Diagnosing Deep Venous Disease Through Optimized Imaging: Magnetic Resonance Venography

Imaging central venous disease using magnetic resonance venography.

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Endovenous interventions for the cavo-ilio-femoral venous system have been increasing over the past decade, facilitated by the development of technology such as dedicated venous stents.[1,2] These developments have led to a need for accurate diagnostic and preoperative imaging to plan complex interventions and aid with patient consent. Although a number of different imaging techniques exist, including CT with contrast agent, ultrasound, and digital subtraction venography, MRI has emerged as an accurate and reliable investigative method for the noninvasive assessment of the central venous system.[2,3] The goal of this article is to discuss the advantages and disadvantages of MRI and examine future developments within the field.

MRI

MRI is a noninvasive imaging technique that requires no ionizing radiation. It utilizes a strong magnetic field that aligns hydrogen ions, abundant in water and fat, along the axis of the MRI scanner. When radiofrequency waves are applied, this net magnetization vector is deflected, and when radiofrequency waves are switched off, it returns to the previous position. This is detected by the receiver coil and the signal is generated. The time it takes for the vector to return to the longitudinal plane is known as the T1 relaxation time, and when it returns to the transverse plane, this is known as the T2 relaxation time.

In addition to visualizing endogenous protons, specifically designed contrast agents can be used to increase

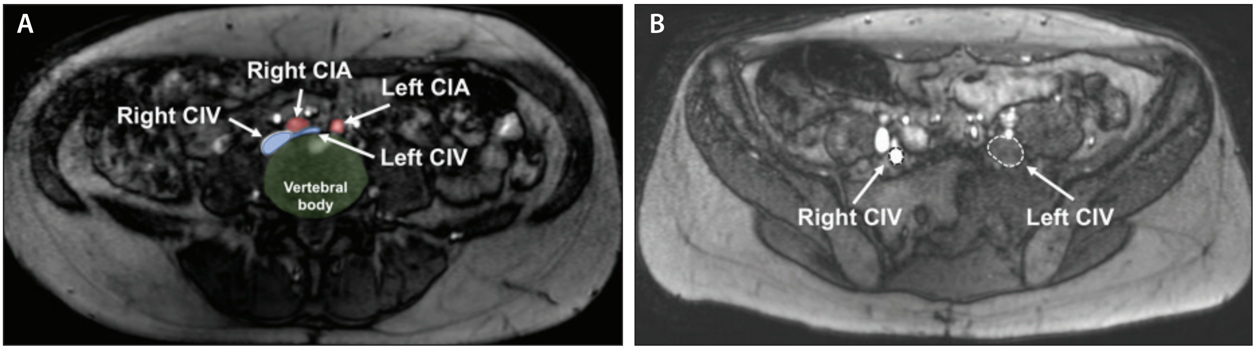

Figure 1. TOF MRV showing compression of the left common iliac vein (CIV) between the right common iliac artery (CIA) and the vertebral body (A). A thrombosed left CIV compared with an unaffected CIV on the right (B).

