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Evan R. Brownie, MD, Ahmmad A. Abuirqeba, BA, J. Westley Ohman, MD, Brian G. Rubin, MD, and Robert W. Thompson, MD, St. Louis, Mo

ABSTRACT

Objective: To assess the utilization and consequences of upper extremity Duplex ultrasound in the initial diagnostic evaluation of patients with suspected subclavian vein (SCV) thrombosis and venous thoracic outlet syndrome (VTOS).

Methods: A retrospective single-center review was conducted for patients that underwent primary surgical treatment for VTOS between 2008 and 2017, in whom an upper extremity ultrasound had been performed as the initial diagnostic test (n = 214). Clinical and treatment characteristics were compared between patients with positive and false-negative ultrasound studies.

Results: There were 122 men (57%) and 92 women (43%) that had presented with spontaneous idiopathic arm swelling, including 28 (13%) with proven pulmonary embolism, at a mean age of 30.7 ± 0.8 years (range 14-69). Upper extremity ultrasound had been performed 23.8 ± 12.2 days after the onset of symptoms, with confirmation of axillary-SCV thrombosis in 169 patients (79%) and negative results in 45 (21%). Of the false-negative ultrasound study reports, only 8 (18%) acknowledged limitations in visualizing the central SCV. Definitive diagnostic imaging (DDI) had been obtained by upper extremity venography in 175 (82%), computed tomography angiography in 24 (11%), and magnetic resonance angiography in 15 (7%), with 142 (66%) undergoing catheter-directed axillary-SCV thrombolysis. The mean interval between initial ultrasound and DDI was 48.9 ± 14.2 days with no significant difference between groups, but patients with a positive ultrasound were more likely to have DDI within 48 hours than those with a false-negative ultrasound (44% vs 24%; P = .02). At the time of surgical treatment, the SCV was widely patent following paracardiac decompression and external venolysis alone in 74 patients (35%). Patch angioplasty was performed for focal SCV stenosis in 76 (36%) and bypass graft reconstruction for long-segment axillary-SCV occlusion in 63 (29%). Patients with false-negative initial ultrasound studies were significantly more likely to require SCV bypass reconstruction than those with a positive ultrasound (44% vs 25%; P = .02).

Conclusions: Duplex ultrasound has significant limitations in the initial evaluation of patients with suspected SCV thrombosis, with false-negative results in 21% of patients with proven VTOS. This is rarely acknowledged in ultrasound reports, but false-negative ultrasound studies have the potential to delay definitive imaging, thrombolysis, and further treatment for VTOS. Initial false-negative ultrasound results are associated with progressive thrombus extension and a more frequent need for SCV bypass reconstruction at the time of surgical treatment. (J Vasc Surg: Venous and Lym Dis 2020;8:118–26.)

Keywords: Subclavian vein; Duplex ultrasound; Upper extremity; Deep vein thrombosis; Thrombolysis; Surgical treatment

Upper extremity deep vein thrombosis (UE-DVT) is relatively uncommon, representing only 10% of all DVT, and is most frequently associated with an underlying secondary cause, such as a central venous catheter, pacemaker wire, malignancy, or pro-thrombotic hematological condition. In contrast, idiopathic “primary” UE-DVT is estimated to occur in approximately 20% to 30% of patients. The most prevalent form of primary UE-DVT is...
due to extrinsic compression of the central subclavian vein (SCV) at the level of the costoclavicular space, also termed venous thoracic outlet syndrome (VTOS), which leads to SCV ‘effort’ thrombosis (Paget-Schroetter syndrome).  

The pathophysiology of VTOS is currently understood to involve repetitive dynamic compression and localized injury of the SCV between the first rib, clavicle, anterior scalene muscle, subclavius muscle, and the costoclavicular ligament.  

