Estimation of Local and Regional Bolus Velocities using Whole Body Functional MR Imaging

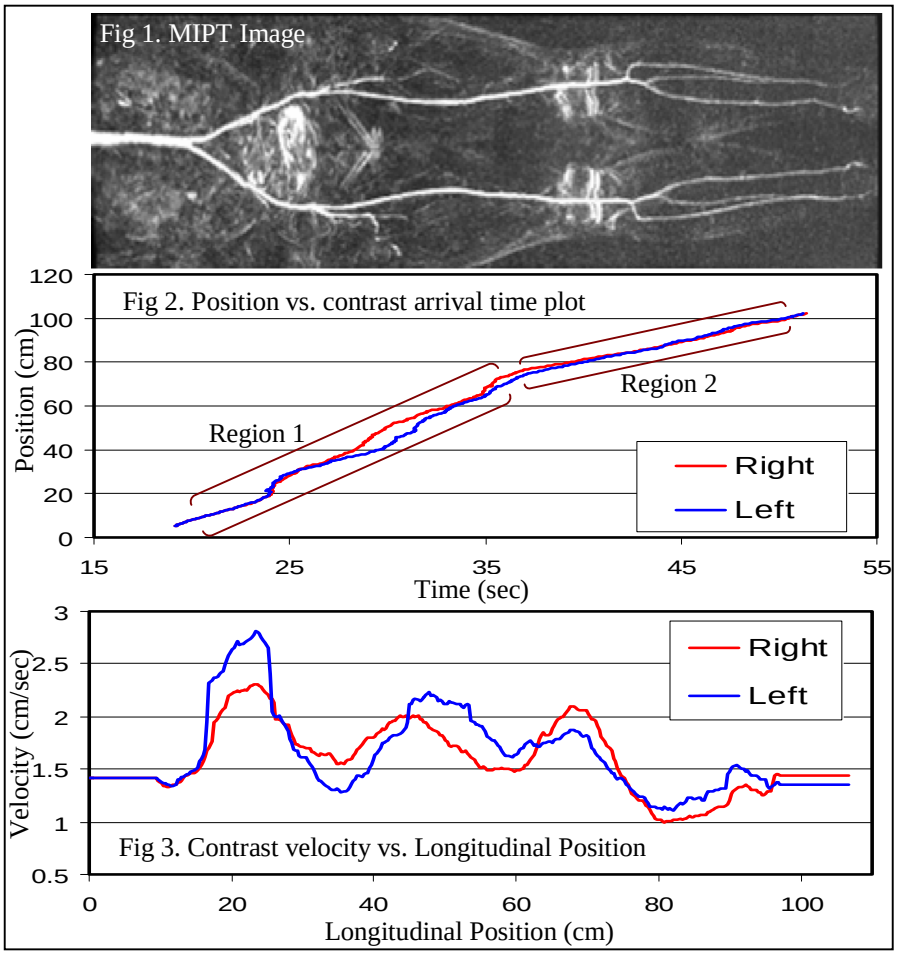
A. J. Madhuranthakam[1], H. H. Hu[1], D. G. Kruger[1], E. A. Rohde[1], J. F. Glockner[2], S. J. Riederer[1]

[1]MR Research Lab, Mayo Clinic College of Medicine, Rochester, MN, United States, [2]Radiology, Mayo Clinic College of Medicine, Rochester, MN, United States

Introduction: Whole-body contrast-enhanced MR angiography (CE-MRA) is widely used in the current clinical practice for evaluating peripheral vascular disease. It is performed either by a multi-station approach (1) or continuously moving table (CMT) techniques (2,3). Typically, these tests are designed to acquire a single high resolution angiographic image. Recently, a 3D time-resolved CMT technique has been demonstrated for CE-MRA in which the leading edge of the bolus can be tracked in real time from the renal artery origins to the feet (4). This acquisition provides data at multiple timepoints for all pixels in the extended FOV. In this current work, we show how this time-resolved data can be used to obtain functional information such as localized bolus velocity on a pixel-by-pixel basis over the entire peripheral vasculature.

Methods: Data acquisition and reconstruction were performed using the time-resolved CMT technique as described in Ref. (4). With this technique a coronal acquisition slab is used, initially at the level of the renal arteries. On injecting the contrast, the 3D time-resolved spoiled gradient echo sequence was initiated without any table motion, and maximum intensity projection (MIP) of the 3D images were generated in real-time. Upon detection of contrast arrival in the abdominal aorta by the operator, the table motion using the time-resolved moving table sequence was triggered. Images were then continuously generated at 2.5 sec intervals. Table motion was stopped at the distal-most position covering the lower legs, but the time-resolved sequence continued to play. After the study, all images were corrected for gradient warping (5) and these were used for the subsequent analysis.

The MIPs of the time-resolved images were then analyzed. Each pixel over the entire FOV is observed in at least five time-resolved images. For each pixel the signal was measured with respect to time, and by setting a minimum threshold value the contrast arrival time was estimated for all points in the peripheral vasculature. Points outside the vasculature did not enhance and were not further considered. Next, an intermediate image was generated in which the pixels in the vasculature were assigned their respective contrast arrival times. This was done separately for the left and right sides distal to the aortic bifurcation. A plot was then generated using these contrast arrival time values on the X-axis and longitudinal position on the Y-axis. A forty-point moving average filter was applied to smooth the curve. The regional slope of this curve gives an absolute measure of regional bolus velocity, while differentiation provides the local bolus velocity for that longitudinal position.



Results: Six normal volunteer studies have been performed using this technique. For each study a maximum intensity projection over time (MIPT) image was generated by taking the maximum contrast signal over all temporally resolved images for each pixel. Figure 1 represents the MIPT image of one volunteer. Figure 2 shows the position versus contrast arrival time of the left and right side of that volunteer. The average slope of the curve from the renal artery origins to the popliteal arteries shown by Region 1 is higher than the average slope from popliteal arteries to the feet shown by Region 2. The average velocities for these regions calculated by linear curve fitting are 3.89 cm/sec and 1.98 cm/sec for the left side and 4.16 cm/sec and 1.79 cm/sec for the right side, respectively. Figure 3 shows the plot of velocity against longitudinal position of the volunteer. This graph represents a wide range of bolus velocity variation but there is a reduction distal to the popliteal arteries (> 70 cm). This extent of reduction in the bolus velocity was consistently observed in all six volunteer studies.

Discussion: We have demonstrated a method to estimate the local bolus velocity for the entire peripheral vasculature and shown how velocity varies with position. The basis of the whole body functional technique is that time-resolved data is available at all points in the extended FOV, and moreover, that the timepoints at which data are collected correspond to the phenomenon of interest. In this case it was critical that a region be imaged during the transit of the leading edge of the contrast bolus. Although data are imaged for only five timepoints for each pixel, having such data for all pixels in the vasculature provides good visualization of the bolus velocity. We believe that this local bolus velocity information, as possibly determined with a test bolus, may be useful to more accurately guide table motion for peripheral CE-MRA. Specifically, reducing the table velocity in the distal vasculature will allow prolonged acquisition time and improved spatial resolution. Future work will account for the slight non-longitudinal orientation of many of the vessels.

References: 1) Meaney JFM, Radiology 211: 59-67 (1999) 2) Kruger DG, Magn Reson Med 47: 224-231 (2002) 3) Fain SB, Proc. 10th Mtg. ISMRM #212 (2002) 4) Madhuranthakam AJ, Proc. 11th Mtg. ISMRM #256 (2003) 5) Polzin JA, Proc. 10th Mtg. ISMRM #380 (2002)