions 10 seconds hold 5 repetitions 15 seconds hold 5 repetitions 20 seconds hold 5 repetitions 25 seconds hold 5 repetitions 30 seconds hold
Neck isometric for side bending. 10 seconds hold	3 x 10 repetitions manual resistance 3 x 10 repetitions, light band 3 x 10 repetitions, medium band 3 x 10 repetitions, heavy band
Scaption with weight, repeat on each side	3 x 12 repetitions 3 x 12 repetitions 1 kg dumbbell 3 x 12 repetitions 1.5 kg 3 x 12 repetitions 2 kg 3 x 12 repetitions 2.5 kg
Seated row resistance exercise, repeat on each side	3 x 12 repetitions 5 kg cable 3 x 12 repetitions 10 kg cable 3 x 12 repetitions 15 kg cable 3 x 12 repetitions 25 kg cable 3 x 12 repetitions 30 kg cable
External rotation from standing with a pillow under the elbow and at 90 degrees of abduction and external rotation	3 x 12 repetitions light band 3 x 12 repetitions medium band 3 x 12 repetitions heavy band 3 x 12 repetitions 5 kg cable

TABLE 3: Detailed multimodal physical therapy program: phase 3 chronic.

Outcome measures

Pain was measured with the NPRS, and arterial velocity with dynamic duplex ultrasound. Changes are presented in Table *4*. The four-month assessment took place at the end of treatment. NPRS decreased from 9/10 to 2/10, so pain improved but was not absent. However, symptoms of numbness and heaviness were resolved. Arterial velocity decreased from 178 to 107 cm/s on the left and from 195 to 122 cm/s on the right in provocative position, against resting velocities of 55 and 57 cm/s. The provocative-to-resting ratio fell from about 4.0 to 1.9 on the left and from 3.9 to 2.1 on the right. The patient returned to work without limitations. She was instructed to continue scapular strengthening, rotator cuff strengthening, and breathing exercises as a home program.

Outcomes	Baseline	After 4 months
NRPS (0–10)	9	2
Blood flow Speed (cm/s)		
Left side in neutral	45	55
Left side in ABER	178	107
Right side in neutral	50	57
Right side in ABER	195	122

TABLE 4: Changes in outcome measures.

NRPS: numeric pain rating scale; ABER: abduction and external rotation

Discussion

In this case, after four months of the proposed criteria-based multimodal physical therapy program, the patient had reduced pain (NPRS 9/10 to 2/10), resolution of numbness and heaviness, and reduced provocative arterial velocity elevations on duplex ultrasound.

TOS is a challenging diagnosis because its symptoms are heterogeneous and overlap with other conditions. After excluding a cervical origin, cubital tunnel syndrome, and other possible sites of compression, TOS was diagnosed once the patient met the CORE-TOS criteria in addition to the duplex ultrasound findings.

Duplex ultrasound can assess dynamic blood flow, which makes it the initial diagnostic imaging study for vascular TOS [13]. In nTOS, one study found a significant association between symptomatic upper limbs and vascular compression (odds ratio = 2.45, 95% confidence interval = 1.33-4.49), with duplex ultrasound sensitivity of 54.5% and specificity of 67% [10].

The examination involves visualizing both the arteries and the veins. In patients with TOS, the axillary vessels can be pinched or occluded by arm elevation or a deep breath and return to normal when the arm is lowered or breathing returns to normal. Hemodynamic impingement has been defined as an increase in blood flow velocity of more than two-fold [14]. In our patient, the provocative-to-resting velocity ratio was about 4.0 on the left and 3.9 on the right at baseline, above this criterion. After treatment, it was about 1.9 on the left and 2.1 on the right, so the left side fell below the criterion and the right side remained marginally above it. Bowing of the pectoralis minor has been described on ultrasound in a patient with TOS. During arm abduction, the muscle was indented from below by the neurovascular bundle [15].

Vascular compression does not by itself establish nerve compression, although the brachial plexus lies close to the subclavian and axillary vessels. A recent opinion paper argues that high-frequency point-of-care ultrasound should complement clinical assessment in suspected nTOS [16]. The same authors note that ultrasound is operator-dependent and dynamic vascular compression can occur in asymptomatic individuals [16].