Gradual fibrous constriction of the SCV is accompanied by expansion of collateral vein pathways, such that patients are typically asymptomatic during early stages of this condition. Eventually, thrombosis occurs in the narrowed SCV, along with thrombus propagation into the axillary vein and obstruction of critical venous collaterals, resulting in abrupt clinical symptoms. SCV thrombus forming central to the point of obstruction may also lead to pulmonary embolism, but this is rarely hemodynamically significant and usually asymptomatic. The onset of upper extremity symptoms is frequently perceived to be associated with recent exertion, heavy lifting, or repetitive vigorous overhead use of the upper extremity, which historically gave rise to the term ‘effort’ thrombosis; however, SCV thrombosis is better viewed as an acute or subacute event superimposed on chronic gradual venous obstruction. VTOS thereby represents a ‘mechanical’ anatomical condition secondary to vein compression and injury that is amenable to surgical treatment, rather than a hematomal condition to be managed primarily by anticoagulation.

Clinical suspicion of axillary-SCV thrombosis resulting from VTOS is typically prompted by presentation of an otherwise healthy, relatively young person with the sudden, spontaneous, onset of whole-arm swelling, with or without cyanotic discoloration, in the absence of a known malignancy, central venous catheter, recent arm injury or surgery, or history of DVT. Prompt diagnosis of VTOS is important to direct initial anticoagulation and catheter-based venography within a timeframe that permits the potential use of thrombolytic treatment (ideally within 6-8 weeks after the onset of symptoms), as an intermediate step toward definitive surgical treatment.

Duplex ultrasound has been described to have a high level of sensitivity and specificity in the diagnosis of UE-DVT and is widely considered the standard for initial evaluation of this condition. However, even the strongest advocates of venous ultrasound acknowledge that “…an important limitation of ultrasonography is that visualization and compression of the subclavian and brachiocephalic veins are hampered by the clavicle, which limits the accuracy of ultrasonography in these segments.” This limitation makes ultrasonography unsuited for early diagnosis of VTOS, when focal central SCV obstruction has not yet led to distal thrombus extension, and its widespread use raises the likelihood that VTOS will be unrecognized and undertreated. In a previous study of competitive athletes with VTOS, we found that 21 of 32 patients (66%) had a duplex ultrasound as the initial diagnostic study, with false-negative results in 29%.

Although this raises concern that a false-negative ultrasound might be associated with treatment delay and unsatisfactory outcomes, there is otherwise little information available on ultrasound in evaluation of patients found to have axillary-SCV thrombosis resulting from VTOS.

The purpose of this study was to better assess the utilization and consequences of using upper extremity ultrasound in the initial evaluation of patients with suspected SCV thrombosis and VTOS. To address these issues, we examined clinical and treatment characteristics in a relatively large series of patients that underwent surgical treatment for VTOS, in whom an upper extremity ultrasound had been performed as the initial diagnostic test, and compared these features between patients with positive and false-negative ultrasound studies.

**METHODS**

The study population was derived from patients referred to the Washington University Center for Thoracic Outlet Syndrome at Barnes-Jewish Hospital (St. Louis, Mo) for evaluation and surgical treatment of VTOS between January 2008 and March 2017. Patients with the neurogenic or arterial forms of TOS were excluded from review, as were patients with VTOS undergoing reoperative procedures or operations for threatened hemodialysis access. Detailed information regarding each patient was obtained from a prospectively maintained database and summarized from office notes, hospital charts, imaging studies, operative findings and records from treating physicians, therapists, and vascular laboratories. The study protocol and informed consent were approved by the Human Research Protection Office at Washington University.

**ARTICLE HIGHLIGHTS**

- **Type of Research:** Single-center retrospective cohort study
- **Key Findings:** Of 214 patients with surgically-treated VTOS, upper extremity ultrasound at initial presentation was positive in 169 (79%) and false-negative in 45 (21%). Patients with false-negative ultrasound studies were significantly less likely to have had definitive diagnostic imaging within 48 hours (24% vs 44%) and more likely to require SCV bypass reconstruction (44% vs 25%).
- **Take Home Message:** False-negative ultrasound studies have the potential to delay definitive imaging and thrombolysis, and are associated with progressive thrombus extension and a more frequent need for SCV bypass reconstruction at the time of surgical treatment.
Comparisons between two groups were made using standard error or the frequency (percent incidence). In extending into the distal axillary vein, concomitant pectoral joint, or transmanubrial extension of the exposure, required division of the sternocleidomastoid muscle, parasternal incision to the junction of the SCV with the internal jugular and innominate veins. Inspection, palpation, and complete intraoperative venography were used to assess the level of functional disability while minimizing the risk of rethrombosis.

