

# Diagnostic criteria of ultrasound duplex doppler for venous thoracic outlet syndrome: fifteen years' experience

Mauricio Figueroa-Sanchez<sup>1,2,a\*</sup> and L. Johanna Montaño-Rodriguez<sup>2</sup>

<sup>1</sup>University Center of Health Sciences, Universidad de Guadalajara; <sup>2</sup>Radiology and Imaging Department, Antiquo Hospital Civil of Guadalajara "Fray Antonio Alcalde" Guadalajara, Jalisco, Mexico

<sup>a</sup>0000-0001-7042-5221

## ABSTRACT

**Introduction:** There is no consensus regarding ultrasound (US) duplex Doppler findings for diagnosing vascular thoracic outlet syndrome (TOS). Our aim was to determine the ultrasound findings of the subclavian vein using US duplex Doppler with dynamic maneuvers to diagnose venous TOS. **Material and methods:** This retrospective cohort study conducted from May 2005 to December 2020 included patients with a clinical suspicion of vascular TOS examined by US duplex Doppler with dynamic maneuvers in three positions, 0°, 90°, and 180° by a single expert radiologist. **Results:** We included 110 US duplex Doppler scans from 97 patients (84 unilateral and 13 bilateral). Nineteen (17.2%) were normal and 91 (82.8%) abnormal; 84 (76.4%) with pure venous TOS and 6 (5.4%) with mixed TOS (venous and arterial); only one case (1%) was pure arterial TOS. In patients with venous TOS, the mean baseline (0°) diameter was  $7.42 \pm 1.36$  mm (pure) and  $7.33 \pm 0.82$  mm (mixed); during the dynamic maneuver at 180°, a complete diameter reduction (0 mm) and flow velocity (0 cm/s) were observed ( $p < 0.001$ ). In contrast, normal US duplex Doppler showed a mean diameter reduction of 50% or less from  $7.37 \pm 0.83$  mm at 0° to  $3.68 \pm 0.48$  mm during the dynamic maneuver at 180°. Flow velocity showed no significant change. **Conclusion:** We propose complete diameter reduction and absence of flow velocity in the subclavian vein during an ultrasound with a dynamic maneuver at 180° as criteria for diagnosing venous TOS. These diagnostic criteria have not been previously reported.

**Keywords:** Dynamic maneuvers. Subclavian vein. Subclavian vein diameter. Subclavian flow velocity. TOS. Ultrasound findings.

## INTRODUCTION

The diagnosis of thoracic outlet syndrome (TOS) is based on the medical history and physical examination. Imaging methods identify and evaluate normal and abnormal anatomic structures to locate affected sites and confirm or exclude a vascular origin and complications. In more than 90% of cases, TOS is neurogenic. The second most common type is venous TOS, and arterial TOS is uncommon (<3%)<sup>1</sup>. Ultrasound (US) duplex Doppler, a contrasted CT of the chest, or catheter venography of the upper extremity are

recommended for the initial diagnosis of venous TOS<sup>2</sup>. US duplex Doppler is a noninvasive procedure that provides dynamic assessment of the subclavian vessels and detects compression and associated complications in the subclavian artery, subclavian vein, or both<sup>2</sup>. The extent of vascular compression may increase during dynamic maneuvers<sup>3</sup>, such as arm abduction, which may narrow the thoracic outlet in all three spaces (the scalene triangle, the costoclavicular space, and the retropectoral space). This reduction is evidenced by decreased vessel diameter, increased flow velocities,

### Corresponding author:

\*Mauricio Figueroa-Sanchez, MD  
E-mail: [figueroa\\_sanchez@hotmail.com](mailto:figueroa_sanchez@hotmail.com)  
2696-8444 / © 2021 Federación Mexicana de Radiología e Imagen, A.C. Published by Permanyer. This is an open access article under the CC BY-NC-ND (<https://creativecommons.org/licenses/by-nc-nd/4.0/>).

Received for publication: 15-10-2021  
Approved for publication: 11-11-2021  
DOI: 10.24875/JMEXFRI.M21000005

Available online: 31-03-2022  
J Mex Fed Radiol Imaging. 2022;1(1):23-31  
[www.JMeXFRI.com](http://www.JMeXFRI.com)

and/or spectral wave change on US duplex Doppler. These parameters may be observed as physiologic (normal) or abnormal changes in patients with TOS<sup>1,3</sup>.

The US duplex Doppler parameters for the diagnosis of venous TOS have not been defined. Longley et al.<sup>4</sup> described significant venous compression with hyperabduction (90°, 135°, 180°) and a complete loss of the spectral waveform in the subclavian vein. The authors reported a US duplex Doppler sensitivity of 92% and a specificity of 95% compared with venography, which is the gold standard for diagnosing venous TOS. Spectral enhancement was not considered sufficient evidence for diagnosis and was associated with mild venous compression and turbulent blood flow. In another report, provocative maneuvers such as arm abduction to 90° and 180° were performed in patients with vascular TOS. It was suggested that a flow velocity reduction of 50% or greater or a complete Doppler signal loss in the subclavian vein confirmed venous TOS<sup>5</sup>. However, the characteristics of the diameter and flow velocity of the subclavian vein in US duplex Doppler in patients with venous TOS have not yet been defined. The aim of this study was to determine the ultrasound findings of the subclavian vein using US duplex Doppler with dynamic maneuvers to diagnose venous TOS.

## MATERIAL AND METHODS

This retrospective cohort study was conducted from May 2005 to December 2020 in the Radiology and Imaging Department of the Antiguo Hospital Civil de Guadalajara “Fray Antonio Alcalde” and the Laboratorio Vascular in Guadalajara Jalisco, Mexico. The US duplex Doppler studies of patients consecutively referred by angiologists, neurosurgeons, and orthopedists with a clinical suspicion of vascular TOS were included. Referring clinicians were experts in vascular and neurogenic TOS. Clinical suspicion was based on the medical history and physical examination with specific maneuvers described in the literature. Patients with a functional limitation of the shoulder to perform dynamic US duplex Doppler maneuvers were excluded. The study protocol and retrospective analysis of radiographic data obtained during routine medical care were approved by the institutional ethics and research committees.

