Three-dimensional MR projection imaging of the coronary arteries following catheter-directed injection of contrast agent

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Introduction: Catheter-directed gadolinium (Gd)-enhanced coronary magnetic resonance angiography (MRA) is feasible in animals using a thick-slice 2D projection (1,2). One of the potential problems with this approach is that incomplete background suppression may lead to poor coronary artery delineation. Decreasing the thickness of the projection can improve background suppression, but will lead to reduction in artery coverage.

3D imaging of coronary arteries following intra-arterial (IA) injection is limited by the longer imaging times associated with a 3D acquisition, during which myocardial perfusion can obscure the vessel of interest. By using a small number of thick partitions in a 3D magnetization prepared SSFP (Steady-State Free Precession) sequence, background suppression can be improved while maintaining high vessel signal, coverage, and a short imaging time. We tested the hypothesis that magnetization prepared thick-partition 3D projection SSFP improves coronary artery depiction compared to 2D imaging following IA injection of contrast media.

Methods: All MR scanning was performed on a 1.5 T Siemens Sonata system (Siemens, Erlangen, Germany). 6-French catheters were introduced into the femoral artery of swine (n = 6) and advanced into the left (n = 4) or right (n = 2) coronary ostium under MR guidance using a 0.030-inch diameter nitinol loopless intravascular coil guidewire (Intercept, Surgi-Vision, Inc, Marietta, GA). MRA with IA administration of Gd (8% diluted by volume) was performed using magnetization prepared SSFP three times per imaging session using: a) 3D projection acquisition (contrast injection duration = 4-6 s; injection rate = 1 mL/s); b) 2D projection acquisition with a reduced imaging time compared to the 3D sequence (injection duration = 2-3 s; injection rate = 1 mL/s); c) 2D acquisition with two signal averages to match imaging time with the 3D sequence (injection parameters the same as the 3D acquisition). In-plane spatial resolution and coverage were identical for all MRA sequences.

All sequences were ECG-triggered to reduce blurring due to cardiac motion. To reduce background signal and increase vessel depiction, a magnetization-preparation scheme was selected which 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 inversion 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 encoding direction. Typical sequence parameters used for all MRA sequences were as follows: TR/TE/flip angle = 3.6 ms/1.7 ms/70^o; FOV = 113 x 400 mm^2; matrix = 98 x 512, 33 lines collected per cardiac cycle. For 3D imaging: number of partitions = 2 interpolated to 4; slab thickness = 4 cm. For 2D imaging: slice thickness = 4 cm.

Contrast-to-noise ratio (CNR) was measured in each image in a proximal and distal segment. We assesed differences in CNR between 2D and 3D imaging using a Wilcoxon signed rank test with $\alpha = 0.05$.

Results: In all cases, the catheter was successfully placed in the targeted coronary artery. Following injection of diluted Gd, the right, the left main, the left anterior descending (LAD), and/or the left circumflex (LCX) coronary arteries became enhanced (Fig. 1). Because the magnetization-preparation scheme provides T1-weighted background suppression, signal from background tissue (i.e. myocardium, fat) was low in all images. Mean CNR ± standard error (SE) using the three different schemes are shown in Table 1. 3D magnetization prepared SSFP improves CNR over 2D imaging with ($p<0.05$) and without ($p<0.05$) signal averaging (Fig. 2).

Table 1: CNR measurements for the three different imaging sequences

Acquisition type	Proximal Segments (CNR ± SE)	Distal Segments (CNR ± SE)
3D	11.1 ± 1.2	4.3 ± 0.4
2D, no averages	5.0 ± 0.7	1.2 ± 0.2
2D, 2 averages	9.4 ± 1.5	2.9 ± 0.4

Discussion: 3D projection SSFP with magnetization preparation improves CNR over 2D imaging. Background suppression of each partition of a 3D slab is easier because less background tissue is present compared to a 2D slice with equal total coverage. However, the increased 3D acquisition time can lead to myocardial perfusion obscuring the artery. The reduction of imaging time with fast imaging techniques (e.g. parallel imaging, sliding window acquisition) may decrease this effect. Magnetization prepared thick-partition 3D imaging may be useful to detect coronary artery disease in an interventional MRI setting.

References

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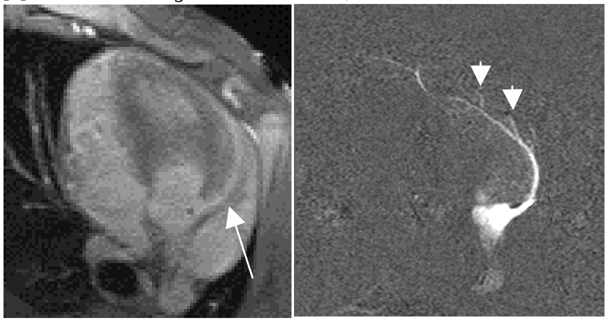
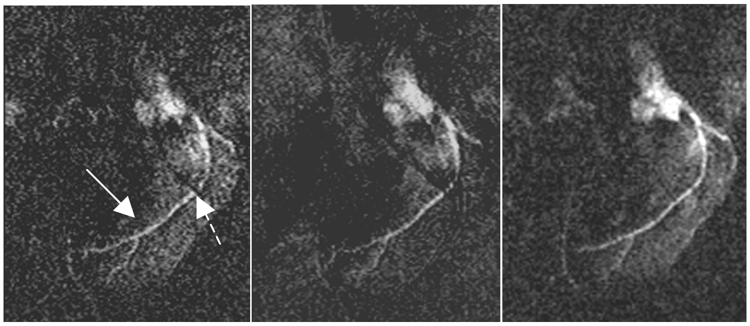


(a) (b)

Figure 1: (a) Pre-contrast localizer of the LAD (arrow) **(b)** Multi-image projection (MIP) of a 3D data set in the same orientation following subtraction of a pre-contrast mask. The LAD and some diagonals (arrowheads) are depicted.



(a) (b) (c)

Figure 2: Comparison of 2D and 3D imaging following IA injection of Gd. All images shown are CE images with subtraction of a pre-contrast mask. **(a)** 2D acquisition acquired in 2 s. Segments of the LAD (solid arrow) are well-depicted, but because of the dominant background signal, a section of the artery is obscured (dashed arrow). **(b)** 2D acquisition using 2-signal averaging. Signal has improved over **(a)**, but improvements in vessel depiction are still limited by high background signal. **(c)** MIP of a 3D data set. The 3D acquisition further improves CNR.