Diagnosis of Deep Venous Thrombosis and Pulmonary Embolism

New Imaging Tools and Modalities

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KEYWORDS

• Pulmonary embolism • Imaging • Computed tomography • MRI • Ultrasound

KEY POINTS

- Imaging has a key role in establishing the diagnosis of DVT and PE, particularly as integrated into diagnostic algorithms.
- Ultrasound remains the gold standard for diagnosis of DVT though CT and MRI based imaging have a role in situations where ultrasound has limitations.
- CT angiography and ventillation perfusion imaging have largely replaced pulmonary angiography as the modality of choice in assessing acute pulmonary embolus.
- MRI, nuclear imaging and dual energy CT are currently being clinically evaluated as tools for diagnosis, subtyping and prognostication in pulmonary embolism.

INTRODUCTION

Untreated venous thromboembolism carries the potential for serious complications and mortality. At the same time, there is also significant risk associated with treatment with anticoagulation and thrombolysis. This leads to a need for sensitivity in diagnosis, certainty in the decision not to treat, as well as relative urgency in making the diagnosis and initiation of treatment. Thus, there is significant impetus to develop and refine tools for detection and management of venous thrombus, both in the extremities and the lungs. Although the importance of these clinical decisions necessitates a comprehensive clinical approach to diagnosis, imaging has long played a pivotal role in detecting the presence and extent of thromboembolic disease. Although many great imaging tools already exist, furthering the application of imaging in thromboembolism remains an area of intense research and development.

Within the realm of imaging, there has been a steady progression towards using noninvasive methods to guide initial diagnosis, with invasive imaging used in complex cases or as part of an interventional strategy. Research has historically focused on the detection of clot, which then inputs into the clinical decision making pathways. However, as the number of tools and options for treatment increase, there is growing interest in using imaging for better quantification and classification

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of thromboembolic disease to improve prognostication and to guide intervention.

In this section, we review the role of imaging in the diagnosis and management of deep venous thrombosis (DVT) and pulmonary embolism (PE), highlighting the current state of the art modalities as well as areas in which current research is uncovering promising tools that may find their way to clinical use in the near future.

IMAGING IN THE DETECTION AND MANAGEMENT OF DEEP VENOUS THROMBOSIS

Contrast venography is an invasive procedure in which venous opacification is evaluated in real time. Although the gold standard for the detection of DVT, this method is rarely practiced outside of expert centers, where it is often used in the context of intervention.[1,2] This is in large part due to the myriad of noninvasive imaging techniques that are now widely available, and in particular, the use of ultrasound examination in the diagnosis of DVT.

Methods using ultrasound examination to evaluate venous thrombosis were developed in the 1960s[3] and were perfected in the following decades. The measurement of venous blood flow as well as venous compressibility[4,5] were also developed. The evaluation of venous compressibility in combination with color and Spectral Doppler assessment of flow and phase is now the recommended approach for detection of a venous clot[2,6] (**Fig. 1**). This is largely due to the availability and ease of deployment in a variety of clinical settings.[6] Although the incidence of upper extremity DVT is much lower than the lower extremity, its presence leads to a significant risk of PE and associated morbidity.[7,8] Imaging approaches similar to the lower extremity can be used for the detection of clot in the upper extremities. However, restrictions imposed by the clavicle significantly limit ultrasound-based techniques.[2,9]

Other imaging modalities have been investigated for clot detection and have shown promising results, although none have replaced ultrasound-based methods in routine clinical settings. As an analogue of direct venography, computed tomography (CT)-based venography (involving direct injection of contrast into the veins) has been shown to have great sensitivity in detection of DVT[10] while reducing contrast load by as much as 80% compared with conventional venography. Additionally, venography using contrast injected in a distal site, for example, in the context of a CT angiography of the chest, have also been investigated.[11] This approach is proposed given the common risk factors between PE and DVT as well as the observation that many individuals with no evidence of PE on CT angiography are noted to have DVT.[11] This approach to CT angiography also improves the ability to detect proximal clots in the pelvis.[12] Subsequent studies of these combined approaches have shown limited usefulness with additional radiation (but not contrast exposure given the need for both angiography

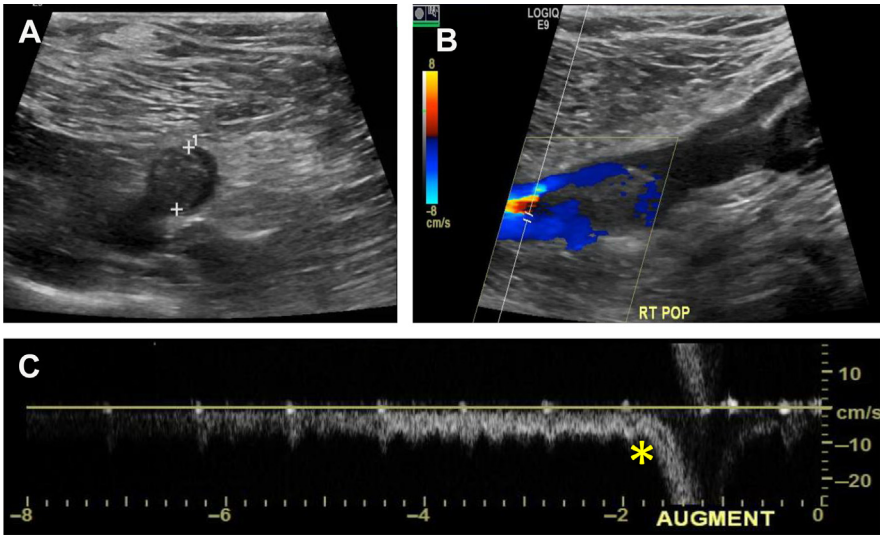

Fig. 1. Ultrasound evidence of deep venous thrombosis at the bifurcation of the right popliteal vein. (*A*) Demonstration of partially occlusive thrombus in the right popliteal vein and accompanying color flow Doppler imaging (*B*) showing decreased flow in the right popliteal vein. Spectral waveforms measuring the velocity of flow demonstrate an increase in velocity during an augmentation (marked by the *yellow star*) (*C*), consistent with the presence of residual flow.