Our intervention was a progressive, multimodal program designed to address the multidimensional nature of the condition. It included electrophysical agents, manual therapy techniques, and therapeutic exercise. The objectives were to modulate pain, increase pectoralis muscle flexibility, and improve neuromuscular control of the scapula and shoulder. In Phase 1, conventional TENS, hot packs, and phonophoresis were delivered to modulate pain and improve blood supply.

A previous study reported symptom relief in 25 of 42 patients with nTOS after six months of physical therapy [17]. Our approach avoided postural correction, stretching exercises, and neural mobilization early on to prevent increased compression or mechanical stress on the neurovascular structures, which could aggravate the patient's symptoms [18].

PM hyperactivity can develop into muscle contracture, leading to scapular protraction and anterior tilt at rest and ultimately narrowing the retropectoral space [8]. Therefore, myofascial release and stretching of the PM were included in the appropriate phases of rehabilitation according to patient irritability. Scapular muscle-strengthening exercises were performed to improve neuromuscular control and position of the scapula, with the goal of increasing the retropectoral space. Rotator cuff strengthening exercises were also performed to enhance glenohumeral joint stability.

Several factors other than the program could explain the improvement. These include natural history, avoidance of provocative overhead activity, medication, patient education, regression to the mean, and the combined nonspecific effects of multiple interventions. The four-month assessment was at the end of treatment, so we cannot say whether improvement lasted after the end of the treatment. Outcomes of conservative treatment for TOS also vary, and reporting of rehabilitation techniques for nTOS is generally poor [19].

This case report provides a detailed, criteria-based rehabilitation program for TOS of pectoralis minor etiology with duplex ultrasound evaluation. Future randomized controlled trials should test the effectiveness of this program in patients with TOS.

Conclusions

Suspicion of TOS should be high in patients with upper extremity neural manifestations, particularly when a previous diagnosis such as cubital tunnel syndrome has not responded to treatment. Dynamic duplex ultrasound can show positional vascular compression, but it does not by itself establish neurogenic compression, so it should be interpreted together with the clinical findings. We described a criteria-based multimodal physical therapy program for a patient with TOS of pectoralis minor etiology. After four months of treatment, pain decreased from 9/10 to 2/10, provocative arterial velocity elevations were reduced compared with baseline, and the patient returned to work without limitations. These findings suggest that a criteria-based multimodal program may be a useful option for patients with TOS of pectoralis minor etiology. However, these are short-term outcomes. Prospective studies are needed to test the effectiveness of this program.

Additional Information

Author Contributions

All authors have reviewed the final version to be published and agreed to be accountable for all aspects of the work.

Concept and design: Ahmed O. Mohamady

Drafting of the manuscript: Ahmed O. Mohamady

Critical review of the manuscript for important intellectual content: Ahmed O. Mohamady, Hosny Elkhawaga, Mohamed Badr

Acquisition, analysis, or interpretation of data: Hosny Elkhawaga, Mohamed Badr

Supervision: Mohamed Badr

Disclosures

Human subjects: Informed consent for treatment and open access publication was obtained or waived by all participants in this study. **Conflicts of interest:** In compliance with the ICMJE uniform disclosure form, all authors declare the following: **Payment/services info:** All authors have declared that no financial support was received from any organization for the submitted work. **Financial relationships:** All authors have declared that they have no financial relationships at present or within the previous three years with any organizations that might have an interest in the submitted work. **Other relationships:** All authors have declared that there are no other relationships or activities that could appear to have influenced the submitted work.