All patients underwent standardized paravascular thoracic outlet decompression, including complete anterior and middle scalenectomy, mobilization of the brachial plexus nerve roots, subclavious muscle resection, and complete first rib resection from the transverse process posteriorly and to the level of the sternum anteriorly. Exposure through the infracavicular incision was used to initiate external venolysis of the axillary-SCV, which was then continued through the supracavicular incision to the junction of the SCV with the internal jugular and innominate veins. Inspection, palpation, and intraoperative venography were used to assess the axillary-SCV and direct vein reconstruction was performed if necessary, using patch angioplasty for focal stenosis or bypass graft placement for long-segment occlusion, as previously described. For occlusions extending into the distal axillary vein, concomitant pectoral minor tenotomy was used to identify a suitable inflow vein for bypass graft reconstruction. No patients required division of the sternocleidomastoid muscle, partial resection of the clavicle, disruption of the sternoclavicular joint, or transmanubrial extension of the exposure.

Descriptive group data are presented as the mean ± standard error or the frequency (percent incidence). Comparisons between two groups were made using the unpaired t-test with Welch correction (for data with continuous variables) or Fisher’s exact test (for categorical data). All statistical tests were performed using Prism version 4.0c (GraphPad Software Inc, San Diego, Calif), with P values < .05 considered significant.

RESULTS

There were 339 patients who underwent primary operations for VTOS in our institution between January 2008 and March 2017, representing 21% of 1630 surgical procedures performed for all forms of TOS (Fig 1, A). There were 255 patients with VTOS (75%) that had undergone upper extremity ultrasound as the initial diagnostic test, with incomplete data for 41 (only verbal results or insufficiently detailed reports), leaving 214 patients available for the purposes of this study.

The study population consisted of 122 men (57%) and 92 women (43%) with a mean age of 30.7 ± 0.8 years (median 28.0, range 14-69). The age distribution of patients included 54 (25%) younger than age 21 and 160 (75%) older than age 21, with 95% younger than 55 years of age (Fig 1, B). The majority of patients were right-hand dominant (n = 191; 89%) with the dominant side affected in 153 (71%). Patients in the study population described their primary occupation as student (n = 42; 20%), office-based deskwork (n = 42; 20%), athlete (n = 41; 19%), skilled labor (n = 24; 11%), nurse or therapist (n = 15; 7%), manager (n = 12; 6%), homemaker (n = 9; 4%), manual labor (n = 7; 3%), physician (n = 7; 3%), unemployed (n = 7; 3%), or executive (n = 5; 2%). There were 55 patients (26%) referred from the St. Louis metropolitan area, 105 (49%) from the central Midwest region, and 54 (25%) from more distant locations in the United States. The presenting symptoms consisted of arm swelling alone in 122 (57%) and arm swelling with cyanotic discoloration in 92 (43%), with 118 patients (55%) initially presenting to an emergency room and 96 (45%) to a primary care physician. There were 28 patients (13%) with radiographic evidence of pulmonary embolism. The overall mean QuickDASH score upon referral was 26.2 ± 1.6.

Using SVS reporting standards definitions, the timing of clinical presentation was characterized as acute (0 to 14 days) in 195 patients (91%), subacute (14 to 90 days) in 9 patients (4%), and chronic (>90 days) in 10 patients (5%). The mean time interval between the onset of arm swelling symptoms and the initial ultrasound was 23.8 ± 12.2 days. The upper extremity ultrasound performed at initial presentation was positive in 169 patients (79%) and negative in 45 (21%).

The positive ultrasound study reports described the distribution of DVT in both the axillary and subclavian veins (n = 59; 35%); the subclavian vein alone (n = 52; 31%); the basilic, axillary, and subclavian veins (n = 41; 24%); the basilic and axillary veins (n = 5; 3%); the axillary vein alone (n = 2; 1%); flow abnormalities consistent with proximal
obstruction but no defined thrombosis (n = 4; 2%); and unspecified (n = 6; 3%). Thirteen (8%) of the positive ultrasound study reports indicated the potential presence of SCV compression within the thoracic outlet. Of the false-negative ultrasound study reports, only 8 (18%) included a description of limitations of the study to visualize the central SCV or the possibility of central venous obstruction at the thoracic outlet, although 14 (31%) of the laboratories performing these studies had current IAC certification for vascular testing. There were no significant differences between the positive and false-negative ultrasound groups with regard to age, gender, side affected, pattern or timing of symptomatic presentation, incidence of pulmonary embolism, or QuickDASH scores (Table I).

