American College of Radiology
ACR Appropriateness Criteria®
Suspected Upper-Extremity Deep Vein Thrombosis

Variant 1: **Suspected upper-extremity deep vein thrombosis. Initial imaging.**

Procedure	Appropriateness Category	Relative Radiation Level
US duplex Doppler upper extremity	Usually Appropriate	O
CTV upper extremity with IV contrast	May Be Appropriate	☢☢☢☢
MRV upper extremity without and with IV contrast	May Be Appropriate	O
MRV upper extremity without IV contrast	May Be Appropriate	O
Catheter venography upper extremity	Usually Not Appropriate	☢☢☢
Nuclear medicine venography upper extremity	Usually Not Appropriate	☢☢☢
Radiography chest	Usually Not Appropriate	☢

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Summary of Literature Review

Introduction/Background

Soft-tissue swelling is usually due to an alteration in capillary hemodynamics causing motion of fluid from the vascular spaces into the interstitium, secondary to either increased plasma volume (eg, heart failure, pregnancy), increased capillary hydrostatic pressure (eg, superior vena cava syndrome, deep vein thrombosis [DVT], reflex sympathetic dystrophy, trauma), decreased capillary oncotic pressure (eg, cirrhosis, malnutrition), or increased capillary permeability (eg, allergic reactions, infection, inflammation). It can also be due to lymphatic obstruction (eg, lymphedema, malignancy). The etiology of acute isolated upper-extremity swelling is often apparent from the clinical history (eg, trauma, infection, inflammatory arthritis) or can be suspected when risk factors are present (eg, venous thrombosis due to a venous catheter).

Upper-extremity DVT (UEDVT) accounts for up to 10% of all diagnosed DVTs [1,2]. It can be primary in a third of cases due to venous thoracic outlet syndrome [3] (ie, effort-related thrombosis/Paget-Schroetter syndrome) and occasionally is idiopathic. Secondary UEDVT is far more common. Indwelling venous devices, such as catheters, pacemakers, and defibrillators, put patients at the highest risk of thrombus [1,4-10]. Other risk factors include advanced age, previous thrombophlebitis, postoperative state, hypercoagulability [4,11,12], heart failure [4], cancer [7,9-14], right-heart procedures, intensive care unit admissions [1,10], trauma, and extrinsic compression. Patients with certain abnormally elevated coagulation factors were demonstrated to be at increased risk of UEDVT [15]. Although many of the same risk factors for lower-extremity DVT also increase the risk for UEDVT, research is helping to elucidate certain variables unique to thrombi in the upper extremity [1,16].

Patients who develop UEDVT often present with symptoms of ipsilateral upper-extremity edema, pain, paresthesia and, in some instances, functional impairment [16]. Catheter-associated thrombosis may be asymptomatic, rather manifesting as catheter dysfunction or as an incidental finding upon imaging. Superficial thrombophlebitis is associated with local pain, induration, and, often, a palpable cord but is rarely associated with diffuse arm swelling [17]. Unilateral swelling indicates an obstructive process at the level of the brachiocephalic, subclavian, or axillary veins [17,18]. DVT limited to the brachial veins need not be associated with swelling. Isolated jugular vein thrombosis is asymptomatic and rarely causes swelling. There may be a correlation between UEDVT and lower-extremity DVT, and investigation of the lower extremities as well should be considered if an upper-extremity thrombus is found in the absence of a local cause [19].

Diagnosis of UEDVT

Venous thrombosis must initially be considered in a patient with upper-extremity swelling because it typically requires anticoagulation and sometimes thrombolysis. Risk stratification can be performed from a combination of clinical features [20] or by using blood tests. Plasma levels of D-dimer, a degradation product of cross-linked fibrin that is elevated during thromboembolic events, is highly sensitive but not very specific [21] and may be useful in ruling out UEDVT in conjunction with low pretest probability [22-24]. However, D-dimer cannot assess the location and extent of DVT, which is critical for proper therapeutic management [25], and is unreliable to distinguish between acute DVT from recurrent DVT. Imaging is often required for definitive exclusion of DVT and to document

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its location and extent. Noninvasive imaging is frequently the initial step to assess DVT and includes ultrasound (US), MRI, or CT. Catheter venography is slightly more invasive but remains the reference standard and offers the potential for initiation of therapy. Other techniques, such as photoplethysmography, lymphoscintigraphy, and fluorine-18-2-fluoro-2-deoxy-D-glucose (FDG)-PET/CT have been discussed in the literature as part of the workup for upper-extremity swelling, particularly when lymphedema is a potential cause [26-30].