References

1. Dengler NF, Ferraresi S, Rochkind S, et al.: Thoracic outlet syndrome part I: systematic review of the literature and consensus on anatomy, diagnosis, and classification of thoracic outlet syndrome by the European Association of Neurosurgical Societies' Section of Peripheral Nerve Surgery. Neurosurgery. 2022, 90:653-67. 10.1227/neu.0000000000001908
2. Hooper TL, Denton J, McGalliard MK, Brismée JM, Sizer PS Jr: Thoracic outlet syndrome: a controversial clinical condition. Part 1: anatomy, and clinical examination/diagnosis. J Man Manip Ther. 2010, 18:74-83. 10.1179/106698110X12640740712734
3. Illig KA, Donahue D, Duncan A, et al.: Reporting standards of the Society for Vascular Surgery for thoracic outlet syndrome. J Vasc Surg. 2016, 64:e23-35. 10.1016/j.jvs.2016.04.039
4. Sanders RJ, Annest SJ: Thoracic outlet and pectoralis minor syndromes . Semin Vasc Surg. 2014, 27:86-117. 10.1053/j.semvascsurg.2015.02.001
5. Cavanna AC, Giovanis A, Daley A, Feminella R, Chipman R, Onyeukwu V: Thoracic outlet syndrome: a review for the primary care provider. J Osteopath Med. 2022, 122:587-99. 10.1515/jom-2021-0276
6. Sanders RJ: Recurrent neurogenic thoracic outlet syndrome stressing the importance of pectoralis minor syndrome. Vasc Endovascular Surg. 2011, 45:33-8. 10.1177/1538574410388311

7. Sanders RJ, Rao NM: The forgotten pectoralis minor syndrome: 100 operations for pectoralis minor syndrome alone or accompanied by neurogenic thoracic outlet syndrome. Ann Vasc Surg. 2010, 24:701-8. 10.1016/j.avsg.2010.02.022
8. Ahmed AS, Graf AR, Karzon AL, et al.: Pectoralis minor syndrome - review of pathoanatomy, diagnosis, and management of the primary cause of neurogenic thoracic outlet syndrome. JSES Rev Rep Tech. 2022, 2:469-88. 10.1016/j.xrrt.2022.05.008
9. Chim H, Hagan RR: Consensus Recommendations for Neurogenic Thoracic Outlet Syndrome from the INTOS Workgroup. Plast Reconstr Surg Glob Open. 2024, 12:e6107. 10.1097/GOX.0000000000006107
10. Fouasson-Chailloux A, Menu P, Daley P, Gautier G, Gadbled G, Abraham P, Dauty M: Subclavian vessel compression assessed by duplex scanning in patients with neurogenic thoracic outlet syndrome and no vascular signs. Diagnostics (Basel). 2021, 11:126. 10.3390/diagnostics11010126
11. Rochkind S, Ferraresi S, Denisova N, et al.: Thoracic outlet syndrome part II: consensus on the management of neurogenic thoracic outlet syndrome by the European Association of Neurosurgical Societies' Section of Peripheral Nerve Surgery. Neurosurgery. 2023, 92:251-7. 10.1227/neu.0000000000002232
12. Hock G, Johnson A, Barber P, Papa C: Current clinical concepts: rehabilitation of thoracic outlet syndrome . J Athl Train. 2024, 59:683-95. 10.4085/1062-6050-0138.22
13. Altuwaijri TA: Comparison of duplex ultrasound and hemodynamic assessment with computed tomography angiography in patients with arterial thoracic outlet syndrome. Medicine (Baltimore). 2022, 101:e30360. 10.1097/MD.0000000000030360
14. 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:e0268842. 10.1371/journal.pone.0268842
15. Sucher BM: Ultrasonography-guided osteopathic manipulative treatment for a patient with thoracic outlet syndrome. J Am Osteopath Assoc. 2011, 111:543-7. 10.7556/jaoa.2011.111.9.543
16. Simpson A, Saaed I, Cooper R, Loftus I, Abbas A: High-definition point-of-care ultrasound in neurogenic thoracic outlet syndrome: an evidence-informed clinical perspective. J Neurol Sci. 2026, 490:126165. 10.1016/j.jns.2026.126165
17. Landry GJ, Moneta GL, Taylor LM Jr, Edwards JM, Porter JM: Long-term functional outcome of neurogenic thoracic outlet syndrome in surgically and conservatively treated patients. J Vasc Surg. 2001, 33:312-7. 10.1067/mva.2001.112950
18. Larsen K: Postural cues for scapular retraction and depression promote costoclavicular space compression and thoracic outlet syndrome. Anaesth Pain Intensive Care. 2018, 22:256-67.
19. O'Sullivan J, Rushton C, Bateman M, Miller C, Stapleton C, Hill J: Physical assessment and rehabilitation for neurogenic thoracic outlet syndrome (NTOS): a scoping review. Hand Ther. 2026, 17589983251411877. 10.1177/17589983251411877