For the overall study population, DDI was obtained by catheter-based upper extremity venography in 175 (82%). CTA was performed in 24 (11%) and magnetic resonance angiography in 15 (7%) patients, primarily when there had been longstanding symptoms. The interval between the initial ultrasound and DDI was 48.9 ± 14.2 days and the interval between the onset of symptoms and DDI was 72.7 ± 18.7 days. There were only 86 patients (40%) that had DDI within 48 hours of ultrasound examination, whereas there were 58 (27%) in whom DDI was performed more than 14 days after the initial ultrasound. Venous thrombolysis was performed in 142 patients (66%), with inclusion of balloon angioplasty in 115 (54%). There were no significant differences between the positive and false-negative ultrasound groups with regard to the interval between symptoms and initial ultrasound, the interval between initial ultrasound and DDI, the proportion of patients having DDI within 14 days of the onset of symptoms or the initial ultrasound, or the proportion of patients undergoing thrombolysis or balloon angioplasty treatment; however,
Table I. Presenting characteristics of 214 patients with subclavian vein thrombosis and venous thoracic outlet syndrome that had undergone upper extremity ultrasound as the initial diagnostic test.

<table>
<thead>
<tr>
<th></th>
<th>U/S positive (n = 169)</th>
<th>U/S negative (n = 45)</th>
<th>P value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age (years)</td>
<td>30.4 ± 0.9</td>
<td>31.9 ± 2.0</td>
<td>.495</td>
</tr>
<tr>
<td>Male</td>
<td>99 (59)</td>
<td>23 (51)</td>
<td>.4005</td>
</tr>
<tr>
<td>Right side affected</td>
<td>126 (75)</td>
<td>32 (71)</td>
<td>.703</td>
</tr>
<tr>
<td>Presented to ER vs PCP</td>
<td>96 (57)</td>
<td>22 (49)</td>
<td>.4001</td>
</tr>
<tr>
<td>Local metropolitan area patient</td>
<td>44 (26)</td>
<td>11 (24)</td>
<td>1.009</td>
</tr>
<tr>
<td>Regional area referral</td>
<td>86 (51)</td>
<td>19 (42)</td>
<td>.3195</td>
</tr>
<tr>
<td>Distant (out-of-region) referral</td>
<td>39 (23)</td>
<td>15 (33)</td>
<td>.1784</td>
</tr>
<tr>
<td>Acute presentation (0-14 days)</td>
<td>157 (95)</td>
<td>38 (84)</td>
<td>.0844</td>
</tr>
<tr>
<td>Subacute presentation (14-90 days)</td>
<td>5 (3)</td>
<td>4 (9)</td>
<td>.0950</td>
</tr>
<tr>
<td>Chronic presentation (&gt;90 days)</td>
<td>7 (4)</td>
<td>3 (7)</td>
<td>.4427</td>
</tr>
<tr>
<td>Arm swelling alone</td>
<td>94 (56)</td>
<td>28 (62)</td>
<td>.4991</td>
</tr>
<tr>
<td>Swelling and cyanotic discoloration</td>
<td>75 (44)</td>
<td>17 (38)</td>
<td>.4993</td>
</tr>
<tr>
<td>Pulmonary embolism</td>
<td>21 (12)</td>
<td>7 (16)</td>
<td>.6202</td>
</tr>
<tr>
<td>Initial QuickDASH</td>
<td>26.4 ± 1.8</td>
<td>25.7 ± 3.4</td>
<td>.8567</td>
</tr>
</tbody>
</table>

ER, Emergency room; PCP, primary care physician; QuickDASH, 11-item version of the Disabilities of the Arm, Shoulder, and Hand survey instrument; SCV, subclavian vein; U/S, ultrasound; VTOS, venous thoracic outlet syndrome.

Patients were identified that had primary surgical treatment for VTOS between 2008 and 2017 and had U/S performed as the initial diagnostic test (n = 214). For each item assessed, the data shown indicate the mean ± standard error for continuous measures or the number of patients (%) for categorical variables.

