Real-time Interactive Imaging Techniques for Visualizing Coronary and Peripheral Arteries and Selective Myocardial Perfusion from Intra-arterial Contrast Injections

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INTRODUCTION

Digital subtraction Angiography (DSA) is a technique successfully used in X-ray angiography to suppress background and enhance visualization of intravascular contrast agent. Executing a similar technique in MRI has been challenging especially in coronary vessels due to cardiac motion and the relatively low spatial and temporal resolution of MRI compared to X-ray. Other investigators have demonstrated saturation prepared thick slab imaging to visualize contrast agent injected directly into a coronary vessel. However, thick imaging slabs do not adequately convey anatomical details, compromising one of the advantages of MRI. We present nongated real-time imaging techniques using multiple thin slices and complex subtraction (RT-MR-DSA) which allow visualization of contrast agent with excellent background suppression both in the intravascular space and during myocardial perfusion without stopping the scanner. Experimental data is shown for intravascular injections into swine LAD and carotid vessels before and after recanalization.

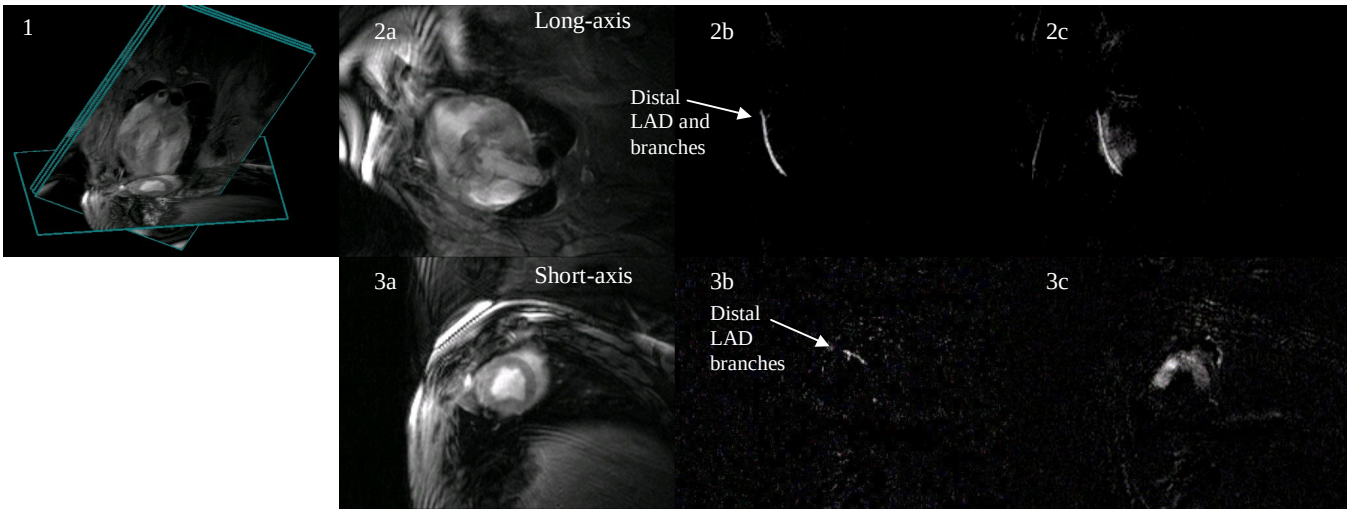
METHODS

The coronary vessel of interest is imaged with 2 or 3 parallel imaging planes, while other imaging planes were placed on ventricular short- or long-axis orientations to view downstream perfusion. With a single key-press, the following steps are taken by the custom reconstruction system: Saturation preparation is optionally enabled to suppress background and temporal filtering is used to suppress noise in the definition of a reference image for each slice. Complex subtraction between the most recently acquired image and the reference is then used for further background suppression. At this point, the maximum signal for each pixel is accumulated in time (a 'timeMIP') continuously. A timeMIP reference is defined after the noise floor is established, and is subtracted from all later timeMIP images, keeping only non-negative values. This provides excellent suppression of background, and allows increased signals to persist as the contrast agent flows through and exits the vessel or perfuses the myocardium fed by the vessel. Once the vessel and perfused regions are visible, another button press restores the imaging modes and starts a movie playback of the injection.

Animal experiments were performed in 3 NIH Minipigs (mean wt approx 40kg). For intracoronary injections, a 2.5mm x 20mm Open Sail coronary angioplasty balloon was delivered into the proximal LAD using a 6F Hockey Stick guide (Cordis), under X-ray guidance. The delivery wire was removed, and the animal was transported into the MR scanner. During RT-MR-DSA imaging, the balloon was inflated with 5mM Gd-DTPA to 4 atm and bolus injections were given via the balloon wire lumen. Each injection was 5cc of 15mM Gd-DTPA lasting approximately 3 seconds. The vessel and perfusion images were observed in real-time in the magnet and control rooms with no post processing. Carotid occlusions were created in 4 Minipigs by transcatehter balloon injury followed by lipid-rich diet for 4-6 weeks. Catheters were placed in the proximal LAD under RT MRI guidance. These occlusions were repaired using a custom active device [P. Karmarkar]. RT-MR-DSA was performed before and after recanalization to assist in planning and to visualize the effects of the treatment. SSFP imaging parameters were TR/TE=3.4/1.7, 8mm slice, 81x192 matrix, view sharing rate 2 or 3, yielding a frame rate of 7 or 10 per second, respectively, divided among the slices. Any slice could be enabled or disabled as needed.

RESULTS

Images from one of the intracoronary injections are shown. A stack of 3 long-axis images containing the LAD were acquired along with a short-axis image were prescribed (Figure 1). After saturation preparation, subtraction and temporal MIP were enabled (2a and 3a), presence of contrast is seen in the LAD and some proximal branches (2b and 3b), then perfusing the myocardium (2c and 3c). The time trajectory of the contrast bolus was appreciated in the continuous imaging. The perfused region appears too large, due to smearing from cardiac motion. Injections during carotid recanalization experiments showed the portion of the vessel proximal to the occlusion before treatment. After successful recanalization, both proximal and distal sections of the vessel were clearly seen.



DISCUSSION and CONCLUSION

We have shown that nongated, free breathing, real-time interactive MR imaging may be used to perform digital subtraction angiography with excellent background suppression in coronary and peripheral vessels, as well as selective myocardial perfusion. Smearing from cardiac motion may be overcome using a synchronized version of this technique, and is not expected to be problematic in peripheral vessels.