Thoracic Outlet Syndrome and the Diagnostic Implications of Anatomical Variation in the Brachial Plexus

Vanessa Leonard1, MS-II; Riley Landreth1, MS-I; Gregory Caldwell1, MS-II; Heather F. Smith2,3, Ph.D.; Richard Gessel1, D.O.

1Arizona College of Osteopathic Medicine, Department of Osteopathic Manipulative Medicine, Midwestern University, Glendale, AZ
2Department of Anatomy, Midwestern University, Glendale, AZ
3School of Human Evolution and Social Change, Arizona State University, Tempe, AZ

Authors for correspondence: vleondan26@midwestern.edu; landrethr1@midwestern.edu

Introduction

Thoracic outlet syndrome (TOS) is a debilitating musculoskeletal condition frequently faced by orthopaedic physicians. It can be further classified into various, arterial or neuralgic, in nature. The neurogenic form of TOS (NTOS) makes up 30%–40% of all cases seen by orthopedic surgeons. Patients report numbness, pain, paresthesia, and even paresis in the upper extremity. Symptoms related to NTOS typically involve the musculature, paraspinal, and paresthesia in the upper extremity. These neurogenic symptoms are traditionally thought to be caused by a proximal compression of the brachial plexus between the anterior and middle scalene muscles. This compression results in a plexopathy (Table 1, Fig. 1). Each subtype of TOS has a distinct set of symptoms resulting from compression of the subclavian artery (arterial), subclavian vein (venous) and/or the brachial plexus (neurogenic). Symptoms related to NTOS typically involve numbness, pain, paresthesia, and even paresis in the upper extremity. These neurogenic symptoms are traditionally thought to be caused by a proximal compression of the brachial plexus between the anterior and middle scalene muscles. This compression results in a plexopathy (Table 1, Fig. 1). Each patient completed a questionnaire describing their symptoms and daily limitations, followed by a complete neurological and vascular exam with provocative positional testing (Table 1, Fig. 1).

Provocative Test

Ascher's Test

Indicated for compression of subclavian artery between anterior and middle scalene muscles. Performed by monitoring radial pulse with abduction, extension and rotation of upper extremity while patient takes a deep breath and turns head (posteriorly) to test externity.

Positive Test

Marked reduction of radial pulse

Coastalveolar Test

Indicated for compression of subclavian artery between clavicle and first rib. Performed by palpating patient's radial pulse and instructing patient to forcefully hyper-extend scapulae posteriorly while flexing clavicle.

Positive Test

Reduction of radial pulse

Wright's Hypoabduction Test

Indicated for compression of subclavian artery by pectoralis minor or muscle belly of anterior scalene muscle. Performed by monitoring patient’s radial pulse and lifting the blistered arm into hypoabduction.

Positive Test

Reproduction of symptoms and/or marked reduction of radial pulse

Modification of Spurling’s Maneuver

Indicated for cervical root compression at the cervical foramina. Performed by keeping head extended, ipsilaterally rotated, and contralaterally tilted while applying pressure on top of head for axial load.

Positive Test

Reproduction of symptoms beyond shoulder. Neck pain alone is non-specific

Methods

Sixty-five cadavers (53M/32F) from the gross anatomy laboratories in Midwestern University were assessed to determine the frequency of the brachial plexus variants. To investigate the potential relevance of the identified variants, the Institutional Review Board approval was obtained to recruit three patients, previously diagnosed with atypical NTOS symptoms, into a pilot study. Each patient completed a questionnaire describing their symptoms and daily limitations, followed by a complete neurological and vascular exam with provocative positional testing (Table 1, Fig. 1).

Results

In the 65 cadavers examined, 31 variations of the classical anatomy were observed (Table 2). The Povlsen Variant (Fig. 5A-B) was characterized by the superior trunk passing through the anterior scalene muscle, creating an anterior and posterior muscle belly. This was the predominant variation, noted in 27 of the 65 specimens (41.5%). The majority of these were unilateral in nature and primarily present on the left side. There were no significant anatomic differences in any provocative positional variations across gender, with 13 found in males and 12 in females.

Two subcategories of the 25 cadavers with Povlsen Variant were noted to include Multiple Povlsen and Bilateral Povlsen. Multiple Povlsen, found in 2 of the 25 cadavers, consisted of both middle and superior trunks piercing the anterior scalene muscle (Table 2, Fig. 5A-B). This specific variation was only found unilaterally and in males. Bilateral Povlsen, found in 8 of the 25 cadavers, consisted of the superior trunk coursing through the anterior scalene muscle on both sides (Table 2). Two of the 4 Bilateral Povlsen had a superior trunk Povlsen Variant on the left and a C5 Single Povlsen Variant on the right (Table 2, Fig. 5A-B). The C5 Single Povlsen Variant consisted of a C5 root piercing the anterior scalene during the remainder of the superior trunk (C5 root) passed between the subclavian (Table 2, Fig. 5A-B).

