Two-Station Time-Resolved 3D Contrast-Enhanced MRA with Real-Time Station Switching

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INTRODUCTION: Bolus-chase MRA techniques have been used to image the extended FOV of the legs with good spatial resolution and low venous contamination (1-4). However, the quality of such bolus-chase arteriograms is generally inferior to that of single-station CE-MRA due to the limited available scan time at each station. Recently, time-resolved imaging techniques accelerated 10x or more using 2D SENSE and homodyne have been used to generate images in the calves with high spatiotemporal resolution and scan times per frame in the range of 5-20 sec (5). The principal purpose of this work was to adapt these acquisitions based on the CAPR technique to obtain comparable quality in multiple stations. Additionally, we developed a system to reconstruct the CAPR images in real time and allow for visually-guided station switching, eliminating the need for a priori estimates of bolus progression. In this work, two-station CE-MRA with high spatiotemporal resolution and interactive station switching is demonstrated for the first time. High-quality arterial updates were consistently acquired in vivo in both stations while avoiding venous contamination.

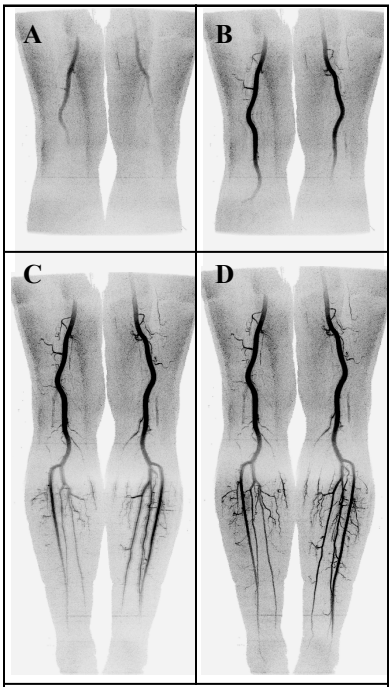

Figure 1: Select extended-FOV MIP time frames acquired at a frame time of 2.5 seconds.

METHODS: ***Extended FOV CAPR:*** An accelerated CAPR acquisition was used to image two stations ("thigh" and "calf") with acquired 1.0 mm isotropic resolution in an FOV encompassing both legs and with an image update time as low as 2.5 sec. An image update time this short in the proximal station was necessary to ensure precise triggering of table motion to avoid venous contamination in the distal station. Two eight-element receive arrays were used, one placed circumferentially around the thighs and the other around the calves (6).
CAPR-Based Real-Time 3D MR Fluoroscopy: A reconstruction cluster (16 processors, 128 GB RAM) was networked to the raw data stream of a 3T MRI system (GE Signa v14x) and to a graphical user interface (GUI). CAPR image updates were reconstructed in real time by the cluster, and coronal maximum intensity projections (MIPs) were displayed on the GUI with < 1.0 sec latency from end of acquisition to display. Station switching was manually triggered once the contrast bolus was observed to have progressed along the full extent of the thigh station. The time for table movement between stations was six seconds.
Two-Station Time-Resolved CE-MRA Studies: All studies were performed under an IRB-approved protocol, and written consent was obtained from all subjects. The thighs and calves of four healthy volunteers (aged 44-65; one male) were imaged on a 3T GE imaging system using a stepping-table approach and a single bolus injection (20 mL Multihance followed by 20 mL flush at 3 mL/sec). Imaging parameters were identical for both stations: coronal 3D GRE, TR/TE = 5.9/2.7 sec, flip angle = 30º, BW = ±62.5 kHz, FOV = 40 (S/I) x 32 (A/P) x 13.2 (R/L) cm^3, and sampling matrix = 400 x 320 x 132, yielding an extended FOV of 70 cm with 1.0 mm^3 resolution. 4x2 SENSE (R/L x A/P) was applied along the phase-encoding dimensions and 2D homodyne provided an additional 1.8x acceleration. All acquired time frames had a 2.5 sec image update time except in one case the distal frames had a 5.0 sec image update time. A calibration scan and subtraction mask were acquired at each station prior to contrast injection.

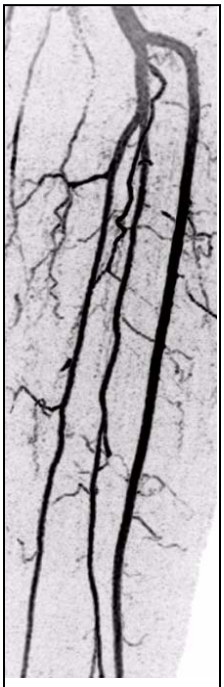

Figure 2: Targeted calf MIP from study of Figure 1.

RESULTS: In all four studies contrast passage was readily seen in the thigh station in real time, and multiple arterial frames in both the thigh and calf stations were acquired prior to venous enhancement. Select time series MIPs from one volunteer are shown in Figure 1. Due to the rapid 2.5 sec image update time and the short temporal footprint, the bolus leading edge was captured in both stations. Figure 2 shows a targeted MIP of the left calf, demonstrating excellent diagnostic quality. The other three studies yielded similar results.

DISCUSSION AND CONCLUSIONS: Real-time station switching combined with accelerated CAPR yielded high-quality diagnostic time frames in both thigh and calf stations while providing sufficient temporal resolution to capture multiple arterial phases in both stations prior to venous enhancement. Rapid reconstruction of CAPR image updates allowed for visually-guided station switching, ensuring consistency in bolus capture that cannot be reliably achieved with a timing bolus or other estimates of contrast progression. It is hypothesized that extension of these methods to three or more stations will further improve both the consistency and diagnostic quality of CE-MRA runoff studies.

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