Single-Injection, Semi-Automated Multi-Station Bolus Timing for Optimization of 3D Peripheral MR Angiography

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Introduction:

Contrast media travel times can vary widely between patients with peripheral vascular disease. Typically, automatic or fluoroscopic detection methods are used to monitor contrast arrival at the abdominal station and to initiate a 3D multi-station exam. However, in the absence of timing information on contrast bolus travel to the distal vasculature, multi-station peripheral MRA using fixed imaging times will result in wide variation in resultant arterial signal and potentially significant venous contamination at the lowermost station. Timing bolus scans using two separate injections have been shown to improve reliability of arterial depiction and reduce venous contamination in peripheral MRA [1]. Furthermore, Maki, et al. demonstrated the value of two-station bolus timing with manual table translation and fluoroscopic triggering [2].

Since automatic detection of the contrast arrival at the abdominal station is more reproducible, we demonstrate the feasibility of obtaining multi-station contrast timing information using a single injection of contrast media by using a moving table automatic detection algorithm that is capable of detecting contrast arrival in the abdominal aorta, automatically moving the table to the calf, and initiating a 2D projection angiogram. This provided two station timing information that can then be used to optimize spatial resolution and timing for a multi-station 3D MRA.

Methods:

Eight healthy volunteers (6 male; 2 female; average age = 46 ± 17 years; average wt = 169 ± 12 kg) were enrolled in this IRB-approved protocol. Multi-station bolus timing was performed on eight subjects. In five subjects, multi-station bolus-chase peripheral 3D MRA was performed using a segmented volume two-pass method (shoot and scoot or SNS) [3-5], following the acquisition of the bolus timing data. All experiments were performed on a 1.5T Signa CV/i MR system (GE Medical Systems, Waukesha WI) equipped with high performance gradients (40mT/m max amplitude, 150T/m/sec max slew rate).

For multi-station bolus timing, a fast 2D RF phase spoiled gradient-recalled echo pulse sequence was modified to support automatic bolus detection (MR SmartPrep, GE Medical Systems) and automatic table motion. Complex subtraction, fat suppression, and an inversion-recovery RF pre-pulse were used to minimize signal from the stationary background. Temporal resolution ranged from 0.7sec/image to 2.2 sec/image, depending on the scan parameters. Between 0.025 mmol/kg to 0.05 mmol/kg of Gd-chelate contrast media was administered using an automatic power injector at rates of 2 to 3 mL/sec followed by 25 mL of saline flush at the same rate. Station specific SNS scan parameters (e.g. number of partitions, partition thickness, matrix, k-space fraction during initial pass) for the multi-station peripheral MRA were then adjusted for optimal timing for each station (including infrapopliteal arteries) based on the initial timing data acquired using the multi-station timing bolus exam.

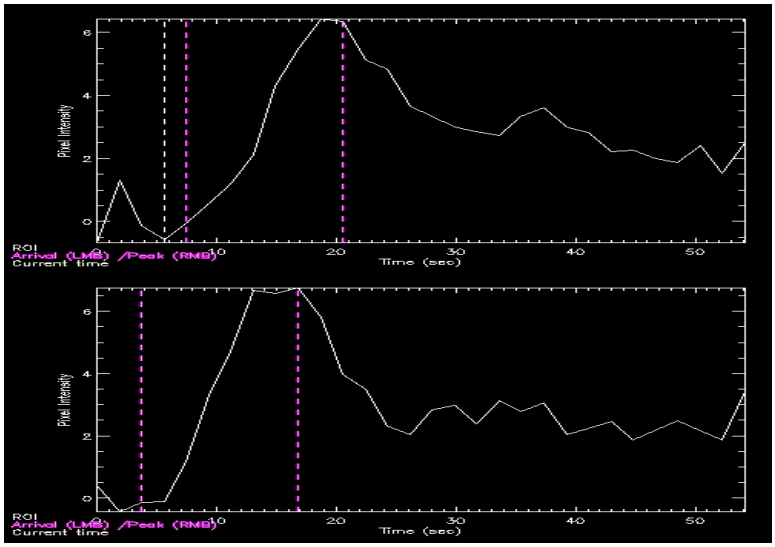
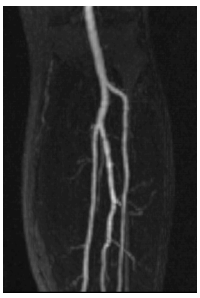


Figure 1: Contrast enhancement data on the right (top) and left (bottom) popliteal artery immediately above the trifurcation (t=0 indicates SmartPrep trigger in the aorta at the renal level)



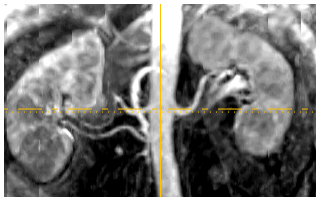


Figure 2: Tibioperoneal and renal arteries imaged with SNS following multi-station bolus timing.

Results and Discussion:

In our subjects, multi-station bolus timing scans revealed a mean travel time of the contrast bolus from the injection site (antecubital vein) to the abdominal aorta at the level of the renal arteries of 15 ± 2 sec; and a mean contrast media travel time from the abdominal aorta to the popliteal trifurcation vessels of 17 ± 5 sec. These bolus travel times in healthy volunteers are consistent with previously reported findings by Prince et al [6]. In all bolus timing scans, table translation and start of the multi-phase 2D acquisition at the distal-most station preceded contrast bolus arrival. Figure 1 shows sample enhancement curves from an ROI placed on the popliteal artery immediately above the trifurcation in the right and left legs of the same subject. Note the bolus arrival times between the right and left side was different by about 3.5 sec. This demonstrated the ability to distinguish different bolus arrival times between the left and right popliteal trifurcation vessels.

Conclusion:

In this pilot study, the additional two-station timing data (using a single small contrast bolus) allowed tailoring of station specific timing, k-space fraction, spatial resolution, and contrast media volume for optimal peripheral MR angiographic imaging, resulting in high quality and high spatial resolution at each station and minimizing venous contamination (Figure 2). Multi-station bolus timing promises to further improve the reliability of 3D bolus chase peripheral MRA studies, especially SNS.

References:

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