The anterior variant, noted in 2 cadavers, described a superior trunk that coursed superficial to the anterior scalene muscle (Table 2, Fig. 7A-B). This variation was only observed unilaterally and in females. In a 5 question survey, the three patients with atypical TOS and reported neurogenic symptoms of the upper extremity induced with physical activity. Provocative test reproduced neurologic symptoms in all three patients without compromising the radial pulse (Table 1, Fig. 1). Additionally, Modified Spurling’s Maneuver elicited no pain or paresthesia, which indicates that the symptoms are not due to nerve root compression.

Discussion

Thoracic outlet syndromic symptoms presents with a vague symptomatology of pain and paresthesia. Current diagnostic methods of TOS rely on the classic compression of both the plexus and the subclavian artery at one of three sites: between the anterior and middle scalene, between the clavicle and first rib, or deep to the pectoralis minor tendon. Each can be diagnosed by monitoring for diminished radial pulse in different provocative positions (Table 1, Fig. 1). Historically, the diagnosis of TOS has been controversial because of the nonspecific patient presentation and insensitivity of the symptoms alone to test results. Provocative positional testing frequently shows an inconclusive or negative result in symptomatic patients. In cases where the brachial plexus and subclavian artery are not palpable or visible due to the tautness of the pectoralis minor, electromagnetic (EMG) and ultrasonic imaging with active patient range of motion to obtain an arthral diagnosis of TOS. This method could be validated to visualize the compression of the brachial plexus in the thoracic outlet.

Currently the majority of TOS can be treated conservatively with lifestyle modifications, anti-inflammatory, physical therapy and OMT. Non-surgical, invasive options include lidocaine block and subtotal lesion injection of the sciatric nerve. Surgical options include transection of the first rib C1-C2 with respect to the carotid artery of the brachial plexus (SNBP). Such blocks can be both diagnostic and therapeutic, causing a relaxation in the muscles impinging upon nerve roots of the brachial plexus. Such changes in the superficial and deep cutaneous potentials changes including nerve, large vessels, and long hairy. There is a meta-analysis of randomized and controlled studies indicating that neither TNR or SNMP decrease pain more than placebo.

Data is lacking regarding the utility of other non-surgical approaches for TOS. While treatment options include both non-surgical and surgical interventions, the anatomical variations of the brachial plexus require unique management strategies.

OMT options for TOS rely on the use of strain-counterstrain and Muscle Energy to target hypertonic symptom complexes. Strain-Counterstrain of the anterior scalene muscle is performed by passively inducing mild flexion of the neck while side-bending and rotating the head towards the side of sciatric variation and improvement.4 Given the similar origin and insertion sites of both anterior and middle scalene muscles, the anterior scalene muscle can be selectively treated based upon its own medial attachment to the first rib. To specifically denote Strain-Counterstrain to the anterior scalene, the hand is translated anteriorly and minor shoulder rotation and abduction are used to fine-tune. Muscle Energy targets the extrinsic muscle fibers of the anterior scalene to reduce tension. This decreases firing of the gamma motor neuron within the muscle spindle and allows the nerve to pass with minimal impingement.2 While both techniques provide relief to a patient with typical impingement between the anterior and middle scalene, a patient with a variant variation would only benefit from treatment of the anterior scalene.

Given the prevalence of variation found (47.7%), there are a significant number of patients with neurogenic symptoms who could benefit from further investigation into the clinical consequences of similar anatomical variations. Awareness of such structural anomalies provides practitioners insight into effective orthotopic treatment plans that may more precisely target the anatomy. We plan to use sonography to identify the location of the brachial plexus in relation to the variant scalene anatomy. These findings would be further explored using orthotopic positional testing.

Table 1. Summary of Provocative Tests

<table>
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<tbody>
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Table 2. Summary of Cadaveric Anatomical Variants

<table>
<thead>
<tr>
<th>Male</th>
<th>Left Single Piercing</th>
<th>Right Single Piercing</th>
<th>Bilateral Piercing</th>
<th>Multiple Piercing</th>
<th>C5 Single Piercing</th>
<th>Anterior</th>
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References and Acknowledgements