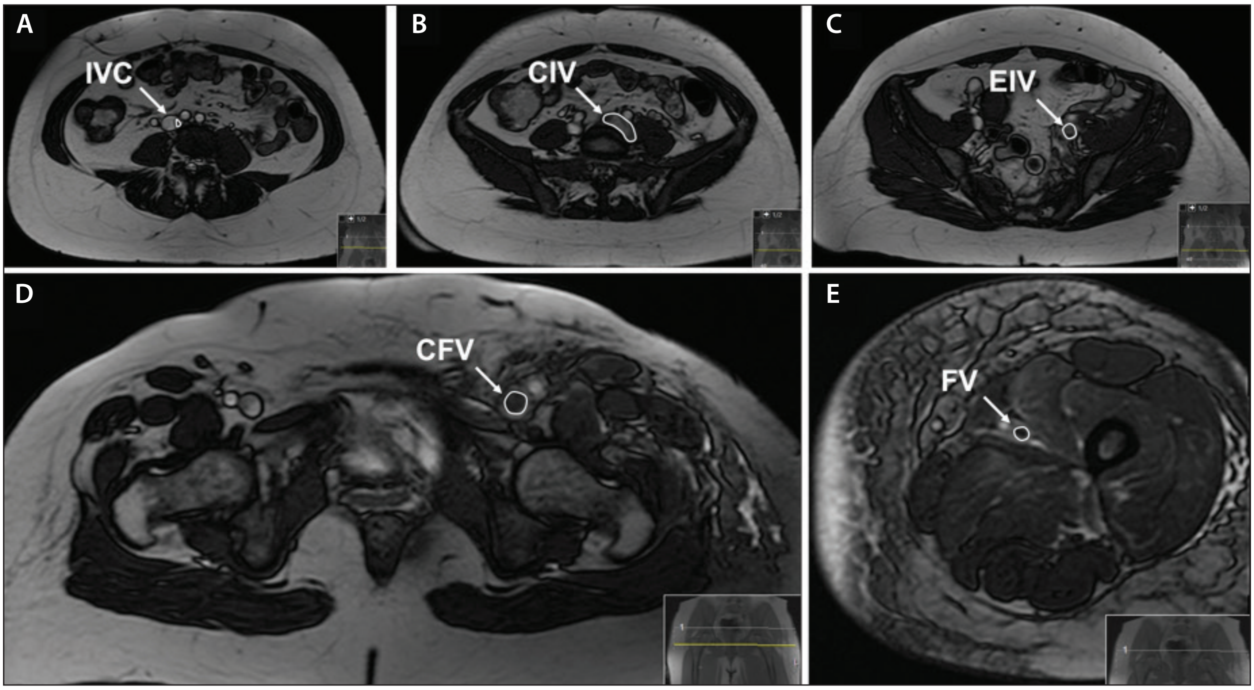

Figure 2. bSSFP MRV of a 49-year-old woman with acute left iliofemoral DVT. Thrombus within the inferior vena cava (IVC) (A); CIV (B); external iliac vein (EIV) (C); common femoral vein (CFV) (D); and femoral vein (FV) (E), with extensive leg edema.

the contrast-to-noise ratio and enhance image quality. Gadolinium-based contrast agents are one example that is readily available; however, care must be taken in patients with renal impairment, as nephrogenic systemic fibrosis can very rarely develop (< 0.002%).[4,5]

MRI AS AN ASSESSMENT TOOL FOR VENOUS DISEASE

MRI is amenable to a range of modifications allowing for the assessment of tissue characteristics without the need for contrast. Time-of-flight (TOF) imaging is a flow-encoded MRA sequence where stationary tissues (including thrombus) are saturated with rapidly repeating radiofrequency pulses. Flowing blood appears bright, while filling defects within the vessel lumen remain dark (Figure 1). It has excellent sensitivity and specificity of 100% and 99%, respectively, for detecting thrombus.[6]

True fast imaging with steady-state precession magnetic resonance venography (MRV) allows accurate diagnosis of deep vein thrombosis (DVT) with overall sensitivity and specificity of 87% and 98%, respectively. However, visualization of tibial and peroneal veins is less accurate.[7] Balanced steady-state free precession (bSSFP) is another flow-independent sequence that has excellent signal-to-noise ratio (Figure 2). It is highly accurate in diagnosing DVT (sensitivity, 95%; specificity, 100%) and has the potential to determine the age of the thrombus.[8] We routinely use it for assessing acute DVT and postthrombotic patients planned for endovenous procedures, where it provides information on the extent of the thrombus, the presence of a compression point, and the condition of the inflow vessels (common femoral vein, femoral vein, and profunda vein) (Figure 3).

A recent systematic review and meta-analysis revealed an estimated overall sensitivity and specificity of 93% and 96%, respectively, for the detection of suspected DVT. However, the heterogeneity of the included studies was high and there is not enough evidence to replace ultrasound with MRV as first-line investigation. Rather, MRV could be used in patients in whom ultrasound has been inadequate.[9]

CHARACTERIZING DVT USING MRI

The main goals for imaging a patient with an acute DVT are the depiction of the venous anatomy, extent of thrombosis, and anatomic abnormalities such as May-Thurner lesion compression of the left common iliac vein between the vertebral body posteriorly and pulsating right common iliac artery anteriorly (Figure 1A). Identifying the exact location of the acute thrombus has implications for treatment. Iliofemoral DVT is associated with a higher risk of postthrombotic syndrome (PTS), which may be reduced with thrombolytic therapy. The CAVENT study concluded that additional catheter-directed thrombolysis resulted in an absolute risk reduction in PTS of 14% at 2 years,[10] and the recent ATTRACT trial found a significant reduction in moderate or severe PTS when the iliofemoral vein was treated.[11] However, lysis is not successful in all patients, and identifying which patients may benefit from fibrinolytic therapy, which is potentially hazardous, would be desirable.