The included variables were age, sex, laterality, unilateral or bilateral involvement, occlusion site, and scalene muscle hypertrophy. The ultrasound parameters recorded for the subclavian vein were diameter (mm), patency (absent or present), flow velocity (cm/s), and

thrombosis (absent or present); for the subclavian artery, diameter (mm), patency (absent or present), flow velocity (cm/s) and A/B ratio.

## Definitions

**Normal US duplex Doppler** was a reduction in the vessel diameter equal to or less than 50% with variable changes in flow velocity. These findings were considered physiological changes in response to dynamic maneuvers<sup>1,3</sup>.

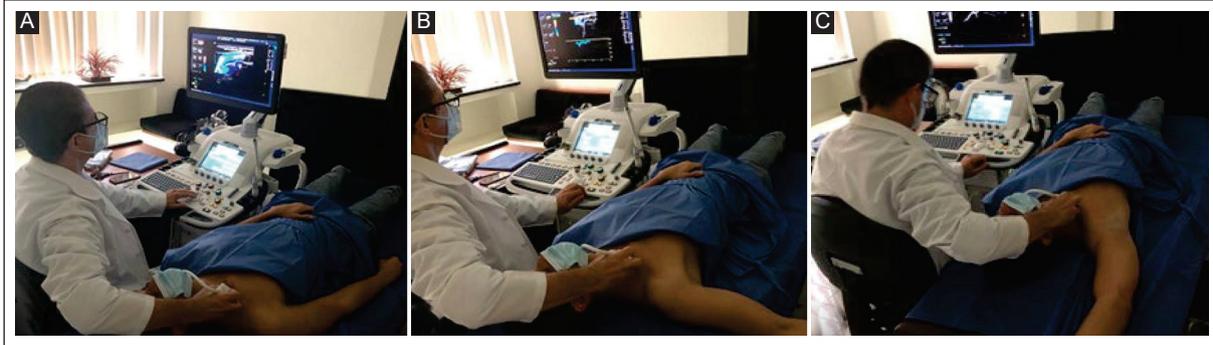
**Abnormal US duplex Doppler** was defined by a reduction of the subclavian vein and/or artery diameter to 0 mm and absence of flow velocity and during a dynamic assessment at 180°.

**A/B ratio in the subclavian artery** was performed with the modified measurement, specifically for the study of arterial TOS with the dynamic maneuvers at 0° and 180° as follows: Flow velocity of the subclavian artery at 0°=B. Flow velocity of the subclavian artery at 180°=A (e.g., flow velocity of A= 200 cm/s/flow velocity of B=50; the A/B ratio is 4). An A/B ratio >3 was considered positive.

## US duplex Doppler imaging protocol

All studies were performed by a single radiologist with 26 years of experience in vascular US duplex Doppler (MFS). Aloka SSD4000™ devices with 10- and 13-MHz linear transducers (Aloka Co. Tokyo, Japan), a LOGIG E9™ (GE, Wisconsin, USA) with 10- and 16-MHz linear transducers, and an Acuson S2000™ (Siemens, Mountain View, USA) with 9-, 14-, and 18-MHz linear transducers were used. An endocavitary 6-10-MHz transducer was also used. Imaging studies were performed with the patient supine. Transverse and sagittal projections were performed in B-mode, pulsed Doppler, color Doppler, and angio-Doppler with vascular presetting (venous and arterial). The US duplex Doppler technique was the same for all three devices. Resolution and image quality improved as the devices were updated, but ultrasound parameters were comparable.

The venous protocol started with a transverse approach in the proximal inframandibular region of the internal jugular vein and continued caudally along its trajectory with a supraclavicular and infraclavicular approach to the junction with the ipsilateral subclavian vein. The transducer was placed slightly oblique to obtain a true sagittal image of the subclavian vein. These areas correspond to the costoclavicular space



**Figure 1.** Patient in supine position with the arm at 0°(A); dynamic maneuver with the arm abducted at 90°(B) and 180°(C) with continuous flexion and extension of the fingers of the ipsilateral hand to increase the subclavian vein flow.

in supraclavicular and infraclavicular approaches, where dynamic maneuvers were performed in three positions: 0°, 90°, and 180° (Figure 1). The variables recorded in these positions were diameter, permeability, flow velocity, scalene muscle hypertrophy, thrombosis, and concomitant findings such as tumors. In the 90° and 180° abduction positions, the patient was asked to continuously flex and extend the fingers of the ipsilateral hand to increase venous flow. A true sagittal projection was then continued to assess the subclavian vein in the infraclavicular approach throughout its course to its junction with the axillary vein. At this point, the third minor retropectoral space was assessed, and an image of the axillary vein was obtained in the three positions mentioned before. In addition, the superior vena cava was examined through the suprasternal approach with an endocavitary transducer to determine the diameter, permeability, and flow velocity.

The study protocol of the subclavian artery was performed in a manner similar to that described previously, beginning with a transverse approach in the common carotid artery from its bifurcation to examine the triangle between the anterior, middle, and posterior scalene muscles, continuing along the common carotid artery to its junction with the subclavian artery. This area was examined in the three positions (0°, 90°, and 180°) and diameter, permeability, flow velocity, A/B ratio, and associated findings such as stenosis, aneurysm, and thrombosis were recorded. The infraclavicular approach was continued to the confluence of the subclavian and axillary arteries, where the third minor retropectoral space is located. The same variables were evaluated in the three described positions.

