State-of-the-art Magnetic Resonance Imaging in Vascular Thoracic Outlet Syndrome

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KEYWORDS

• Vascular thoracic outlet syndrome • MR imaging • Contrast-enhanced 3D MR angiography

KEY POINTS

- The use of contrast-enhanced 3D MRA using provocative arm positioning provides comprehensive information on arterial and venous compression by surrounding organs.
- Equilibrium phase images increase detection venous abnormalities when enhancement is not adequate on the venous phase of contrast-enhanced 3D MRA.
- Contrast-enhanced 3D MRA with equilibrium phase images is a valuable tool, however should be used as complementary tests in diagnosis of vascular thoracic outlet syndrome.

INTRODUCTION

Thoracic outlet syndrome (TOS) is a constellation of symptoms caused by impingement of the subclavian vessels and brachial plexus during their passage from the thoracic cavity to the axilla. TOS has been classified into several types, including neurogenic TOS (nTOS), arterial TOS (aTOS), and venous TOS (vTOS).[1] The true incidence of TOS is controversial, and has been reported to range from 0.3% to 8%.[2] nTOS accounts for almost 90% of cases of TOS, whereas less than 10% of patients have only vascular or combined symptoms.[1,3–7] The female/male ratio for nTOS is 3.5:1 and there is no sex predilection for the arterial type.[4,8,9] vTOS is traditionally considered to be male predominant; however, the largest study reported a similar proportion of men and women.[10]

Underlying causes for compression are congenital or acquired factors, such as cervical rib, long C7 transverse process, exostosis, hypertrophic callus, congenital fibromuscular anomalies, posture, repetitive movements, and posttraumatic fibrosis of the scalene muscle.[1,11,12] aTOS is almost always associated with bone abnormalities, such as cervical rib, callus, or exostosis,[1,8] whereas venous disorder is caused by repetitive injury to the subclavian vein by the first rib, clavicle, subclavius muscle, anterior scalene muscle, and costoclavicular ligament.[13] Both vTOS and aTOS usually develop in young, healthy patients with few if any comorbid conditions.[8,13]

The symptoms caused by arterial compression are pain, claudication, pallor, and coldness; however, pain and edema can be seen with vTOS.[1] Edema of the upper extremity is the hallmark for venous compression, especially when it is associated with thrombosis (effort thrombosis, which is also known as Paget-Schroetter syndrome).[13] Pain is the most common feature in aTOS,

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although some patients with venous compression experience paresthesia caused by swelling rather than nerve compression.[1,5] Although rare, potential severe complications have been reported, including venous gangrene of the hand, pulmonary embolism as a result of venous compression or digital ischemia, and stroke associated with aTOS (Table 1).[3,4,6,7,14,15]

TOS can be diagnosed with history and a physical examination that includes provocative tests. However, imaging is required to identify vascular abnormalities. Conventional digital subtraction angiography (DSA) has been considered the reference standard for diagnosis of vascular TOS.[16] However, DSA has potential risks, including nephrotoxicity from iodinated contrast agent, arterial puncture site complications, ionizing radiation, and rarely stroke. Also, it requires separate procedures for arteries and veins; therefore, DSA is reserved for minimally invasive interventions and preoperative evaluation of the vessel anatomy to determine surgical approach or bypass graft planning. Computed tomography angiography (CTA) can be used as an alternative to DSA to reveal vascular anatomy and disorders using multiplanar reformatted techniques and maximal intensity projections (MIPs).[17] However, similar to DSA, it requires iodinated contrast agent and considerable irradiation, particularly with multiphase acquisitions during the arm abduction and rest positions. Also, bolus injection at a high rate results in a streak artifact from contrast material in the superior vena cava, which may obscure disorders in these regions.

Contrast-enhanced three-dimensional (3D) magnetic resonance angiography (MRA) with provocative arm positioning has emerged as the primary imaging tool to evaluate patients with TOS.[18–22] Contrast-enhanced 3D MRA is a noninvasive, user-independent imaging modality that does not affect renal function[23] when used in the recommended amount in patients who have normal renal function (glomerular filtration rate >30 mL/min). For vascular TOS assessment, flow-based bright-blood MR venography (MRV) including time of flight (TOF) has been used.[24] However, it is limited to a two-dimensional implementation because of signal saturation of slow flow. TOF is also more time consuming and images may be impaired by breathing artifacts.[25,26]

This article reviews the anatomy of the thoracic outlet, MR imaging techniques for evaluation of vascular TOS, and imaging features of vascular TOS.

ANATOMY

The thoracic outlet is an area located between thorax, shoulder, and under the clavicle.[27] Subclavian vessels course through several narrow passageways in the thoracic outlet (Fig. 1). First, the scalene triangle (interscalene triangle) is delineated by the anterior scalene muscle anteriorly, middle scalene muscle posteriorly, and the medial surface of the first rib inferiorly. The interscalene

Table 1
Vascular TOS: contrast-enhanced 3D MRA protocols for 1.5-T and 3-T MR imaging scanners

	aTOS	vTOS
Sex	Female/male equally	
Age (y)	20–30	20–35
Risk factors	Bone abnormalities (cervical rib and articulating with the first rib as a pseudoarthrosis; anomalous first rib; long C7 transverse process) Congenital fibrocartilaginous bands associated with the anterior scalene muscle Hypertrophic callus from healed clavicle or first rib fracture Vigorous exercise or activity involving affecting extremity Repetitive injury contributed by first rib, clavicle, subclavius muscle, and fibrous costoclavicular ligament leads to perivenous fibrosis and endothelial injury Posture	
Sign and symptoms	Pain Claudication Pallor Coldness	Paresthesia Hand swelling caused by edema Feeling of tightness worsens with exertion Venous engorgement with collateralization
Potential severe complications	Digital ischemia Stroke	Venous gangrene of the hand Pulmonary embolism