

Deep Vein Thrombosis (DVT): comparison of MR Direct Thrombus Imaging and Non-Contrast-Enhanced MRA

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Target audience Physicists and clinicians concerned with vascular imaging or venous thromboembolism

Purpose

Deep venous thrombosis (DVT) is a common condition with high morbidity and mortality. Duplex ultrasonography, the current gold standard for diagnosis, is unable to reliably determine the age of the thrombus and thus to distinguish acute recurrent DVT from a persisting previous thrombus in the same location—a distinction which is important in determining subsequent clinical management. The thrombus signal on MR Direct Thrombus Imaging (MR-DTI)¹ has been shown to vary with age² and so might be valuable in the assessment of suspected same-location recurrences. Non-contrast-enhanced MR venography (NCE-MRV) has also been shown to be effective in diagnosing DVT in the thigh. As a precursor to the possible future use of MR in suspected recurrent thrombus, this study aims to further investigate these temporal changes for patients with a first DVT, by comparing MR-DTI and NCE-MRV at three different time points after diagnosis.

Methods

Seven Patients with ultrasound-proven above-knee DVT (in the femoral vein and/or proximal popliteal vein) and no previous history of venous thrombosis were imaged at 1.5 T (MR450, GE Healthcare, Waukesha, WI) using a 12-channel phased array coil, after obtaining ethical permission and informed consent. The first scan (visit 1) was performed within 7 days of diagnosis, and further scans were performed after 3 months (visit 2) and 6 months (visit 3). During this time the patients received standard anti-coagulant therapy.

For each examination, non-contrast-enhanced MR venography was acquiring using Acceleration-Dependent Vascular Anatomy for Non-Contrast-Enhanced MR Venography (ADVANCE-MRV)^{3,4} using dual flow-preparation modules, which combined flow sensitisation using effective first gradient moments of 1.2, 0.6, 0.3 and 0.15 $\mu\text{T}^2/\text{m}$. This technique uses subtraction of velocity- and acceleration-dependent angiography methods^{5,6}. The readout was a 3D balanced-SSFP (oblique coronal orientation, flip angle 65°, TE 1.7 ms, TR 3.7 ms, ASSET factor 2, acquisition matrix 288×288×20, FoV 40×40 cm², slice thickness 2.4 mm). Due to previously-noted poor performance of this technique near the edges of the field of view, two separate acquisitions covering the upper and lower halves of the thigh were acquired.

MR Direct Thrombus Imaging (MR-DTI) was acquired with the following optimised⁷ parameters: TI 340 ms, TE 6.3 ms, TR 12.2 ms, flip angle 25°, matrix 320×288×96, FoV 40×40 cm², slice thickness 2 mm, ASSET factor 2, 2 shots per k-space plane, 320 ms delay after each shot. The coronally-acquired 3D volumes were reformatted to match the NCE-MRA images.

The individual-slice images were assessed by an experienced radiologist, who firstly determined the location and length of the (complete or partial) occlusion from the NCE-MRA images. These results were then compared with the locations and lengths of high-signal regions observed with MR-DTI.

Results

Fig. 1 shows images for an example patient. The NCE-MRV shows an occluded right femoral vein at all 3 time-points, but the thrombus is visible on MR-DTI only for the first examination. Fig. 2 shows a bar chart of the length measurements. On visit 1, the NCE-MRV-visualised thrombus length ranged from 6.4–37.0 cm. At visit 2, the thrombus was no longer present in 2/7 cases and had reduced in length in a further 3/7 cases. At visit 3, only 3/7 cases still had thrombus present.

The lengths and locations of thrombus observed as bright signal on MR-DTI exactly matched those from NCE-MRV in all cases for visit 1. For visits 2 and 3 the thrombus was always predominantly dark on MR-DTI, with any bright signal extending over less than 3 cm at visit 2 and 0.5 cm at visit 3.

Discussion

MR-DTI and our NCE-MRV method are in good agreement in the characterisation of the size and location of acute thrombus. The acute thrombus was clearly depicted by MR-DTI, but older thrombus (3 & 6 months) was either not visualised at all or only very small bright-signal regions were seen (less than 12% of the occluded vessel length or residual thrombus). Similar results were found by Westerbeek et al². Thus MR-DTI, in combination with other methods such as NCE-MRV or US, may in future prove to be a valuable tool for distinguishing between acute and chronic thrombus in cases of suspected recurrence, potentially improving clinical management. Further patient evaluation and imaging is ongoing.