*aUnpaired t-test.
*bFisher’s exact test.

patients with a positive initial ultrasound were significantly more likely to have DDI performed within 48 hours than those with a false-negative ultrasound (44% vs 24%; P = .02; Table II).

Table II. Diagnosis and initial treatment of 214 patients with subclavian vein thrombosis and venous thoracic outlet syndrome.

<table>
<thead>
<tr>
<th></th>
<th>U/S positive (n = 169)</th>
<th>U/S negative (n = 45)</th>
<th>P value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Symptoms to U/S (days)</td>
<td>23.3 ± 15.1</td>
<td>25.5 ± 12.6</td>
<td>.9118</td>
</tr>
<tr>
<td>Symptoms to U/S &gt;14 days</td>
<td>12 (7)</td>
<td>6 (13)</td>
<td>.2246</td>
</tr>
<tr>
<td>Symptoms to U/S &gt;90 days</td>
<td>7 (4)</td>
<td>3 (7)</td>
<td>.4421</td>
</tr>
<tr>
<td>U/S to DDI (days)</td>
<td>43.0 ± 13.8</td>
<td>71.1 ± 43.9</td>
<td>.5444</td>
</tr>
<tr>
<td>U/S to DDI &lt;48 hours²</td>
<td>75 (44)</td>
<td>11 (24)</td>
<td>.0177</td>
</tr>
<tr>
<td>U/S to DDI &gt;14 days</td>
<td>44 (26)</td>
<td>14 (31)</td>
<td>.3516</td>
</tr>
<tr>
<td>U/S to DDI &gt;90 days</td>
<td>13 (8)</td>
<td>5 (11)</td>
<td>.5443</td>
</tr>
<tr>
<td>Symptoms to DDI (days)</td>
<td>66.3 ± 20.4</td>
<td>96.6 ± 45.9</td>
<td>.5493</td>
</tr>
<tr>
<td>Symptoms to DDI &gt;14 days</td>
<td>50 (30)</td>
<td>18 (40)</td>
<td>.2082</td>
</tr>
<tr>
<td>Symptoms to DDI &gt;90 days</td>
<td>20 (12)</td>
<td>7 (16)</td>
<td>.4614</td>
</tr>
<tr>
<td>DDI Type: venogram</td>
<td>140 (83)</td>
<td>35 (78)</td>
<td>.5140</td>
</tr>
<tr>
<td>DDI Type: MRA</td>
<td>11 (7)</td>
<td>4 (9)</td>
<td>.5250</td>
</tr>
<tr>
<td>DDI Type: CTA</td>
<td>18 (11)</td>
<td>6 (13)</td>
<td>.6001</td>
</tr>
<tr>
<td>Thrombolysis performed</td>
<td>114 (67)</td>
<td>28 (62)</td>
<td>.5956</td>
</tr>
<tr>
<td>Balloon angioplasty</td>
<td>94 (56)</td>
<td>21 (47)</td>
<td>.3155</td>
</tr>
</tbody>
</table>

CTA, Computed tomography angiography; DDI, definitive diagnostic imaging; IAC, Intersocietal Accreditation Commission; MRA, magnetic resonance angiography; U/S, ultrasound; VTOS, venous thoracic outlet syndrome.

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*aUnpaired t-test.
*bFisher’s exact test.
²P < .05
thrombolysis and surgical treatment was 50.3 ± 6.8 days: 27.2 ± 4.7 days for local patients (n = 40), 47.3 ± 6.2 days for regional referral patients (n = 63) and 80.6 ± 22.2 days for distant referral patients (n = 38). Each patient underwent paraclavicular thoracic outlet decompression with complete resection of the first rib and external venolysis of the axillary SCV. In 74 patients (35%), the axillary SCV was widely patent, by visual inspection, palpation, and intraoperative venography, following decompression and external venolysis alone. In 76 patients (36%), there remained a focal high-grade SCV stenosis that was treated by patch angioplasty, whereas 63 patients (29%) had a long-segment SCV occlusion for which axillary-innominate vein bypass was performed. In 52 of these patients (24%), the venous occlusion extended laterally underneath the pectoralis minor muscle, such that pectoralis minor tenotomy was required to expose a patent axillary vein of suitable caliber for bypass reconstruction.

