

Review

Role of Ultrasound in Diagnosis of Thoracic Outlet Syndrome: A Review Article

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**Keywords:**

Neurogenic thoracic outlet syndrome
High-resolution ultrasound
Nerve compression
Decompression
Dynamic ultrasound

Received: August 05, 2023

Revised: August 15, 2023

Accepted: August 20, 2023

First Published: August 25, 2023

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Citation: Sabr NS, Abdullah F, Namiq HS, Mohammed NA, Ahmed ZM, Ghafour AK et al. Role of Ultrasound in Diagnosis of Thoracic Outlet Syndrome: A Review Article. Barw Medical Journal. 2023;1(3):26-29. <https://doi.org/10.58742/bmj.v1i2.47>

Abstract

Neurogenic thoracic outlet syndrome (nTOS), characterized by brachial plexus compression within the thoracic outlet, poses diagnostic challenges due to its variable symptoms and lack of standardized criteria. Ultrasound has emerged as a valuable diagnostic tool, offering dynamic imaging, high-resolution visualization of soft tissues, and differentiation between neurogenic and vascular forms. We reviewed the literature regarding ultrasound's role in nTOS diagnosis. Ultrasound's dynamic assessment aids in understanding nerve and vessel compression during arm movements, providing insights beyond static imaging. High-resolution imaging detects structural anomalies contributing to nTOS and reveals direct and indirect signs, such as brachial plexus or vessel compression. Varied findings exist regarding ultrasound sensitivity and specificity. Despite potential benefits, controversy remains, highlighting the need for further research to establish standardized protocols, refine techniques, and explore integrated diagnostic approaches for nTOS.

1. Introduction

Neurogenic thoracic outlet syndrome (nTOS) is a multifaceted condition characterized by the compression of the brachial plexus or related nerves as they traverse the thoracic outlet [1]. This compression can lead to a wide array of neurological symptoms in the upper extremities, including pain, numbness, tingling, and muscle weakness. However, diagnosing nTOS presents significant challenges due to the variability of symptoms and the lack of standardized diagnostic criteria. In recent years, ultrasound has emerged as a valuable diagnostic tool in the assessment of nTOS, offering dynamic imaging capabilities, high-resolution visualization of soft tissues, and the ability to differentiate between neurogenic and vascular forms of TOS [1,2]. Despite that, there are still controversies regarding the role of ultrasound in the diagnosis of nTOS.

This review focuses on the feasibility of ultrasound in the diagnosis of nTOS.

2. Ultrasound Imaging Technique and Dynamic Assessment

Ultrasound is a non-invasive imaging technique that utilizes high-frequency sound waves to create real-time images of internal structures within the body. It is widely employed in various medical fields for its ability to provide detailed images of soft tissues, muscles, tendons, blood vessels, and nerves. In the context of nTOS, ultrasound offers several advantages over other imaging modalities. The images can be manipulated in real-time, providing clinicians with insights into the dynamic interactions between various anatomical components of the thoracic outlet region [3].

The role of ultrasound in diagnosing nTOS lies in its dynamic imaging capability. In contrast to static imaging techniques such as magnetic resonance imaging or computed tomography scans, ultrasound enables real-time visualization of anatomical structures and their responses to different arm movements and postures. Given that nTOS symptoms often exacerbate with specific movements, such as reaching overhead or turning the head, ultrasound may offer crucial insights into how the brachial plexus and adjacent structures (subclavian and axillary vessels) react during these motions. This dynamic assessment is instrumental in identifying areas of nerve and vessel compression or entrapment that might remain unnoticed in static images, contributing to a more accurate and comprehensive diagnosis [2,3].

3. Visualization of Structural Abnormalities and Compression

Ultrasound's high-resolution imaging capabilities allow for the identification of structural anomalies that contribute to nTOS. These anomalies encompass a range of variations, including muscle attachments, cervical ribs, fibrous bands, and hypertrophied scalene muscles. By visualizing these anatomical features, clinicians can pinpoint potential sites of nerve

compression and acquire a deeper understanding of the underlying causes of patient symptoms. Furthermore, ultrasound enables the assessment of how these structures interact dynamically, shedding light on the mechanisms through which nerve compression occurs during specific movements or postures [3].

