Automated Dynamic MR Arteriography and Venography with Time-Resolved Contrast-Enhanced Imaging

J. Du[1,2], F. J. Thornton[3], S. B. Fain[1], C. A. Mistretta[1,3], T. M. Grist[1,3]

[1]Medical Physics, University of Wisconsin-Madison, Madison, WI, United States, [2]Department of Radiology, University of California-San Diego, San Diego, CA, United States, [3]Radiology, University of Wisconsin-Madison, Madison, WI, United States

INTRODUCTION

Magnetic resonance imaging has been used in detecting deep venous thrombosis (1-5). Techniques such as time-of-flight and phase contrast methods are limited in depicting paired veins, perforator veins and venous valves below the knee due to the flow artifacts and low resolution (1-2). Recently contrast-enhanced MR venography has been proposed, where multiphase acquisitions are typically used to depict the difference in arterial and venous enhancement, followed by a subtraction algorithm to produce a venogram (3-5). The temporal resolution is quite low (typically 30 second-per-frame), and the whole process is not fully automated. The present work aims to generate the contrast dynamics in both the arterial and venous structures with high spatial and temporal resolution. The separation of the venous contrast dynamics was fully automated through an iterative processing algorithm based on the temporal information.

MATERIALS AND METHODS

In this study, a time-resolved hybrid projection reconstruction (PR) sequence, which combines undersampled PR in-plane and Cartesian slice encoding through-plane in a TRICKS fashion (6), was applied for data acquisition in the distal extremity. The acquisition parameters were: FOV = 40 cm, TR/TE = 6.9/2.6 ms, flip angle = 30°, BW = 62.5 KHz, readout = 384, projections = 80, slices = 72, slice thickness = 1.5 mm, 21 time frames, frame rate = 4.3 sec, with 14 ml contrast dose. The contrast dynamics in the whole vasculature were depicted with both high spatial and temporal resolution. The isolation of the venous contrast dynamics was based on a contrast arrival time threshold on a voxel-by-voxel basis. A contrast arrival time map and a contrast enhancement map were generated. A histogram of the contrast arrival time was generated for voxels surviving the contrast enhancement threshold, which could be automated by reducing the enhancement threshold iteratively until there were only two peaks in the histogram, corresponding to the arterial and venous contrast arrival time, respectively. Considering the large variation in contrast arrival times, the whole FOV is divided into multiple regions (typically 16) to generate the region-specific arterial/venous contrast arrival times and contrast dynamics.

RESULTS AND DISCUSSION

Figure 1 shows the automatically generated contrast dynamics in the arterial and venous structures, including the asymmetric venous and background tissue enhancement. Figure 2 shows the coronal and sagittal MIP of the peak venous frame. Quantitative analysis shows a venous/arterial signal ratio enhancement from 1.2 to 4.3 after the arterial signal suppression.

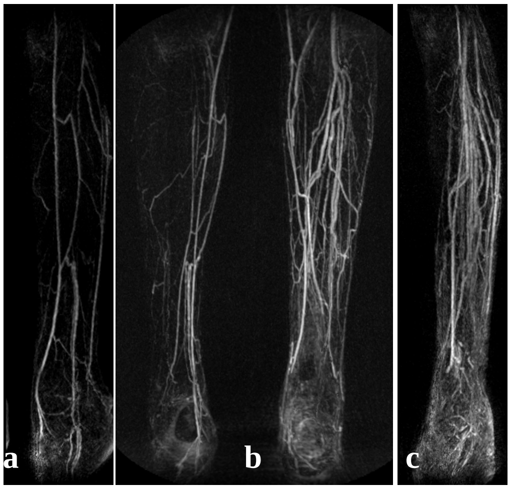

Figure 2 shows the high spatial resolution ($1 \times 1 \times 1.5$ mm^3) peak venous frame in both coronal (b) and sagittal plane (a, c).

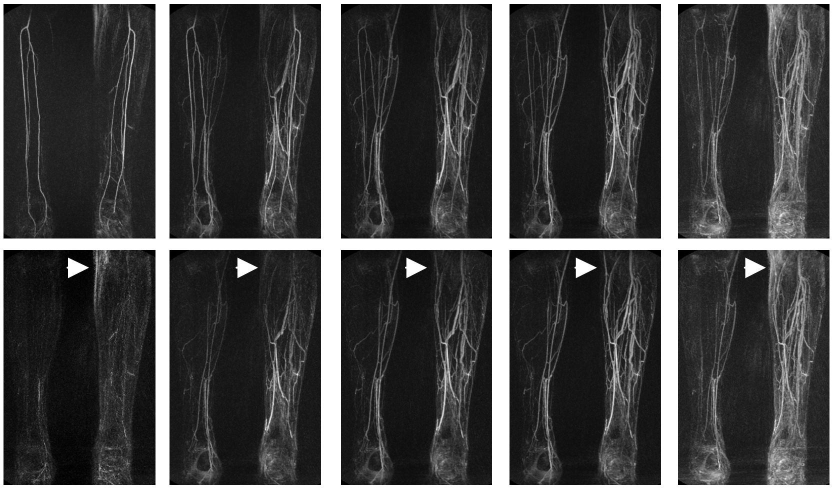

Figure 1 shows the contrast dynamic images of the calf vasculature (upper row) and venous structures only (lower row) with a frame rate of 4.3 seconds. The whole process is fully automated through a region-specific iterative contrast enhancement and contrast arrival time threshold algorithm.

CONCLUSIONS

Time-resolved hybrid undersampled PR acquisition provides high spatial and temporal resolution arteriogram and venogram simultaneously. The region-specific iterative contrast enhancement and contrast arrival time threshold algorithm fully automated the generation of the contrast dynamics for both the arterial and venous structures.

REFERENCES 1. Evans *et al*., JMRI 1996;1:44. 2. Galix *et al*., JMRI 2003; 17:421. 3. Fraser *et al*., Radiology 2003; 226:812. 4. Lebowitz *et al*., AJR 1997; 169:755. 5. Ruehm *et al*., Radiology 2000; 215:421. 6. Du *et al*., MRM 2002; 48:516.