Discussion of Procedures by Variant

Variant 1: Suspected upper-extremity deep vein thrombosis. Initial imaging.

US Duplex Doppler Upper Extremity

US is a noninvasive test that can be performed at the bedside and used for serial evaluations. US grayscale imaging directly identifies thrombus by visualizing echogenic material in the vein and by lack of compression of the vein walls from manual external pressure by the US probe. Lack of compression is seen for both acute and chronic thrombus [12,31]. Acute hypoechoic thrombi may be missed using grayscale imaging alone.

US indirectly identifies thrombus from altered blood-flow patterns [12,31-35]. This is assessed by Doppler US, which produces profiles either as color-flow display or Doppler velocity [36]. Color-flow images can also directly display thrombus and determine whether it is obstructive or partially obstructive. Dampening of cardiac pulsatility or respiratory variation waveforms on Doppler examination are reliable indicators of central venous obstruction [8,35,37]. Rapid inspiration or "sniffing" should normally cause the walls of the central veins to collapse because of rapid venous emptying [37-39]. Impairment of this collapse may indicate a central obstructive process [5,35,37], such as a central thrombus, an obstructive mass, or a benign stricture.

US is most useful in the evaluation of veins peripheral to the subclavian, such as the jugular, axillary, basilic, cephalic, and brachial veins. US can also be used for the evaluation of arteriovenous fistulas in renal patients [40,41]. Compression cannot be used to evaluate more central veins because bony structures prevent visualization or compression of the vessel lumen, but flow in these central veins can be assessed by US [5,12,37]. If only blood flow abnormalities are seen, conventional venography may be necessary [12].

Correlative studies between US and venography show diagnostic sensitivities and specificities above 80% [5,8,12,31,34,35,38,39,42,43].

MRV Upper Extremity

MRI uses several techniques to image the veins, with or without intravenous (IV) contrast agents. Noncontrast sequences include bright-blood and black-blood imaging [44] as well as flow-based imaging, such as time-of-flight [45-49] and phase-contrast imaging [47,50]. Contrast-enhanced MR venography (MRV) techniques are either high resolution or time resolved [47,51]. MRI can image the vessel lumen, the vessel wall, the surrounding structures, and assess for the presence of flow in the vessel. Thrombus can also be imaged directly [52]. Nephrogenic systemic sclerosis has been associated with exposure to some brands of gadolinium-based contrast agents in patients with renal failure [53].

Spin-echo techniques produce black-blood images [33,50] on which thrombus displays high intravascular signal often accompanied by venous enlargement. The high signal decreases after 6 months, and the technique is less useful for chronic thrombus [54]. This imaging technique is not always consistent and is affected by a variety of flow artifacts [50]. Newer double inversion-recovery techniques provide more reliable black-blood imaging [47]. Black-blood imaging is also useful to image the vessel wall, where scan parameters can be adjusted to enhance either T1 or T2 weighting.

Balanced gradient-echo techniques produce bright-blood images on which acute thrombus is relatively isointense to blood, making the sequence insensitive to detect acute thrombus [55,56]. The signal of thrombus varies in intensity over time. Cardiac-gated 3-D steady-state free precession and fast spin-echo techniques also produce bright-blood images. Because steady-state free precession images are T1/T2 weighted, visibility of clots depends on the age of thrombus. The weighted subtraction of fast spin-echo images in various phases of the cardiac cycle can help differentiate transient flow artifacts from true filling defects that persist over the cardiac cycle. Both techniques have been implemented for noncontrast MR angiography and appear promising [57-59].

