Quantification of Coronary Artery Stenoses using Interventional MRI: Comparison to X-ray Fluoroscopy

J. D. Green[1], R. A. Omary[1], B. E. Schirf[1], R. Tang[1], B. Lu[1], J. A. Gehl[1], J. C. Carr[1], J. J. Huang[1], F. S. Pereles[1], D. Li[1]

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

Introduction: Interventional MRI (iMRI) is an alternative to X-ray fluoroscopy for the detection of coronary artery disease (CAD). In the iMRI setting, catheter-directed coronary magnetic resonance angiography (MRA) has been primarily used for vessel delineation [1] because it uses minimal contrast agent. However, the accuracy of this technique is unknown and imaging time is limited because of rapid perfusion following an intra-coronary injection. An alternative approach to improve accuracy would be to use catheter-directed MRA as a rapid screening method to identify potential stenoses and then obtain MRI cross-sections at these stenoses without additional contrast injections.

Purpose: The purpose of this study was to identify and quantify coronary artery stenoses using a two-step iMRI protocol, consisting of stenosis detection using catheter-directed MRA and stenosis measurement using thin-slice 2D cross-sections. We compared iMRI to X-ray angiography for quantification accuracy.

Methods: We conducted studies in 9 swine. We surgically induced a chronic model of coronary artery stenosis by placing ameroid constrictors around the proximal left circumflex coronary artery (LCX). Three weeks later, animals were transported to the X-ray fluoroscopy suite. A 6-F coronary catheter was used to engage the left main coronary artery for X-ray angiography. The catheter was removed and each pig transferred to a 1.5 T Sonata (Siemens Medical Solutions, Erlangen, Germany).

We advanced a loopless antenna guidewire coil (Intercept, Surgi-Vision, Inc., Gaithersburg, MD) and the same angiographic catheter into the left coronary ostium under MR. We then performed MRA using 3D thick-partition magnetization prepared SSFP with intra-coronary injection of diluted Gadolinium. Once the stenosis was localized, we acquired 2D SSFP images at the stenosis and proximal to the stenosis without contrast injection.

Typical sequence parameters for MRA: TR/TE/flip angle = 3.8 ms/1.5 ms/70^o, 2 partitions interpolated to 4, slab thickness = 4 cm, resolution = 1.1 x 0.8 mm^2; for cross-section imaging: TR/TE/flip angle = 3.8 ms/1.7 ms/65^o, slice thickness = 2 mm, resolution = 0.8 x 0.8 mm^2, 4 signal averages.

We calculated percent stenosis for each of the three data sets (X-ray angiography, catheter-directed MRA, cross-sectional MRI) using a full width at half maximum (FWHM) criteria. MRA data sets were used to screen subjects for the presence of CAD. At all sites that MRA detected a stenosis of $\geq$30 %, we performed subsequent cross-sectional MRI. 30 % was chosen because it was assumed that the error for MRA is at least as great as the error for x-ray angiography (up to 20 %, [2]) and a 50 % stenosis is considered clinically significant. To compare the ability of X-ray fluoroscopy and cross-sectional MRI to quantify CAD, we measured agreement between percent stenosis values using the intra-class correlation coefficient (ICC). Alpha was set to 0.05.

Results: X-ray angiography was successfully performed in 9/9 pigs. Under MR, the coronary ostium was successfully engaged in 8/9 pigs. 3D catheter-directed MRA was performed in the 8 animals where catheterization was successful. A percent stenosis of $\geq$30 % was detected in 8/8 pigs. This data set was then used to plan MR cross-sections of the LCX (Fig. 1). In the one animal where the coronary ostium was not engaged, the pre-contrast LCX localizer was used to plan the proximal and stenosis cross-sections. Cross-sectional MRI was compared to X-ray fluoroscopy in all surgically prepared animals (Fig. 2). The ICC was 0.955 ($p<0.05$).

Conclusion: The combination of catheter-directed MRA and cross-sectional MRI successfully identifies and quantifies coronary artery stenoses in swine. This two-step iMRI approach may be useful for future MRI-guided coronary interventions.

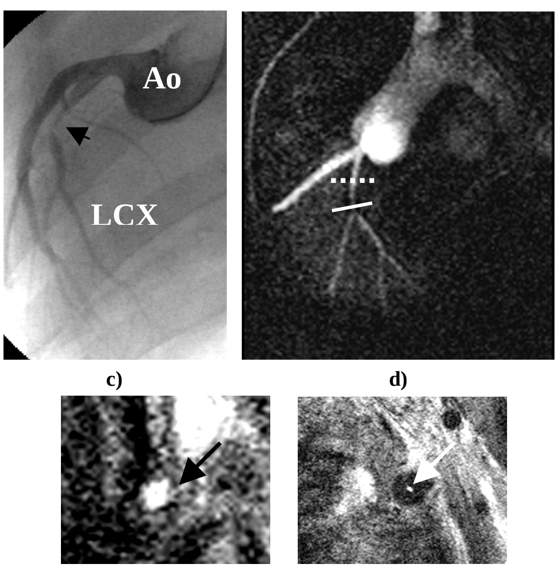

Figure 1. Coronary angiograms with corresponding MRI cross-sections. **a)** X-ray angiography. Stenosis is present in the proximal LCX (arrowhead). **b)** MIP of a 3D catheter-directed MRA, used to plan cross sections proximal to the stenosis (dashed line, **c)**) and at the stenosis (solid line, **d)**).

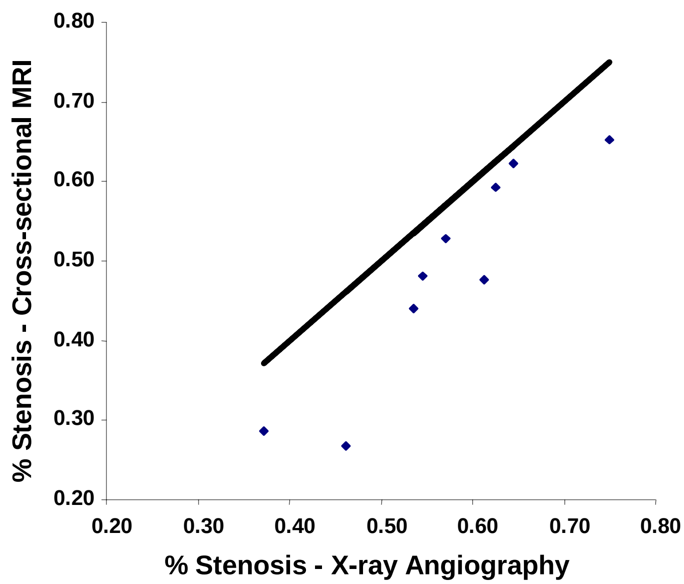

Figure 2. Percent stenosis measured using cross-sectional MRI vs. X-ray. Dark line represents line of identity. Correlation between the two methods was outstanding, with ICC = 0.955 ($p<0.05$).

References

1. Serfaty J-M et al. *Radiology* 2000; 217: 290-295.
2. Key H et al. *Br J Radiol* 1987; 60: 1083-1088.