Although there were no significant differences between the positive and false-negative ultrasound groups with regard to the incidence of external venolysis alone or patch angioplasty reconstruction, patients that had a false-negative ultrasound as the initial diagnostic study were significantly more likely to require axillary-SCV bypass than those who had a positive ultrasound as the initial diagnostic test (44% vs 25%; P = .017; Fig 2).

**DISCUSSION**

The approach to diagnosis and management of VTOS varies between different physicians and institutions, and the most effective strategy for this condition continues to elicit debate. In this study, we examined the clinical presentation for a large number of patients with proven VTOS to assess the utilization and consequences of using upper extremity ultrasound as the initial diagnostic test (positive ultrasound, black bars, n = 169; false-negative ultrasound, white bars, n = 45). *P = .017, Fisher’s exact test. SCV, Subclavian vein; U/S, ultrasound.

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**Operative Findings:**

- **Surgical Treatment:**
  - Patent SCV Venolysis Alone
  - Focal Stenosis Patch Angioplasty
  - Long Occlusion Bypass Graft

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**DISCUSSION**

The approach to diagnosis and management of VTOS varies between different physicians and institutions, and the most effective strategy for this condition continues to elicit debate. In this study, we examined the clinical presentation for a large number of patients with proven VTOS to assess the utilization and consequences of using upper extremity ultrasound as the initial diagnostic test (positive ultrasound, black bars, n = 169; false-negative ultrasound, white bars, n = 45). *P = .017, Fisher’s exact test. SCV, Subclavian vein; U/S, ultrasound.

Although there were no significant differences between the positive and false-negative ultrasound groups with regard to the incidence of external venolysis alone or patch angioplasty reconstruction, patients that had a false-negative ultrasound as the initial diagnostic study were significantly more likely to require axillary-SCV bypass than those who had a positive ultrasound as the initial diagnostic test (44% vs 25%; P = .017; Fig 2).
clearing of clot from the axillary and distal subclavian veins but is unlikely to be successful more than 6 to 8 weeks after the onset of symptoms. Prompt recognition of axillary-SCV thrombosis is therefore crucial to direct patients toward early venography and thrombolysis. Hematologic and oncologic evaluations are generally not needed in this population and should not delay definitive imaging, thrombolysis, or surgery. The optimal timing is still uncertain, but surgical treatment should generally be performed within 4 to 6 weeks of thrombolysis to minimize the chance of rethrombosis. Surgical treatment within the same hospitalization as thrombolysis is also an acceptable approach.29 Once surgical decompression has been achieved, direct or indirect (endovascular) intervention to restore a patent subclavian vein can be successfully undertaken, either in the operating room or in a delayed manner through interventional approaches, as described in some protocols.5,6,26,27,30 The principal limitation in the treatment of VTOS is for patients who have long-segment occlusion of the SCV that persists despite adequate decompression; in nearly every published series, such patients represent 5% to 20% of those presenting for surgery.5 Although this situation is managed differently in different protocols, there remain some patients who cannot be satisfactorily treated and for whom long-term anticoagulation may be the only remaining option. Overall management of VTOS should consequently be aimed at minimizing the number of patients with chronic long-segment occlusions. The methods used in

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**Fig 3.** Recommended management algorithm for patients presenting with suspected subclavian vein (SCV) thrombosis. AxV, Axillary vein; CTA, computed tomography angiography; InnV, innominate vein; MRA, magnetic resonance angiography; Rx, treatment; VTOS, venous thoracic outlet syndrome.
the initial evaluation of patients with suspected axillary-
SCV thrombosis are therefore important to permit
prompt and effective treatment toward this goal, and a
negative duplex ultrasound should not be used to
exclude a diagnosis of VTOS.