### Statistical analysis

The mean, standard deviation, minimum, median, and maximum of quantitative variables were calculated and compared with the one-way ANOVA and the Kruskal-Wallis test. The statistical significance between categories of qualitative variables was determined using the Chi-squared test and Fisher's exact test. A p-value < 0.05 was considered significant. The IBM-SPSS statistical program version 20.0 (IBM Corp., Armonk, NY, USA) was used.

### RESULTS

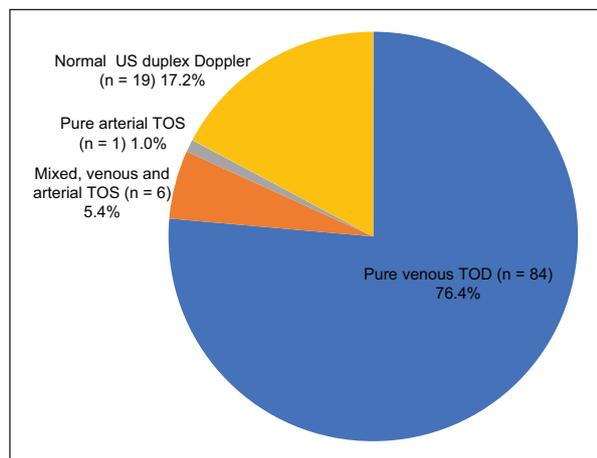
Ninety-seven patients were included, 33 (34%) men and 64 (66%) women with a mean age of  $45.07 \pm 15.26$  years; the age range was wide (9 to 89 years). A total of 110 US duplex Doppler examinations were performed, of which 84 were unilateral and 13 bilateral. Nineteen (17.2%) were normal in 17 patients (bilateral US duplex Doppler was performed in two cases), while 91 (82.7%) were abnormal, confirming the diagnosis of vascular TOS in 80 (87.9%) of 97 patients; 73 with pure venous TOS (62 unilateral and 11 bilateral US duplex Doppler), 6 with mixed venous TOS (arterial and venous) and one case with arterial TOS. The results of 110 US duplex Doppler are shown in Figure 2. In 19 (17.2%) normal US duplex dopplers, a neurogenic etiology was considered the cause of the symptoms, defined by the clinicians based on the results of magnetic resonance imaging of the brachial plexus and electromyography (not shown).

Ultrasound findings of normal US duplex Doppler, pure venous TOS, and mixed (venous and arterial) TOS are shown in Table 1. Diameter of the subclavian vein with the maneuver at 90° was not reported. The mean basal (0°) diameter of the subclavian vein in pure venous

**Table 1.** Comparison of subclavian vein findings in normal and abnormal US duplex Doppler in pure and mixed venous TOS

Characteristics	Normal US duplex Doppler (n = 19)	Abnormal US duplex Doppler		p-value
		Pure venous TOS <sup>a</sup> (n = 84)	Mixed TOS <sup>b</sup> (Venous and arterial) (n = 6)	
Age, years	40.47 ± 11.08 (29 – 65)	46.65 ± 15.79 (9 – 89)	53.17 ± 10.03 (43 – 64)	0.093
Basal diameter at 0° (mm)	7.37 ± 0.83 (6 – 8)	7.42 ± 1.36 (5 – 13)	7.33 ± 0.82 (6 – 8)	0.984
Flow velocity at 0° (cm/s)	35.74 ± 17.67 (17 – 81)	29.98 ± 16.14 (0 – 86)	22.83 ± 7.31 (16 – 36)	0.155
Flow velocity at 90° (cm/s)	35.79 ± 12.79 (17 – 57)	27.87 ± 17.28 (0 – 90)	18.83 ± 11.25 (10 – 38)	0.023
Flow velocity at 180° (cm/s)	35.53 ± 10.25 (11 – 48)	0	0	0.001
Diameter at 180° (mm)	3.68 ± 0.48 (3 – 4)	0	0	0.001

US: Ultrasound; TOS: Thoracic Outlet Syndrome; <sup>a</sup>73 patients with 62 unilateral and 11 bilateral US duplex Doppler; <sup>b</sup>6 patients with unilateral US duplex Doppler; Data are mean ± SD (range) unless otherwise specified.



**Figure 2.** Normal and abnormal US duplex Doppler in patients with clinical suspicion of a vascular TOS. The diagnosis of venous (pure or mixed) and arterial TOS was defined based on ultrasound findings.

US: ultrasound; TOS: thoracic outlet syndrome.

TOS (7.42 ± 1.36 mm) and mixed TOS (7.33 ± 0.82 mm) showed a reduction to 0 mm with the dynamic maneuver at 180° (p<0.001). In contrast, the mean basal (0°) diameter of the subclavian vein in patients with a normal US duplex Doppler showed a reduction of 50% or less with 7.37 ± 0.83 at 0° versus 3.68 ± 0.48 with the dynamic maneuver at 180°. There was no significant difference in the flow velocity of the subclavian vein at 0° between the groups. A lower mean flow velocity was observed at 90° in pure venous TOS (27.87 ± 17.28 cm/s) and mixed venous TOS (18.83 ± 11.25 cm/s) compared with normal US duplex Doppler (35.79 ± 12.79 cm/s). Flow velocity was not absent during the 90° maneuver

in any of the venous TOS cases. In contrast, in patients with pure and mixed venous TOS, the flow velocity in the subclavian vein was absent during the dynamic maneuver at 180° (p<0.001); whereas a flow velocity at 0°, 90°, and 180° showed no change in normal US duplex Doppler. A complete diameter reduction and absence of flow velocity in the subclavian vein during the dynamic maneuver at 180° were ultrasound findings of venous TOS.