Conclusion

Consistency between MR-DTI and NCE-MRV evaluations of thrombus size and location appears to indicate that the thrombus is acute, while a large discrepancy, or absence of NCE-MRV-observed thrombi on MR-DTI, suggests an older, pre-existing thrombus.

References

1. Moody AR. Magnetic resonance direct thrombus imaging. *J Thromb Haemost*. 2003;1(7):1403–9.
2. Westerbeek RE, Van Rooden CJ, et al. MR DTI of the evolution of acute deep vein thrombosis of the leg. *Journal of Thrombosis & Haemostasis*. 2008;6:108701092.
3. Priest AN, Graves MJ, Lomas DJ. Non-contrast-enhanced vein imaging in the deep veins: impact of velocity patterns and improved image quality. *Proc Intl Soc Mag Reson Med*. 2012;20:1210.
4. Priest AN, Joubert I, Hilborne S, et al. Non-contrast-enhanced imaging of lower limb veins: improved imaging using multiple flow preparations. *Proc Intl Soc Mag Reson Med*. 2013;21:1287.
5. Priest AN, Graves MJ, Lomas DJ. Non-contrast-enhanced vascular magnetic resonance imaging using flow-dependent preparation with subtraction. *Magn Reson Med*. 2012;67(3):628–637.
6. Priest AN, Taviani V, Graves MJ, Lomas DJ. Improved Artery–Vein Separation with Acceleration-Dependent Preparation for Non-Contrast-Enhanced Magnetic Resonance Angiography. *Magn Reson Med*. 2014. doi: 10.1002/mrm.24981.
7. Priest AN, Joubert I, Hilborne S, et al. MR Direct Thrombus Imaging with optimised signal and improved lipid suppression. *Proc Intl Soc Mag Reson Med*. 2013;21:1280.

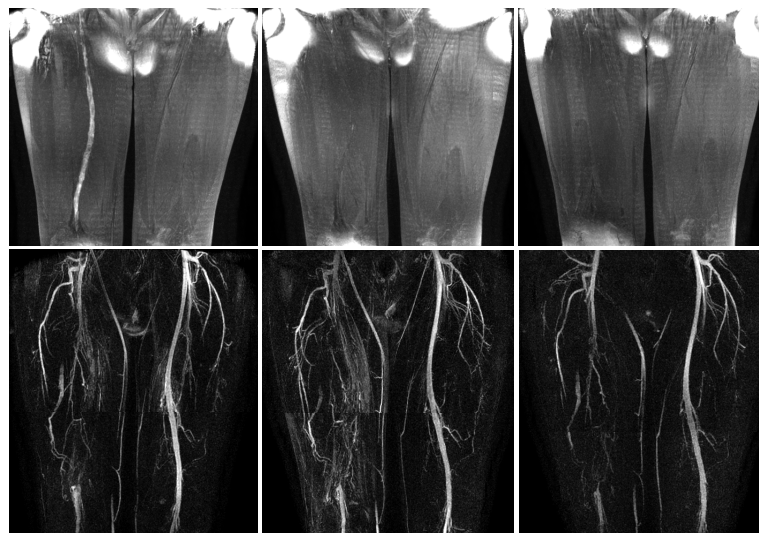


Fig. 1: MR-DTI (upper) and NCE-MRV (lower) MIPs showing a right-thigh DVT, acquired 2 days (left), 3 months (centre) and 6 months (right) after diagnosis.

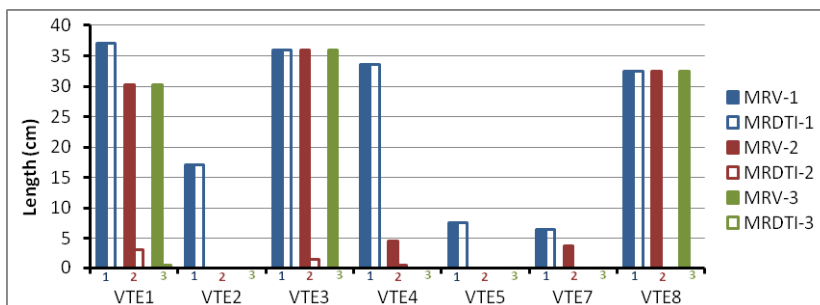


Fig. 2: Length measurements for NCE-MRV (filled bars) and MR-DTI (open bars) shown for each subject and visit. The two length measurements always match for visit 1. For visits 2 and 3 the MR-DTI length is always zero or close to zero.