Using time of flight to image veins is usually limited to a 2-D technique. Rapid flow through the imaging plane produces a bright signal, whereas slow flow or in-plane flow can produce a dark signal due to signal saturation [59]. On axial 2-D time-of-flight images, the jugular veins, right brachiocephalic vein, and superior vena cava are oriented in the superior-inferior direction and produce a bright signal, whereas the left brachiocephalic vein and subclavian

veins are oriented in-plane and produce a darker signal, often requiring sagittal 2-D time-of-flight images for best assessment. Breathing artifacts may also impair imaging quality [11,59,60]. Phase-contrast flow imaging has not been widely used for upper-extremity venography because of the slow flows that must be detected [59].

IV gadolinium-based contrast agents [59] can be administered during acquisition of 2-D or 3-D T1-weighted gradient-echo images with fat saturation to produce a very bright signal in patent vessels [45,61,62]. A 90- to 120-second delay is required after injection to allow the contrast bolus to enter the venous or equilibrium phase [47,59] and to generate an MRV. MRV has proven very useful to evaluate the central venous structures, which cannot be directly imaged by US, but US or venography are still preferred to image the more peripheral veins. A few IV contrast agents persist longer in the vessels and have been useful to image the venous structures. Fibrin-specific MR contrast agents can further enhance all thrombi and may even detect thrombi not readily visible in noncontrast imaging [63].

The dynamic filling of vessels by IV contrast agents can be imaged with time-resolved techniques. Such techniques can reduce both IV contrast volume and acquisition time while improving specificity when used as an adjunct to conventional MR sequences [64,65]. It has found use in protocols for whole-body venography [66] and was shown to produce images of comparable diagnostic quality but lower specificity compared with conventional MRV [67] in the assessment of central thoracic veins. It might eventually be used as a fast, noninvasive, and relatively safe imaging tool for screening and serial follow-up of patients with poor renal function, but further study is required [68].

Standard MRI sequences are always included in MRV protocols because they produce high-resolution images of the soft tissues surrounding the vessels and can help identify mimics of DVT and potential sources of extrinsic venous compression as well as signs of soft-tissue inflammation around the veins (edema on T2-weighted images and contrast enhancement on postcontrast T1-weighted sequences). MRV can be as effective as venography [46,62] but has limitations [33,45,50]. A meta-analysis found MRV to have both a high sensitivity and specificity [69], although the study did not focus on the upper extremities.

CTV Upper Extremity

CT can be used to assess the lumen of venous structures. It involves the injection of an iodinated contrast agent [34,38]. Delayed imaging at 90 to 120 seconds can permit evaluation of the central veins. CT can detect thrombi in vascular lumen or stenosis of the lumen. It has been used to assess the jugular veins [70,71], the brachiocephalic veins [72,73], and the superior vena cava [72]. Perivascular inflammatory changes around acute thrombi can also be detected by CT [74]. CT can be used to visualize external processes causing vascular compression or invasion, such as neoplastic processes [75]. CT is the main imaging modality for staging neoplastic involvement in the mediastinum and axillae, which can include vascular invasion or compression. No large series of studies have looked at the diagnostic accuracy of this technique for diagnosing upper-extremity venous thrombosis, although extensive experience is accumulating with lower-extremity venous thrombosis. One small series showed that the performance of CT venography (CTV) is similar to that of conventional venography in the thoracic and upper-extremity veins and it evaluates the central extent of obstruction more effectively [75].

Catheter Venography Upper Extremity

Catheter venography is the "reference standard" examination for evaluating the upper-extremity veins [38] but is rarely the first imaging modality because noninvasive modalities are preferred. It involves the injection of an iodinated contrast agent [34,38], but the risks of adverse events have been reduced with low-osmolar contrast agents. The contrast agent flows in the veins, opacifying them, and thrombus can be identified as a filling defect in a vein, an abrupt cutoff of opacification of a vein, complete absence of filling by contrast, or the presence of collateral channels [31]. Venography can also identify recurrent acute venous thrombus in patients with a prior history of venous thrombus. Venography can identify fixed venous stenoses and, with upper-extremity maneuvers (abduction), can identify extrinsic venous compression. The utility of these maneuvers has also been described with US [76]. Asymptomatic or minimally symptomatic venous compression with arm abduction should be treated with caution because this finding is present in many normal individuals.

