CORONARY MRA AT 7T

Matthias Stuber, PhD

There is a strong need for a non-invasive and safe technique for the detection of significant luminal coronary artery disease without ionizing radiation. Therefore, there has been a strong focus on coronary magnetic resonance angiography over the past two decades. While tremendous potential was documented in early studies (1, 2), progress has been steady but relatively slow. In the first multicenter trial (3), it was documented that coronary MRA can reliably identify significant proximal luminal coronary artery disease while patients without significant stenoses in proximal coronary segments can be ruled out with high confidence. However, the specificity was relatively low with too many false positive readings. Therefore, ensuing technical developments have focused on an increased volumetric coverage (4), on the use of contrast agents (5, 6) and implementations on higher magnetic field strength (7). While most recent multicenter data of 1.5T whole heart coronary MRA are available and show improved sensitivity and specificity in selected patient cohorts (8) (9), an extension of this technique incorporating slow infusion of Gd, 12-channel coil architecture and 3T (7) enabled a higher spatial resolution and has demonstrated excellent results in a single center setting. On this background, and provided that higher magnetic field strengths holds the promise of a higher signal-to-noise ratio (SNR) and a further improved spatial resolution, the implementation of coronary MRA at 7T is highly attractive.

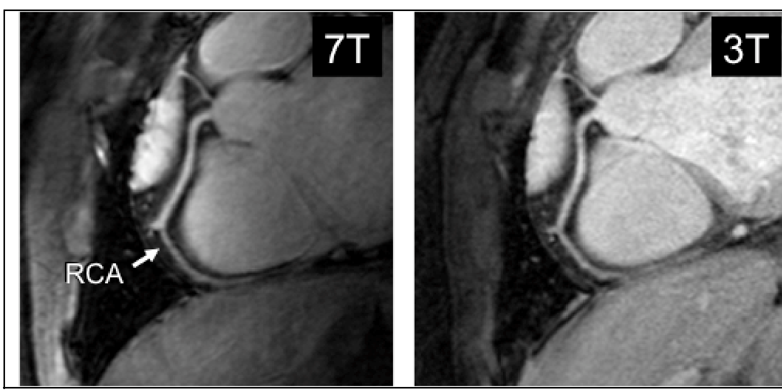

Figure: Coronary MRA of the right coronary artery (RCA) obtained in the same human subject at 7T (left) and 3T (right). A 3D free-breathing navigator gated and corrected fat suppressed segmented k-space gradient echo imaging sequence was used.

7T systems have recently been approved for human use. Among those, only whole body system will be adequate for cardiac imaging in general and coronary MRA more specifically. However, 7T body imaging currently is in its infancy and neither 7T signal receive surface coils nor body transmit antennae are commercially available. Furthermore, specific absorption rate (SAR) constraints pose major challenges for sequence design and significantly limit the choice and parameter settings of coronary MRA pulse sequences. Additional field strength-dependent characteristics that may adversely affect coronary MRA include an increased susceptibility at tissue borders and an amplified magneto-hydro dynamic effect which limits the reliability of R-wave triggering that is essential for cardiac segmented k-space imaging approaches. To address these issues, van Elderen et al. (10) have initially implemented coronary MRA at 7T with a custom-built single-element transmit/receive local surface coil and with vector ECG technology (the use of acoustic triggering devices (11) appears promising but remains to be implemented and tested for coronary MRA). Provided the SAR constraints, a segmented k-space gradient echo sequence with relatively low RF excitation angles was used. Magnetization preparation using an adiabatic T2Prep (12) is not practical due to the SAR limitations but a combination of the imaging sequence with a preceding fat saturation module was still reported. For motion suppression during free breathing, the respiratory navigator approach as commonly used at lower field strengths (1.5T and 3T) had to be modified as well. Since the volumetric coverage of the single-element surface transmit/receive coil was limited to the heart, a navigator placement at the base of the heart (rather than at the lung-liver interface) was used. While this first study showed feasibility it also demonstrated shortcomings: First, the penetration depth of the coil was limited and therefore only the right coronary artery could be visualized. Secondly, contrast enhancement between myocardium and the blood pool using T2Prep was not feasible due to SAR constraints. In direct response to this initial study, a coil array incorporating two larger coil elements was custom built by the same team. 7T Coronary MRA with this improved coil configuration were then directly compared to those obtained at 3T and in the same subjects. When compared to the first report, a much improved image quality could be obtained while the contrast-to-noise ratio between the blood-pool and fat as well as the blood-pool SNR and vessel sharpness were significantly improved at 7T relative to 3T. However, and despite the improved volumetric coverage attributable to the improved coil design, imaging of the left coronary system was still not successful since contrast between the coronary blood-pool and the myocardium could not be enhanced with an adiabatic T2Prep because of SAR constraints. Nevertheless, these early results are very encouraging and the improvements in SNR can now be traded for an improved spatial resolution. To date, only data from healthy adult volunteers have been reported and future research in this particular domain will likely be focused on coil design, SAR management and further improved motion suppression schemes that will support imaging at improved spatial resolution.

