Contrast-enhanced SSFP: 2D thick-slice projection MR imaging of the coronary arteries in healthy volunteers

J. D. Green[1], B. E. Schirf[1], R. A. Omary[1], R. M. McCarthy[1], D. Li[1]

[1]Northwestern University, Chicago, Illinois, United States

Introduction: The detection of coronary artery stenosis using MRA requires viewing the coronary artery as a whole; otherwise vessel tortuousity may mimic stenosis. Image evaluation is typically performed by displaying adjacent images in a dynamic mode or by reformatting images using maximum intensity projection or multiplanar reconstruction. Because cardiac chambers produce strong signal adjacent to coronary arteries, these steps may not be easy, even for contrast-enhanced 3D coronary MRA, where myocardium is dramatically suppressed (1). It would be desirable to minimize signal from adjacent cardiac chambers for clear delineation of the entire coronary artery.

During first pass of the contrast agent after a tight bolus injection, there is a few seconds of time delay between the enhancement of the right ventricle and that of the right coronary artery (RCA). Our motivation for this study was to exploit this time delay to acquire contrast-enhanced images of the right coronary artery (RCA) using thick-slice projection imaging. Recently, intravenous (IV) administration of gadolinium (Gd) contrast agent was shown to improve coronary artery depiction using Steady-State Free Precession (SSFP) in first-pass coronary artery imaging with a large contrast bolus (2). We tested the hypothesis that 2D thick-slice projection magnetization prepared SSFP can be used to obtain RCA images following injection of a tight, small IV bolus of Gd contrast agent.

Methods: All experiments were performed in healthy volunteers (n = 5) on a 1.5 T Sonata scanner (Siemens, Erlangen, Germany) and were approved by our Institutional Review Board.

After obtaining pre-contrast localization scans of the RCA, we administered a small dose of contrast agent (4 mL at a rate of 1 mL/s) followed by an injection of saline (20 mL at 1 mL/s). Imaging was performed using thick-slice 2D breath-hold, segmented, ECG-triggered, magnetization prepared SSFP. A sliding window technique was used to reconstruct a new image every heartbeat, with each image consisting of data from three heartbeats. Magnetization preparation consisted of a non-selective 90^o saturation pulse followed by a train of four 180^o inversion pulses played out during the trigger delay period (3). After the train of 180^o pulses and immediately prior to data acquisition, a series of five preparation pulses with linearly increasing flip angle were applied, followed by data acquisition which was centrically-encoded in the phase encode direction.

Typical scan parameters were: TR/TE/flip angle = 3.7 ms/1.6 ms/70^o; FOV = 150 x 300 mm^2; matrix = 104 x 256; 35 lines/segment; slice thickness = 2 cm. Signal-to-noise ratio (SNR), contrast-to-noise ratio (CNR), and vessel length were measured in each data set.

Results: Images of the RCA were successfully obtained in all five volunteers. Because a new image was reconstructed every heartbeat, it was possible to monitor the path of contrast as it sequentially entered the right heart, the pulmonary arteries, the left heart, the aorta, and the RCA (Fig. 1). In all cases, the RCA was well depicted, with at least 5 cm of the vessel visible. The mean visible RCA vessel length was 6.4 cm. Mean SNR ± standard error (SE) was 12.8 ± 1.0. Mean CNR ± SE was 5.8 ± 0.8. Distal branching was not visible on any of the localization scans, but was visible in 3/5 cases (Fig. 2). No post-processing of 2D images was required.

Discussion: Thick-slice projection 2D MRA of the RCA using SSFP is feasible following a short IV injection of Gd. This technique could be employed to provide additional information regarding the status of the RCA without significantly increasing the dose of contrast agent or lengthening MR study time. Further work will be required to extend this method to imaging the left coronary artery because the left ventricle and left coronary artery enhance simultaneously during a tight contrast agent bolus.

References

[1] Li D et al. *Radiology* 2001; 219: 270-277.
[2] Deshpande et al. *Magn Reson Med* 2003; 50: 570-577.
[3] Mani S et al. *Magn Reson Med* 1997; 37: 898-905.

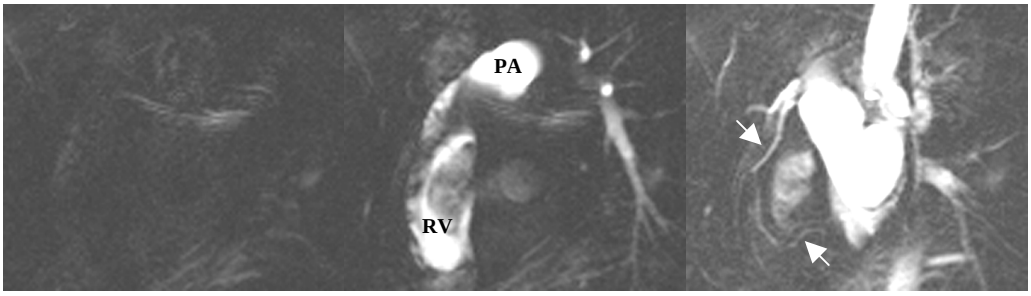

Figure 1: Vessel enhancement following tight bolus IV Gd injection, imaged using a thick slice 2D magnetization prepared sequence. **(a)** Before injection, the image is mostly dark. **(b)** Initially, Gd enhances the right ventricle (RV) and pulmonary artery (PA). **(c)** When first-pass Gd reaches the aorta, it has exited the right side of the heart, allowing clear depiction of the RCA (arrows).

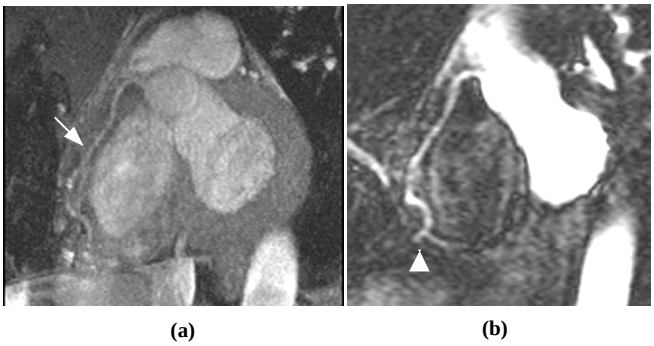

Figure 2: (a) Multi-image projection (MIP) of pre-contrast RCA localizer (arrow). **(b**) Thick slice projection of RCA following injection of contrast agent. Note the distal branching which is visible on the 2D image (arrowhead) but not in the 3D localizer MIP.