MR Leg Venography: Improved methodology & impact of subject positioning

A. N. Priest[1], M. J. Graves[1], and D. J. Lomas[1]
[1]Department of Radiology, Addenbrookes Hospital and University of Cambridge, Cambridge, United Kingdom

Introduction

Several recently developed non-contrast-enhanced (NCE) vascular imaging methods [1–5] use motion-sensitised preparation modules to suppress signal from flowing blood, due to intra-voxel velocity dispersion. Angiograms and/or venograms are generated by subtraction of bright- and dark-blood images, obtained without and with flow suppression respectively. Initial work in the lower extremities using one such method [2,4,5] indicated that: (a) it did not achieve complete separation between arteries and veins; (b) venous image quality was poor relative to the corresponding arterial images, with veins being poorly depicted in some subjects; and (c) venous signal loss occurred mid-calf (which may have resulted from simple venous compression by the weight of the legs). This work investigates two improvements in MR venography - firstly, a mixed acceleration- and velocity-dependent method to reduce arterial contamination and secondly, the effect of subject position on vein image quality.

Materials/Methods

Following ethical approval and informed consent, the lower legs of 7 healthy volunteers were imaged with a 1.5 T Signa HDx MR scanner (GE Healthcare, Waukesha, WI) using an 8-channel cardiac coil.

Venograms were formed by subtraction of acceleration-sensitised and velocity-sensitised images. Fig. 1(a) shows the acceleration-sensitive preparation module, which has an effective first gradient moment of zero and so is insensitive to constant-velocity flow. With appropriately chosen parameters, it suppresses the arterial signals, due to the pulsatility of the arterial flow, without significantly affecting the venous signals. This approach allows better discrimination between arteries and veins than when using purely velocity-dependent sequences. Fig. 1(b) shows the velocity-sensitive preparation module [6] which is used to suppress signals from both arteries and veins, with little effect on background signals e.g. from muscle. Both sequences use composite refocusing and tipup pulses [7].

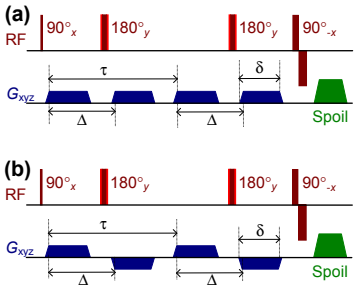

Fig. 1: acceleration-sensitive (a) and velocity-sensitive (b) preparation modules. The motion-sensitisation gradients (MSG) are shown in blue.

The acceleration- and velocity-dependent sequences had motion-sensitisation gradient (MSG) amplitudes of 2 mT/m and 5mT/m respectively. A bright-blood reference dataset was also acquired with no MSG. Timing parameters (defined in Fig. 1) were $\delta = 8$ ms, $\Delta = 13.1$ ms, $\tau = 25$ ms. The preparation sequence was placed approximately 100 ms after the peripheral pulse trigger, corresponding to approximately peak arterial flow, with a further 200 ms delay before the 3D balanced-SSFP readout (coronal orientation, flip angle 65°, TE/TR=1.6/3.4 ms, ASSET factor 2, acquisition matrix 256×230×28, FoV 33.3×30 cm, slice thickness 2.4 mm, 2 segments per slice). Spectral fat suppression was applied before both the preparation module and the readout [4].

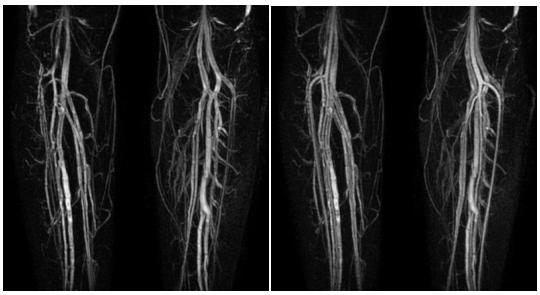

Fig. 2: Example vein images (MIP of subtractions) with (left) and without (right) arterial suppression.