In pure venous TOS, the costoclavicular space was commonly involved (n=82, 97.6%). Only two (2.4%) cases were in the costoclavicular and retropectoral space. Thrombosis of the subclavian vein (Paget-Schroetter syndrome) was found in 11 patients, seven with complete occlusion and four with partial occlusion. One patient with mixed TOS was found to have non-occlusive thrombosis. In 68 (86.1%) of 79 patients with pure or mixed TOS, we found intermittent subclavian vein compression (McCleery syndrome). On the other hand, hypertrophy of the scalene muscle was found in 13 (14%) of 97 patients. This finding was found in only one case with normal US duplex Doppler. Figure 3 shows a US duplex Doppler of a 31-year-old male patient with normal patency and flow velocity in the subclavian vein during dynamic maneuvers at 0°, 90°, and 180°. A physiological decrease in diameter vein was observed from 6.6 mm to 2.2 mm at 180°. Figure 4 shows a US duplex Doppler of a 31-year-old male patient with normal diameter, patency, flow velocity, and spectrum of the subclavian artery during dynamic maneuvers at 0°, 90°, and 180°. Figure 5 shows a US duplex Doppler of a 34-year-old male patient with venous TOS. The subclavian vein

**Table 2.** Comparison of subclavian artery findings on normal and abnormal US duplex Doppler in arterial, pure, and mixed TOS

Characteristics	Normal US duplex Doppler (n = 19)	Abnormal US duplex Doppler		p-value
		Pure arterial TOS (n = 1)	Mixed TOS (Venous and arterial) (n = 6)	
Diameter (mm)	6.42 ± 0.77 (5 – 8)	7	7.17 ± 0.41 (7 – 8)	0.069
Flow velocity at 0° (cm/s)	76.11 ± 25.53 (40 – 136)	41	70.67 ± 39.19 (40 – 144)	0.231
Flow velocity at 90° (cm/s)	75.95 ± 27.61 (44 – 148)	48	66 ± 40.09 (36 – 142)	0.186
Flow velocity at 180° (cm/s)	71.68 ± 19.27 (42 – 121)	0	0	0.001
Maximum velocity during dynamic maneuvers (cm/s)	80.26 ± 25.80 (45 – 148)	48	66 ± 40.09 (36 – 143)	0.113
A/B ratio	0.91 ± 0.26 (0.18 – 1.27)	0.85	1.10 ± 0.11 (1.00 – 1.28)	0.065

US: Ultrasound; TOS: Thoracic Outlet Syndrome; Data are mean ± SD (range) unless otherwise specified.

**Table 3.** Comparison of superior vena cava findings on normal and abnormal US duplex Doppler in relation to pure venous, mixed, and arterial TOS

Characteristics	Normal US duplex Doppler (n = 19)	Abnormal US duplex Doppler			p-value
		Pure venous TOS <sup>a</sup> (n = 83)	Mixed TOS (Venous and arterial) (n = 6)	Pure arterial TOS (n = 1)	
Diameter (mm)	15.74 ± 2.28 (13 – 21)	15.76 ± 2.01 (12 – 21)	16.17 ± 0.41 (16 – 17)	19	0.331
Flow velocity (cm/s)	47.58 ± 8.93 (33 – 36)	44.96 ± 11.77 (20 – 76)	44.67 ± 9.58 (37 – 58)	67	0.264

US: Ultrasound; TOS: Thoracic Outlet Syndrome; <sup>a</sup>Patient with mediastinal lymphoma was not included; Data are mean ± SD (range) unless otherwise specified.

diameter, patency, and flow velocity were normal at 0°; the diameter, patency, and flow velocity decreased during dynamic maneuvers at 90°, and a complete reduction in the diameter and flow velocity occurred at 180°.

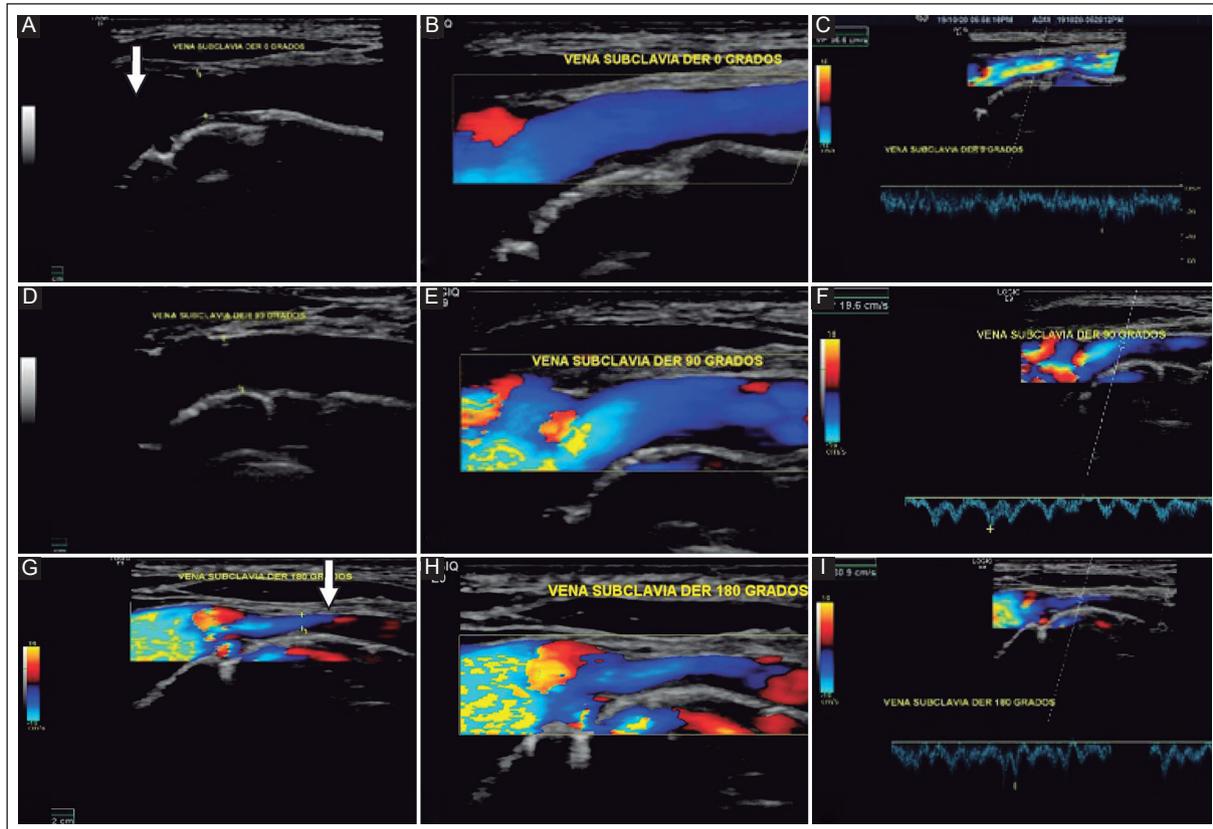
Table 2 compares the subclavian artery findings in 19 normal US duplex Doppler, one with pure arterial TOS and 6 with mixed arterial and venous TOS. No significant differences in diameter and flow velocity were observed at 0° and 90°. In contrast, an absence of subclavian artery flow velocity was observed in the dynamic maneuver at 180° with pure arterial and mixed TOS ( $p < 0.001$ ). In one patient, pure arterial TOS involvement was found in the scalene triangle; in addition, an accessory cervical rib was found on a chest x-ray. In no case was an A/B ratio  $> 3$  or hypertrophy of the scalene muscle observed.