Nuclear Medicine Venography Upper Extremity

Radionuclide venography involves the peripheral injection of radiopharmaceuticals or labeled small particles (eg, macroaggregated albumin, red blood cells, albumin, platelets) to assess drainage of extremities via the veins or lymphatics, or to directly detect the presence of thrombus (eg, platelets or specific markers). Patent vessels will take up the radiopharmaceuticals, whereas obstructed vessels will not. Failure to visualize specific veins, combined with

visualization of collateral veins, indicate either venous thrombosis or external compression of venous segments [2,25,26,28]. Radionuclide venography has been considered the reference standard for lymphedema [77]. For edema related to lymphatic obstruction, the presence of certain features, such as dermal backflow and lymph node asymmetry, can increase the diagnostic specificity after intradermal injection [78]. Some authors have indicated that differentiating between primary lymphedema and secondary lymphedema, such as that due to venous obstruction, may be limited when using intradermal lymphangiography alone [79]. MR lymphangiography is currently being evaluated as an alternative to conventional, radionuclide lymphoscintigraphy and may play a larger role in the future [80,81].

Radiography Chest

Although chest radiography cannot assess vascular patency, it can identify factors that can cause external compression or invasion of vessels, such as cervical rib or a mass lesion. It can also identify intravascular material such as intact or fragments of wires and catheters.

Summary of Recommendations

- **Variant 1:** US duplex Doppler of the upper extremity is usually appropriate for the initial imaging of patients with suspected UEDVT.

Supporting Documents

The evidence table, literature search, and appendix for this topic are available at https://acsearch.acr.org/list. The appendix includes the strength of evidence assessment and rating round tabulations for each recommendation.

For additional information on the Appropriateness Criteria methodology and other supporting documents go to www.acr.org/ac.

Appropriateness Category Names and Definitions

Appropriateness Category Name	Appropriateness Rating	Appropriateness Category Definition
Usually Appropriate	7, 8, or 9	The imaging procedure or treatment is indicated in the specified clinical scenarios at a favorable risk-benefit ratio for patients.
May Be Appropriate	4, 5, or 6	The imaging procedure or treatment may be indicated in the specified clinical scenarios as an alternative to imaging procedures or treatments with a more favorable risk-benefit ratio, or the risk-benefit ratio for patients is equivocal.
May Be Appropriate (Disagreement)	5	The individual ratings are too dispersed from the panel median. The different label provides transparency regarding the panel's recommendation. "May be appropriate" is the rating category and a rating of 5 is assigned.
Usually Not Appropriate	1, 2, or 3	The imaging procedure or treatment is unlikely to be indicated in the specified clinical scenarios, or the risk-benefit ratio for patients is likely to be unfavorable.

Relative Radiation Level Information

Potential adverse health effects associated with radiation exposure are an important factor to consider when selecting the appropriate imaging procedure. Because there is a wide range of radiation exposures associated with different diagnostic procedures, a relative radiation level (RRL) indication has been included for each imaging examination. The RRLs are based on effective dose, which is a radiation dose quantity that is used to estimate population total radiation risk associated with an imaging procedure. Patients in the pediatric age group are at inherently higher risk from exposure, because of both organ sensitivity and longer life expectancy (relevant to the long latency that appears to accompany radiation exposure). For these reasons, the RRL dose estimate ranges for pediatric examinations are lower as compared with those specified for adults (see Table below). Additional

information regarding radiation dose assessment for imaging examinations can be found in the ACR Appropriateness Criteria® Radiation Dose Assessment Introduction document [82].

Relative Radiation Level Designations		
Relative Radiation Level*	**Adult Effective Dose Estimate Range**	**Pediatric Effective Dose Estimate Range**
O	0 mSv	0 mSv
☢	<0.1 mSv	<0.03 mSv
☢☢	0.1-1 mSv	0.03-0.3 mSv
☢☢☢	1-10 mSv	0.3-3 mSv
☢☢☢☢	10-30 mSv	3-10 mSv
☢☢☢☢☢	30-100 mSv	10-30 mSv
*RRL assignments for some of the examinations cannot be made, because the actual patient doses in these procedures vary as a function of a number of factors (eg, region of the body exposed to ionizing radiation, the imaging guidance that is used). The RRLs for these examinations are designated as "Varies."		

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