4. Sonographic Direct and Indirect Signs of nTOS

Precise diagnosis is pivotal in determining the most appropriate treatment approach for nTOS. Ultrasound can provide two types of signs: direct signs which mean the visualization of the brachial plexus compression by high-resolution ultrasound and indirect signs mean compression of subclavian and axillary vessels without clinical signs of vascular TOS [2,4-8]

There are controversies regarding the sensitivity and specificity of direct signs. Aryani and associates investigated nTOS using high-resolution ultrasound to identify fibromuscular structures in the thoracic outlet region as the primary cause. The authors differentiated between neurogenic and non-specific TOS, observing a preponderance of females and early symptom onset. The study introduced the "wedge-sickle sign," a novel ultrasonographic marker facilitating pre-surgical identification of fibromuscular bands causing TOS, especially in cases without overt neurological deficits. This non-invasive diagnostic approach holds the potential for early intervention and effective management of TOS-related symptoms. In their study, there was a great success (95%) for the ultrasound to identify brachial plexus compression [2]. Leonhard et al. investigated the connection between structural variations in the thoracic outlet and the risk of nTOS. The researchers discovered common anatomical variations in the brachial plexus branching, where parts of the proximal plexus penetrated the anterior scalene muscle, potentially leading to nerve impingement and a predisposition to nTOS. The study aimed to link brachial plexus piercing variations with nTOS symptoms and assess the effectiveness of ultrasound in identifying patients with clinically relevant variations. After dissecting 82 cadaveric necks, the researchers found that over 60% had brachial plexus variations. Subsequently, they screened 22 subjects using questionnaires, tests, and ultrasound, and found that 21% displayed atypical brachial plexus branching on ultrasound, with 50% reporting nTOS-like symptoms—significantly higher than those with classic brachial plexus anatomy (14%). The study suggested that adding ultrasound to nTOS diagnosis, especially for patients with brachial plexus branching variations, could enhance clinicians' ability to identify and visualize unusual anatomical patterns [4]. In a retrospective cohort study involving 167 patients with suspected TOS, Dollinger et al. investigated the diagnostic effectiveness of combined nerve and vascular ultrasound. The study focused on two sites and examined nerve anomalies/compression in the brachial plexus and vascular compression in the subclavian artery. Abnormal ultrasound findings significantly differed from the control group. Sensitivity was 48% for nerve ultrasound, 85% for vascular ultrasound, and 94% when combined. Specificity was highest for the fibromuscular 'wedge-sickle sign' indicating lower trunk compression by a fibromuscular anomaly (e.g. Roos ligaments),

and a bony 'wedge-sickle sign' indicating compression from the 1st rib's neck. The method identified compression sites, primarily the costoclavicular space. They concluded that combined nerve and vascular ultrasound was a reliable and sensitive diagnostic tool for TOS, aiding in identifying compression sites with potential therapeutic implications [5].

The above finding was contradicted by Pesser and colleagues. In their prospective study, the diagnostic potential of high-resolution ultrasound for nTOS was explored. The study, conducted at the nTOS-center of the Catharina Hospital in the Netherlands, involved patients suspected of having nTOS. A multidisciplinary approach was employed. After a comprehensive evaluation process, high-resolution ultrasound of the brachial plexus was utilized to diagnose nTOS in a subset of patients. Among the patients included, high-resolution ultrasound identified a hyper-echoic fibromuscular structure called the wedge-sickle sign in only four nTOS arms among 54 patients. Overall, while high-resolution ultrasound did not significantly contribute to nTOS diagnosis, it demonstrated potential value in identifying fibromuscular bands causing compression, particularly in specific cases involving cervical ribs or elongated transverse processes [6].