The ultrasound findings of the superior vena cava from normal and abnormal US duplex Doppler are shown in table 3. No significant differences in diameter

and flow velocity were found between groups. The superior vena cava was not visualized in only one patient because of severe extrinsic compression by a mediastinal mass diagnosed as lymphoma. Figure 6 shows a US duplex Doppler examination of the superior vena cava with normal diameter, patency, and flow velocity. In contrast, in the case of a 42-year-old male patient with mediastinal lymphoma, the superior vena cava could not be visualized. A solid mediastinal mass measuring 6.4 x 5.9 cm was identified. A chest angiogram (not shown) in this patient showed filiform passage of the contrast agent into the superior vena cava. This finding was due to extrinsic compression by the tumor.

## DISCUSSION

In our study, the US duplex Doppler findings of venous TOS were complete reduction of the diameter to 0 mm and the absence of flow velocity in the



**Figure 3.** Normal US duplex Doppler of a 31-year-old male patient with dynamic maneuvers showing a normal diameter (A), patency (B), and flow velocity (C), in the subclavian vein at 0° (D, E, F), and 180° (G, H, I), respectively. Physiological decrease in diameter was observed from 6.6 mm at 0° (A) (arrow) to 2.2 mm at 180° (G) (arrow).

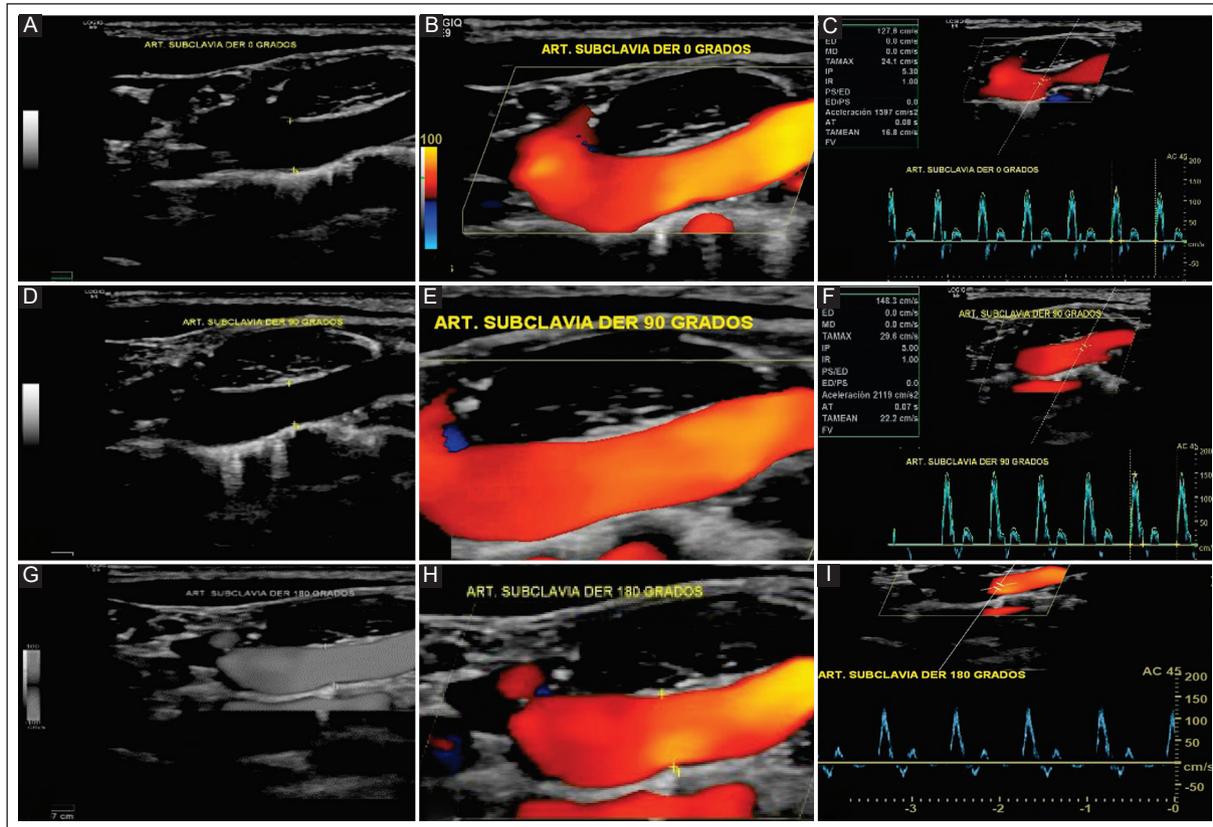
US: Ultrasound.

subclavian vein with the dynamic 180° maneuver. We propose these findings as ultrasound criteria for the diagnosis of venous TOS. These diagnostic criteria have not been previously reported in the literature. US duplex Doppler is suggested as the primary imaging modality for evaluating patients with clinical suspicion of vascular TOS.