There are inherent technical limitations in the use of
duplex ultrasound for evaluation of the central SCV.[21]
These include the abbreviated acoustic window through
which to visualize the SCV due to the overriding clavicle,
the inability to compress the SCV because of anatomic
constraints, the presence of large transverse collateral
veins that may be misinterpreted to represent the SCV,
and high flow through venous collaterals that may mini-
mize hemodynamic alterations even in the presence of
central SCV obstruction. Although these limitations are
acknowledged by experts in the field and in various pub-
lications, they are often overlooked in clinical practice
and only rarely mentioned in clinical ultrasound reports.
It is not clear that these limitations are unique to noncer-
tified vascular laboratories because 31% of the false-
negative ultrasound evaluations in this study were per-
formed in IAC-certified laboratories. The usefulness of ul-
trasound in the initial evaluation of patients with
suspected SCV thrombosis is thereby often misunder-
stood and overstated. Although not addressed in this
study, the same concerns exist for the use of ultrasound
in postoperative follow-up of patients after treatment for
VTOS, where reports describing SCV patency based
solely upon ultrasound should be interpreted with
cautions.

Clinicians ordering upper extremity ultrasound testing
to exclude DVT may not be aware of the limitations of
these studies and, as found in the current study, the re-
ports of ultrasound testing infrequently state the limita-
tions in assessing the central SCV. This may lead
clinicians to forego further evaluation or specialist
referral when ultrasound testing is reported to be
‘negative,’ rather than treat with presumptive anticoa-
gulation and obtain definitive imaging. For patients
with SCV thrombosis and VTOS, this approach may
delay or eliminate the potential use of thrombolytic
therapy, resulting in propagation of thrombus from a
focal lesion to a long-segment axillary-SCV occlusion
that cannot be readily treated at the time of surgery.
Indeed, in this study the incidence of long-segment
SCV occlusion at the time of surgery was nearly twofold
higher in patients that had a false-negative ultrasound
at initial evaluation. Unfortunately, in this study, only
11% of the reports describing false-negative ultrasound
studies had included a statement of limitations. We
therefore recommend that vascular laboratory reports
and IAC guidelines reflect these concerns by more
clearly stating the limitations of ultrasound in assessing
the central SCV, especially when studies are otherwise
negative for DVT in the distal subclavian, axillary, basilic,
and brachial veins.

One of the main limitations of this study is that it is
retrospective in nature and the type of data collected
do not allow determination of the overall sensitivity,
specificity, or accuracy of upper extremity ultrasound
for UE-DVT. The incidence of false-negative ultrasound
studies was thereby higher than would be observed in
a broader screening study of all patients presenting
with arm swelling. Another limitation is that the initial
clinical presentation and diagnosis of SCV thrombosis
took place at diverse locations and practice settings
and by a variety of different physicians; thus, it was not al-
ways clear if the initial ultrasound examination was done
in an IAC-certified vascular laboratory or if each patient
was evaluated by a vascular specialist. We also did not
have access to complete descriptions of the methodol-
ogy used in the initial ultrasound examinations, being
limited to the information obtained from the printed ul-
trasound reports. Nonetheless, one of the main strengths
of this study is that it reflects real-world clinical practice
regarding the presentation of patients with possible
UE-DVT and VTOS. Additional strengths are that all pa-
ients underwent treatment with a standardized proto-
col involving complete thoracic outlet decompression
and flexible SCV reconstruction, depending on operative
findings, and that there were a large number of study
subjects for a relatively uncommon condition. We cannot
expect to eliminate use of upper extremity ultrasound in
the initial evaluation of suspected SCV thrombosis and
possible VTOS, but hope our findings will bring more
attention to this issue by vascular laboratories and
specialists.

CONCLUSIONS

Duplex ultrasound is limited in the initial evaluation of
patients with suspected SCV thrombosis, with false-
negative results in 21% of patients with proven VTOS.
This is rarely acknowledged in ultrasound reports, but
false-negative ultrasound studies have the potential to
delay definitive imaging, thrombolysis, and further treat-
ment for VTOS. False-negative ultrasound results are
associated with progressive thrombus extension and a
more frequent need for SCV bypass reconstruction at
the time of surgical treatment. Our findings suggest that
one step toward improving the diagnosis and treat-
ment of SCV thrombosis would be to only employ ultra-
sound with understanding that a negative study should
delay definitive imaging, thrombolysis, and surgical
intervention.

AUTHOR CONTRIBUTIONS

Conception and design: EB, AA, BR, RT
Analysis and interpretation: EB, AA, WO, BR, RT
Data collection: EB, AA, RT
Writing the article: EB, RT
Critical revision of the article: EB, AA, WO, BR, RT
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