For each volunteer, this series of acquisitions was repeated three times in different positions: supine, prone, and 'supported supine' (supine orientation but with weight supported by pads under the thighs and ankles to avoid compressing the calf).

An experienced radiologist, blinded to subject orientation, compared subtraction MIPs, assessing which gave better visualisation of the major deep veins for each pair of orientations. This assessment was performed separately for the upper, middle and lower third of the images. The presence or absence of arterial contamination was also assessed, using comparison with the unsuppressed dataset to locate the arteries.

Results

Fig 2 shows example MIPs with and without arterial suppression, demonstrating the complete removal of arterial signal, without suppression of the venous signal. No arterial contamination was observed for any of the vein images. Fig 3 demonstrates effect of patient position. In this subject, the veins are poorly depicted in standard supine orientation, especially in the central third of the image. Depiction is substantially improved for prone and supported supine orientations.

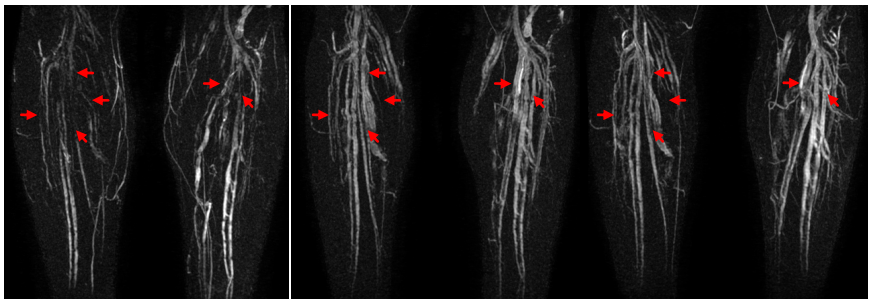

Fig. 3: Comparison of supine (left), supported supine (centre) and prone (right) vein images. Signal loss in supine orientation may be linked to compression by the weight of the calf.

Fig. 4 shows the results of the pairwise comparisons. Prone orientation was rated better in more images compared to both supine and supported supine (Sup Supine), especially in the middle and lower thirds of the image. Supported supine and unsupported supine orientations were rated approximately equally.

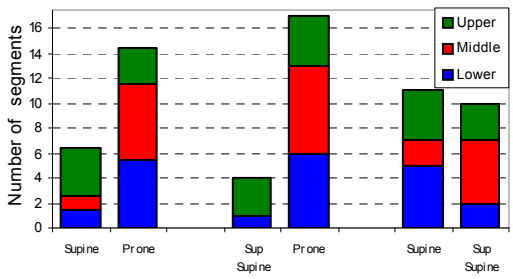

Fig. 4: Results of direct pair-wise comparisons. The colour divisions indicate the numbers of upper, middle and lower segments graded better for each orientation.

Discussion & Conclusions

This novel method, combining acceleration- and velocity-sensitised preparation, generates subtraction venograms with excellent background suppression and no apparent arterial contamination in healthy volunteers. After further evaluation, this method might be clinically appropriate for imaging venous anatomy or suspected deep vein thrombosis.

When using supine orientation, poor visualisation of lower leg veins in some subjects may be due to compression resulting from the weight of the calves. Prone orientation, which avoids this calf compression, improved image quality in these subjects especially. 'Supported supine' orientation, also designed to relieve this pressure, resulted in improved image quality in some cases (e.g. Fig. 3) but was worse in others. Prone orientation offered no improvement in the upper third of the image, where less weight falls; however prone images may have been affected by signal loss from coil positioning and/or poor shimming, which will be investigated in future.

References
[1] Miyoshi M et al. proc ISMRM 2007;15:180.
[2] Priest AN et al. proc ISMRM 2008;16:727.
[3] Fan Z et al. MRM 2009;62:1523.
[4] Priest AN et al. proc ISMRM 2010;18:1374.
[5] Priest AN et al. proc ISMRM 2010;18:406.
[6] Wang J et al, JMRI 2010; 31:1256.
[7] Brittain JH et al. MRM 1995;33:689–696.

Acknowledgements Addenbrookes Charitable Trust, NIHR Cambridge Biomedical Research Centre