There is no consensus on the definition of ultrasound findings for diagnosing venous TOS in patients with clinical suspicion<sup>2,4-8</sup>. In 1992, Longley et al.<sup>4</sup> in a study of 16 patients with clinical manifestations of vascular TOS and 20 healthy controls evaluated with US duplex Doppler, identified a complete loss of the spectral waveform in the subclavian vein as a criterion for significant venous compression during arm hyperabduction (90°, 135°, and 180°) with a sensitivity of 92% and a specificity of 95%, compared with venography for the diagnosis of venous TOS. US duplex Doppler with dynamic arm abduction maneuvers at 90° and 180° is useful for evaluating subclavian vessels<sup>5</sup>. We included 97 patients with a clinical suspicion of vascular TOS, 73 cases with pure

venous TOS, and 6 with mixed TOS. The mean basal (0°) diameter of the subclavian vein was comparable in both normal and abnormal US duplex Doppler. In pure venous and mixed TOS, a reduction of 0 mm was found with the dynamic maneuver at 180° ( $p < 0.001$ ). In contrast, the mean basal (0°) diameter of the subclavian vein in patients with normal US duplex Doppler showed a reduction of 50% or less with the dynamic maneuver at 180° ( $7.37 \pm 0.83$  and  $3.68 \pm 0.48$ , respectively). We propose a complete diameter reduction in the subclavian vein during the 180° dynamic maneuver as a diagnostic ultrasound criterion for venous TOS.

In a healthy population, physiological thoracic outflow changes are detected by variations in the diameter and flow velocity of the subclavian vein, the subclavian artery, or both during dynamic maneuvers in different arm positions<sup>3,5,9</sup>. Our study considered normal US duplex Doppler with physiological changes in response to dynamic maneuvers as a decrease in the vessel diameter of 50% or less with variable changes in flow velocity. There was no significant difference in the flow

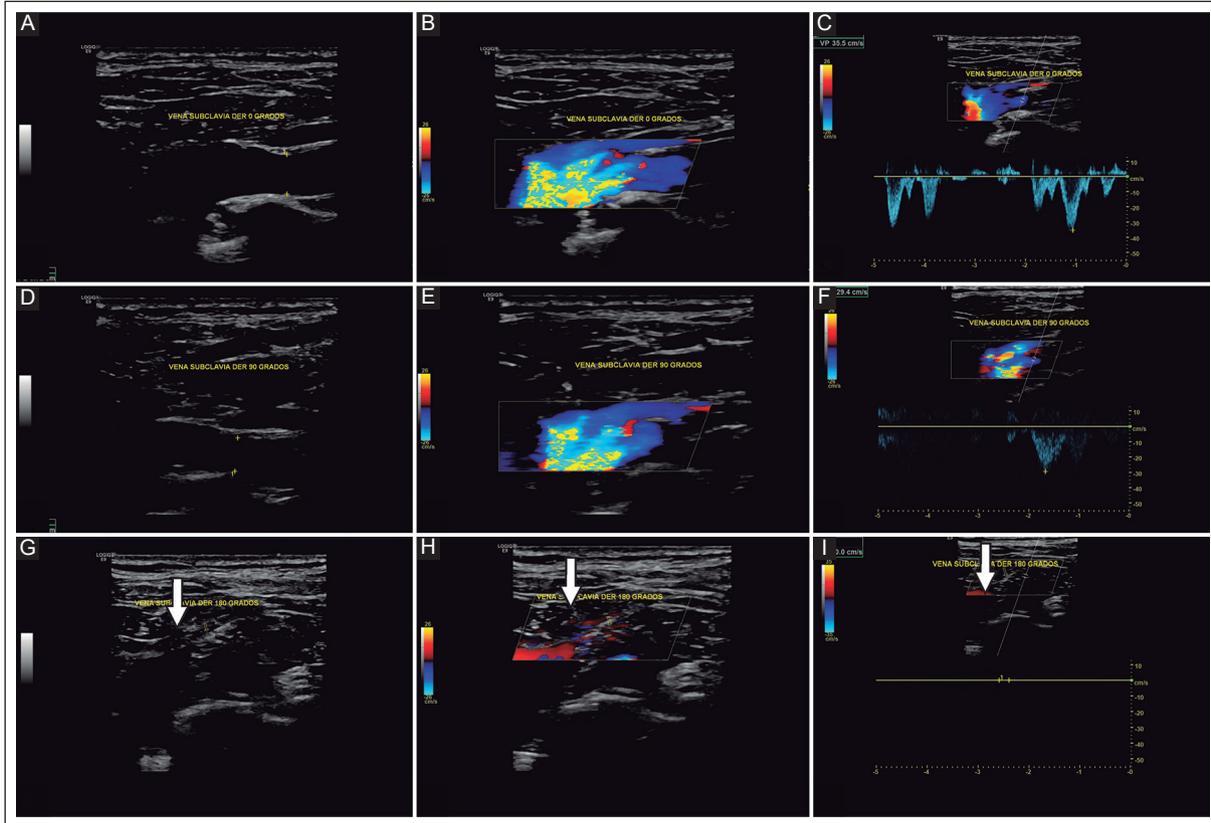


**Figure 4.** Normal US duplex Doppler of a 31-year-old male patient with dynamic maneuvers showed normal diameter (A) patency (B), flow velocity, and spectrum (C) in the subclavian artery at 0° (A, B, C), 90° (D, E, F), and 180° (G, H, I), respectively. US: ultrasound.