Other authors also denied the role of ultrasound in the diagnosis of nTOS. In their study, Goeteyn et al. explored the utility of duplex ultrasound as a diagnostic tool for nTOS. The study involved a retrospective review of patients referred to the management of TOS. The aim was to assess the correlation between vascular symptoms and ultrasound findings, as well as their link to clinical outcomes. The study specifically focused on patients with "proven nTOS," defined as those responding successfully to thoracic outlet decompression surgery. Results indicated that while vascular symptoms are observed in a significant portion of patients, alterations in flow velocities measured through ultrasound do not significantly correlate with these symptoms or clinical outcomes. Notably, dysautonomia was suggested as the primary cause of most signs and symptoms rather than vascular compromise. Thus, the role of ultrasound in diagnosing nTOS, particularly in patients with vascular complaints was unclear, with clinical acumen deemed more important in nTOS diagnosis and treatment [7].

Compression of the subclavian and axillary vessels are regarded as indirect sonographic signs of nTOS which can be found in nearly 50% of the cases [8,9]. Orlando and colleagues conducted a study aiming to assess the diagnostic significance of venous and arterial duplex scanning in nTOS. The researchers retrospectively reviewed those patients who underwent duplex ultrasonography before first rib resection and splenectomy during eight years. They categorized abnormal scans based on specific compression patterns. Out of 143 patients (76% female, average age 34), 31% exhibited ipsilateral compression, 8% had contralateral compression, and 10% displayed bilateral compression. About 51% of patients showed no compression. Those with ipsilateral compression were more likely to experience intraoperative pneumothoraces and have positive Adson tests. The study concluded that identifying subclavian vein or artery compression through duplex ultrasonography can aid in diagnosing nTOS, with ipsilateral compression during abduction often correlating with positive Adson testing [8].

Chailloux et al. focused on evaluating the results of duplex scanning in patients with nTOS, particularly those without clinical vascular signs. Their study involved 101 patients with unilateral or bilateral nTOS and assessed subclavian vessels using duplex scanning. Compressions were identified when there was a >50% increase or decrease in blood flow. Of the patients meeting nTOS criteria, 56.4% exhibited vessel compression, with similar rates in the unilateral and bilateral groups. Notably, there was a significant difference in the rates of vascular compression between symptomatic and non-symptomatic upper limbs. However, despite this association, duplex scanning's sensitivity and specificity for diagnosing nTOS were 54.5% and 67%, respectively, and it didn't significantly aid in making the diagnosis [9].

5. Conclusion

The use of ultrasound in diagnosing nTOS presents a complex landscape with varying perspectives. nTOS is a challenging condition to diagnose due to its diverse symptomatology and the absence of standardized diagnostic criteria. Ultrasound dynamic assessment provides insights into the interactions between anatomical structures during arm movements and postures, crucial for understanding nerve and vessel compression mechanisms. However, ultrasound has shown promise in identifying structural anomalies and direct and indirect signs of nTOS, controversies exist regarding its sensitivity and specificity. Therefore, while ultrasound holds promise in enhancing our understanding of nTOS, its definitive role in diagnosis remains a subject of ongoing investigation and debate. Future research should aim to establish standardized protocols, refine imaging techniques, and explore the integration of ultrasound with other diagnostic tools to achieve more accurate and comprehensive nTOS diagnoses.

Declarations

Conflicts of interest: The author(s) have no conflicts of interest to disclose.

Ethical approval: Not applicable.

Patient consent (participation and publication): Not applicable.

Funding: The present study received no financial support.

Acknowledgements: None to be declared.

Authors' contributions: FHK, NSS, AKG and SKA designed the study; BAA, KFH, and HSN participated in preparing the manuscript; NSS, NAM, SHT, CSO, RJR, ZMA, BAA and AAA participated in data collection; FA and SHK, DAO and ZMA critically revised the manuscript; FHK, NSS confirmed the authenticity of the data; all authors approved the final version of the manuscript

Data availability statement: Note applicable.

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