Qualification of thrombus as acute, subacute, or chronic has been demonstrated with MRI.[12] T1-weighted imaging has been shown to detect recurrent DVT in humans[13] and can also predict thrombus lysability in an experimental model.[14] Translation of the MSTI (multisequence thrombus imaging) technique, which includes anatomic imaging by bSSFP and TOF sequences and thrombus characterization using T1 mapping, magnetization transfer, and diffusion-weighted imaging, is underway and shows promise in providing "virtual histology" of the thrombus to aid clinical decision-making.

Another area of promising research is through the use of molecular imaging techniques that utilize specifically designed nanoagents that bind to constituents of a thrombus. Probes have been developed that can target platelets, fibrin, and factor XIIIa and have demonstrated an ability to characterize thrombus within a research setting.[15-21] Combining diagnostic and therapeutic probes also offers the potential for a more targeted and personalized approach.

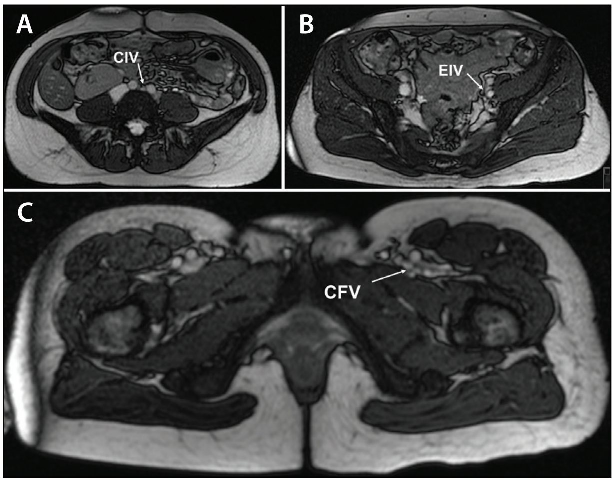

Figure 3. bSSFP MRV of a 53-year-old patient with PTS. High-grade extrinsic compression of the left CIV (May-Thurner syndrome) (A). High-grade stenosis of the left EIV (B). Stenosis of the left CFV with postthrombotic web (C).

ADVANTAGES AND DISADVANTAGES OF MRI

The main advantage of MRI over CT is the lack of ionizing radiation, which is particularly important in patients presenting with acute iliofemoral DVTs who are typically young. As thrombus can be readily imaged using MRI without the use of a contrast agent, the investigation of patients with renal failure can safely be carried out. MRI also has excellent visualization of soft tissues, and it is ideally suited for screening of occult cancer that is detected in 1 in 20 patients within a year of DVT diagnosis.[22]

The main limitation of MRI is the strong magnetic field that can interfere with the function of some implantable devices, such as MR-unsafe pacemakers. Although most nitinol venous stents are MR conditional, the interference with the signal generated is such that the stent lumen might not be visualized. Therefore, MRI cannot be recommended for follow-up of patients who have previously undergone endovenous reconstruction with stents.

The cost of MRI is frequently raised as one of the main barriers for a wider implementation. The cost-effectiveness of this technique has yet to be evaluated, but with the increasing availability of the scanners, costs are likely to reduce. In addition, the extra information gained from MRI may improve patient outcomes in the long term, thus increasing efficacy.

CURRENT GUIDELINES

Due to the scarcity of randomized controlled trials comparing MRV with other imaging modalities for diagnosis of DVT, high-quality evidence is lacking. Clinical practice guidelines of the European Society for Vascular Surgery describe MRV as a complementary tool for assessment of chronic venous obstruction and planning deep venous reconstruction.[23] MRV is recommended as an additional imaging modality if treatment of suprainguinal venous pathology is planned (level 1C evidence).[23] American College of Radiology appropriateness criteria state MRV with or without contrast may be appropriate as an initial imaging modality.[24] In children, MRV should be considered if there is a suspicion of proximal extension of the femoral DVT (level 2C evidence).[25] Currently, MRV should be considered complementary to other imaging modalities, all of which offer unique information that may help the treating clinician.

CONCLUSION

MRV is an accurate method for assessing acute thrombotic and postthrombotic lesions affecting the cavo-iliofemoral venous system. It can complement other imaging modalities in the preoperative planning of deep venous reconstructive surgery and offers an opportunity to develop novel sequences that can provide anatomic, structural, and functional information that together may help guide treatment. Cost and expertise remain a limitation; however, with increased availability, we believe that the clinical utility of this method will become more apparent. ■

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