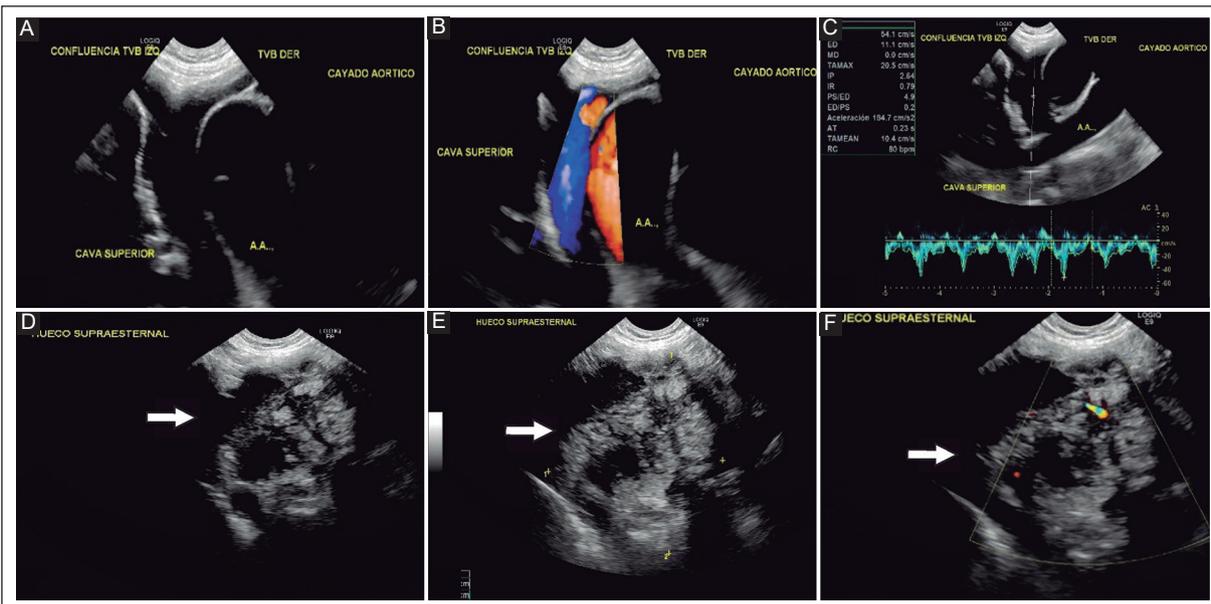
velocity of the subclavian vein at 0° between the normal and abnormal US duplex Doppler. Furthermore, the flow velocity at 0°, 90°, and 180° did not change in normal US duplex Doppler. In these cases, symptoms were attributed to neurogenic TOS; in no case was catheter venography recommended. On the other hand, in patients with pure and mixed venous TOS, the flow velocity in the subclavian vein was absent during the dynamic maneuver at 180° ( $p < 0.001$ ). Accordingly, we propose the absence of flow velocity in the subclavian vein with the dynamic 180° maneuver as another diagnostic ultrasound criterion of venous TOS. According to our proposed diagnostic criteria, identification of physiological changes during dynamic US duplex Doppler maneuvers may avoid overestimation of venous TOS.

US duplex Doppler has undergone amazing technological development in the last 30 years. This fact together with a high level of experience of the operator makes US duplex Doppler the primary modality for diagnosing venous TOS. Its limitations are related to a reduced acoustic window that may restrict the

acquisition of images in the costoclavicular space in muscular patients or in the presence of abundant adipose tissue<sup>1</sup>. CT with IV contrast or catheter venography are equivalent alternatives for venous TOS diagnosis<sup>2,10</sup>; however, these techniques have disadvantages related to the use of intravenous contrast agents, radiation, and high cost. The latter is a limitation, especially in middle- or low-income countries such as ours. On the other hand, we recommend that catheter venography be performed only in acute thrombosis when fibrinolytic therapy is used. US duplex Doppler is popular because it is a widely available, noninvasive, cost-effective method that does not use ionizing radiation or contrast agents. In our study, US duplex Doppler was used as the primary diagnostic modality in patients with clinical suspicion of vascular TOS. Venous TOS diagnosis based on our proposed ultrasound criteria was established in 79 (81.4%) of 97 cases. In our study population, the diagnosis of pure or mixed venous TOS was confirmed in 4 of 5 cases, which represents a high diagnostic accuracy of US duplex Doppler.



**Figure 5.** Abnormal US duplex Doppler in a 34-year-old male patient with venous TOS. The subclavian vein was assessed at 0° with a normal diameter (A), patency (B), and flow velocity (C); with dynamic maneuvers at 90°, a decreased diameter (D), patency (E), and flow velocity (F) were observed, and at 180° a complete reduction in diameter (G) (arrow) absent patency (H) (arrow) and flow velocity (I) (arrow) were observed.  
 US: Ultrasound; TOS: thoracic outlet syndrome.



**Figure 6.** Normal US duplex Doppler in a 36-year-old female patient with a normal diameter (A), patency (B), and flow velocity (C) of the superior vena cava with a suprasternal approach. Abnormal Doppler US in a 42-year-old male patient with a solid mass (lymphoma) (D) (arrow) of 6.4 cm x 5.9 cm (E) (arrow) with intralesional vascularity in the mediastinum (F) (arrow) that did not allow identification of the superior vena cava.  
 US: Ultrasound.