1. Manning WJ, Li W, Boyle NG, Edelman RR. Fat-suppressed breath-hold magnetic resonance coronary angiography. *Circulation* 1993; 87(1):94-104.

2. Manning WJ, Li W, Edelman RR. A preliminary report comparing magnetic resonance coronary angiography with conventional angiography. *N Engl J Med* 1993; 328(12):828-832.

3. Kim WY, Danias PG, Stuber M, Flamm SD, Plein S, Nagel E, Langerak SE, Weber OM, Pedersen EM, Schmidt M, Botnar RM, Manning WJ. Coronary magnetic resonance angiography for the detection of coronary stenoses. *N Engl J Med* 2001; 345(26):1863-1869.

4. Weber OM, Martin AJ, Higgins CB. Whole-heart steady-state free precession coronary artery magnetic resonance angiography. *Magn Reson Med* 2003; 50(6):1223-1228.
5. Bi X, Li D. Coronary arteries at 3.0 T: Contrast-enhanced magnetization-prepared three-dimensional breathhold MR angiography. *J Magn Reson Imaging* 2005; 21(2):133-139.
6. Liu X, Bi X, Huang J, Jerecic R, Carr J, Li D. Contrast-enhanced whole-heart coronary magnetic resonance angiography at 3.0 T: comparison with steady-state free precession technique at 1.5 T. *Invest Radiol* 2008; 43(9):663-668.
7. Yang Q, Li K, Liu X, Bi X, Liu Z, An J, Zhang A, Jerecic R, Li D. Contrast-enhanced whole-heart coronary magnetic resonance angiography at 3.0-T: a comparative study with X-ray angiography in a single center. *J Am Coll Cardiol* 2009; 54(1):69-76.
8. Kato S, Kitagawa K, Ishida N, Ishida M, Nagata M, Ichikawa Y, Katahira K, Matsumoto Y, Seo K, Ochiai R, Kobayashi Y, Sakuma H. Assessment of coronary artery disease using magnetic resonance coronary angiography: a national multicenter trial. *J Am Coll Cardiol* 2010; 56(12):983-991.
9. Nagel E. Magnetic resonance coronary angiography: the condemned live longer. *J Am Coll Cardiol*; 56(12):992-994.
10. van Elderen SG, Versluis MJ, Webb AG, Westenberg JJ, Doornbos J, Smith NB, de Roos A, Stuber M. Initial results on in vivo human coronary MR angiography at 7 T. *Magn Reson Med* 2009; 62(6):1379-1384.
11. Frauenrath T, Hezel F, Renz W, de Geyer TdO, Dieringer M, Knobelsdorff-Brenkenhoff FV, Prothmann M, Schulz-Menger J, Niendorf T. Acoustic cardiac triggering: a practical solution for synchronization and gating of cardiovascular magnetic resonance at 7 Tesla. *J Cardiovasc Magn Reson* 2010; 12(1):67.
12. Nezafat R, Stuber M, Ouwerkerk R, Gharib AM, Desai M, Pettigrew RI. B1 insensitive T2 preparation for improved coronary magnetic resonance angiography at 3T. *Magn Reson Med* 2006; In Press.