Three-Station Time-Resolved 3D Bolus Chase MRA with a Single Injection of Contrast Material

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INTRODUCTION: Since the introduction of 3D bolus chase MRA techniques over a decade ago [1,2], a number of technical advancements have been implemented to improve spatial resolution, imaging efficiency, and timing of table motion. These include station-specific imaging parameters [3], parallel imaging acceleration at some stations as high as 4× [4], cuff compression to delay venous enhancement [5], adjustment of scan parameters based on patient-specific hemodynamics [6], and dual-injection hybrid techniques to acquire a separate time-resolved acquisition at the distal-most station to better avoid venous contamination [7]. In this work we further advance 3D bolus chase MRA by imaging the arterial phase with both high spatial and temporal resolution over all stations of a 122 cm FOV using a single injection of contrast material. This is accomplished using 8× 2D SENSE and 1.8-1.9× 2D partial Fourier (net 14.4-15.2×) acceleration at three imaging stations in conjunction with the CAPR view-shared time-resolved imaging strategy [8]. Additionally, real-time reconstruction of 2.5 sec 3D time frames at the two proximal stations allows fluoroscopic tracking [9] of the contrast bolus progression for visually-guided triggering of table advance. The technique is demonstrated with in vivo pelvis-to-foot MRA studies of five healthy volunteers.

METHODS: Subjects were recruited to participate in an institutionally-approved IRB study, and all provided written informed consent. Imaging was performed on a 3T GE Discovery MR750 system using a fast 3D GRE sequence. The three-station imaging protocol consisted of the following components (~15 min total): (i) scout images; (ii) calibration images; (iii) real-time system initialization; (iv) mask images; (v) contrast injection; and (vi) time-resolved 3D CE-MRA with fluoroscopic tracking. Each station was imaged in coronal format with unique imaging parameters and receiver settings. A custom-built modular 32-channel receiver coil array with 40-cm-long elements was used with 12-14, 10, and 8 coils at the abdomen-pelvis (I), thigh (II), and calf-foot (III) stations, respectively, and wrapped circumferentially about the subject. 4×2 (L/R × A/P) 2D SENSE was applied at each station. 3D angiograms at stations I, II, and III were acquired with 1.5, 1.5, and 1.0 mm isotropic spatial resolution, 2.5, 2.5, and 5.2 sec frame times, and 6.8, 6.6, and 18.5 sec temporal footprints using N3, N3, and N4 CAPR. FOVs were 42×42×14.4, 42×42×13.2, and 42×32×13.2 cm3 and TR/TEs were 4.7/2.0, 4.7/2.0, and 6.0/2.8 ms. Flip angle and bandwidth were 30º and ±62.5 kHz at each station. 20 mL MultiHance followed by 20 mL saline flush was administered at 3 mL/sec using a power injector. The 3D angiogram for each time frame was reconstructed in real-time in <120 ms, and MIPs were displayed on the scanner console to allow visual tracking of contrast bolus progression. At stations I and II, the operator triggered the table to move 40 cm in 5 sec to the subsequent station once the bolus traversed the FOV.

RESULTS: Figure 1 shows results of an 81-year-old male volunteer study. Arterial frames without degrading venous enhancement were acquired at all three stations and imaging extended from the aortic bifurcation to the feet. The high spatial resolution of these angiograms is evident by the sharp appearance of small vessels and low-grade stenoses as seen in the targeted reformats (c-g). The other four studies had similar image quality, and venous contamination was routinely avoided.

DISCUSSION: Three-station 3D bolus chase MRA with fluoroscopic tracking has been demonstrated for high spatiotemporal imaging of the peripheral vasculature. The spatial resolution of the technique is competitive with prior methods, and the addition of temporal resolution improves the flexibility of the technique, enables assessment of filling dynamics, and better protects against venous contamination. The ability to perform accurate and patient-specific real-time tracking of the contrast bolus and triggering of table advance eliminates need for a timing bolus or other means of estimating the bolus travel. This in turn allows efficient imaging of the contrast bolus and may lead to reduced doses. Finally, compared to other bolus chase techniques, the exam protocol is relatively simple and short, which will make it attractive for the clinical setting.


![Figure 1: Extended FOV and targeted MIPs of an 81-year-old male volunteer study. Coronal (a) and sagittal (left leg) (b) long FOV MIPs were created by combining the final time frames at stations I and II and the second time frame at station III. Targeted MIPs (c-g) are zoom-ins of the boxed regions (interpolated 3x). The final three time frames of the station I targeted MIP region are shown (c-e) with the time post-contrast injection indicated. Triggering of table advance from station I to station II occurred after viewing the image of the full FOV at 35.1 sec. The acquisition of the frame at 37.6 sec was then completed before moving the table. Only two 2.5 sec time frames were acquired at station II before the table was advanced to station III. Venous contamination was successfully avoided throughout the extended FOV while high spatial resolution of the arterial vasculature was provided.](image-url)