Traditionally, US duplex Doppler examination of the thoracic outlet does not include a description of the superior vena cava diameter, permeability, and flow velocity. Its evaluation in our study, was performed with an endocavitary transducer that provided adequate visualization of the superior vena cava in 96 (99%) of 97 patients. A mean diameter of  $15.74 \pm 2.28$  mm and a mean flow velocity of  $45.72 \pm 11.32$  cm/s were found. No differences were observed between patients with normal and abnormal US duplex Doppler. The superior vena cava was not visualized in only one patient because of severe extrinsic compression by a mediastinal mass diagnosed as lymphoma. We suggest that superior vena cava assessment should be included in the US duplex Doppler of patients with a clinical suspicion of vascular TOS.

Our study has several strengths. The sample size was the largest of patients diagnosed with venous TOS in any study. In addition, the US duplex Doppler examination was performed by the same radiologist in all cases. On the other hand, there were some limitations. The study design was retrospective, and catheter venography, the gold standard, was not performed. The ultrasound criteria proposed for the diagnosis of venous TOS could have limited applicability with less experienced vascular ultrasound operators.

## CONCLUSION

We propose two ultrasonographic criteria for diagnosing venous TOS: a complete reduction in the subclavian vein diameter to 0 mm and the absence of flow velocity during a dynamic maneuver at  $180^\circ$ . The accuracy of US duplex Doppler for the diagnosis of venous TOS requires an experienced operator in vascular imaging and a systematic protocol of the thoracic outlet, and time (between 60 and 90 minutes for each thoracic limb). It is possible that, in the coming years, the diagnosis of venous TOS in young adults will increase due to sports activities that cause hypertrophy of the scalene muscle. Other imaging modalities such as CT with IV contrast and catheter venography may be used as equivalent alternatives to US duplex Doppler<sup>2</sup>. Research studies with a prospective design in other populations are needed to apply and validate the proposed US duplex Doppler criteria for diagnosing venous TOS.

## Acknowledgments

The authors thank Professor Ana M. Contreras-Navarro for her guidance in preparing and writing this scientific paper.

## Funding

Supported with funds from the National Quality Postgraduate Program of the Consejo Nacional de Ciencia and Tecnología of México (Conacyt).

## Conflicts of interest

The authors declare that they have no conflicts of interest.

## Ethical disclosures

**Protection of human and animal subjects.** The authors declare that the procedures followed were in accordance with the regulations of the relevant clinical research ethics committee and with those of the Code of Ethics of the World Medical Association (Declaration of Helsinki).

**Confidentiality of data.** The authors declare that they have followed the protocols of their work center on the publication of patient data.

**Right to privacy and informed consent.** Approval for analysis of routinely acquired clinical data was obtained from the Ethics Committee and informed consent was not required for this retrospective observational study of information collected during routine clinical care.

## REFERENCES

1. Raptis CA, Sridhar S, Thompson RW, Fowler KJ, Bhalla S. Imaging of the Patient with Thoracic Outlet Syndrome. *RadioGraphics*. 2016;36 (4): 984-1000. doi.org/10.1148/rg.2016150221.
2. Expert Panels on Vascular Imaging, Thoracic Imaging, and Neurological Imaging, Zurkiya O, Ganguli S, Kalva SP, Chung JH, Shah LM, Majdalany BS, et al. ACR Appropriateness Criteria® Thoracic Outlet Syndrome. *J Am Coll Radiol*. 2020;17(5S): S323-S334. doi: 10.1016/j.jacr.2020.01.029.
3. Chen H, Doornbos N, Williams K, Criado E. Physiologic variations in venous and arterial hemodynamics in response to postural changes at the thoracic outlet in normal volunteers. *Ann Vasc Surg*. 2014; 28(7):1583-1588. doi.org/10.1016/j.avsg.2014.05.003.
4. Longley DG, Yedlicka J W, Molina EJ, Schwabacher S, Hunter DW, Letourneau JG. Thoracic outlet syndrome: evaluation of the subclavian vessels by color duplex sonography. *AJR Am J Radiol*. 1992;158 (3):623-630. doi/10.2214/ajr.158.3.1739007.
5. Hamby BA, Ronningen EL, Humphries MD, Freischlag JA. Role of the Noninvasive Vascular Laboratory in Thoracic Outlet Syndrome. In Abu-Rahma AF, Noninvasive Vascular Diagnosis. A Practical Textbook for Clinicians. 4<sup>th</sup> Edition. West Virginia (USA). © Springer International Publishing AG; 2017:569-577.
6. Gillard J, Pérez-Cousin M, Hachulla É, Remy J, Hurtevent J-F, Vinckier LA, et al. Diagnosing Thoracic Outlet Syndrome: Contribution of Provocative Tests, Ultrasonography, Electrophysiology, and Helical Computed Tomography in 48 Patients. *Joint Bone Spine*. 2001; 68 (5): 416-424. doi.org/10.1016/s1297-319x (01)00298-6.
7. Li N, Dierks G, Vervaeke HE, Jumonville A, Kaye AD, Myrcik D, et al. Thoracic Outlet Syndrome: A Narrative Review. *J Clin Med*. 2021;10: 962. doi.org/10.3390/jcm10050962.
8. Baz AA. An overview of the findings of dynamic upper limbs' arterial and venous duplex in cases of vascular thoracic outlet syndrome. *Egypt J Radiol Nucl Med*. 2019; 50 (76):1-11. doi.org/10.1186/s43055-019-0100-1.
9. Moore R, Lum YW. Venous thoracic outlet syndrome. *Vasc Med*. 2015; 20(2):182-189. doi.org/10.1177/1358863X14568704.
10. Butros SR, Liu R, Oliveira GR, Ganguli S, Kalva S. Venous compression syndromes: clinical features, imaging findings and management. *Br J Radiol*. 2013;86:1-11. doi.org/10.1259/bjr.20130284.