A first report on self-navigated 3D isotropic whole heart MRI for the visualization of coronary artery bypass grafts.

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Target Audience: Basic researchers interested in cardiovascular and coronary imaging, cardiac surgeons, MR technicians

Introduction: Coronary artery bypass graft (CABG) surgery is commonly used for the treatment of multi-vessel coronary artery disease. However, CABG occlusions are often reported [1]. In this context, a non-invasive imaging technology that operates without ionizing radiation may be highly valuable to support decision-making in CABG patients. Early studies have reported on the use of free-breathing navigator-gated 3D targeted coronary magnetic resonance angiography (CMRA) to visualize limited segments of the CABG [2,3]. However, with recent hardware and software advances, whole-heart imaging and larger coverage of CABG became feasible [4]. Nevertheless, navigator-gated approaches suffer from a limited ease-of-use and anisotropic spatial resolution, while scanning time still depends on the efficiency of the navigator. To address these shortcomings, the use of self-navigated (SN) whole-heart techniques [5] has been proposed. Combined with 3D radial imaging, the SN approach enables the acquisition of a large 3D FOV with isotropic spatial resolution, while fold-over is no longer a concern because of intrinsic oversampling. Navigator localization is no longer needed, and 100% scan efficiency is achieved, thus leading to shorter and predictable scanning times. For these reasons, we evaluated SN whole-heart imaging for the in vivo visualization of the complex geometry of CABG, to our best knowledge for the first time.

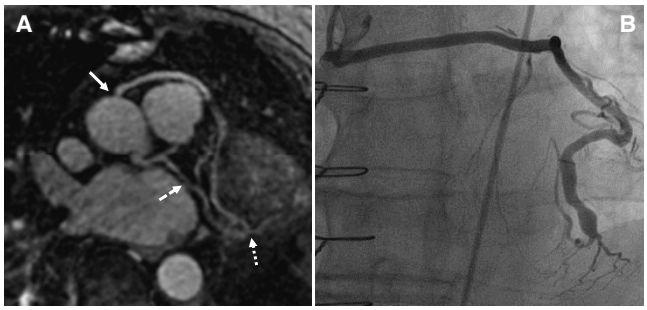

Figure 1: 2D reformat (A) of the vein bypass graft to the LCX of patient 2 from the proximal anastomosis on the aorta (solid arrow) and the distal anastomosis on the coronary (dotted arrow). The occlusion of the LCX (dashed arrow)is also clearly visible. The X-ray angiography of the same bypass is reported for comparison (B).

Methods: Free breathing SN whole heart CMRA was performed in 3 CABG patients on a 1.5T clinical system (Aera, Siemens, Healthcare Sector, Erlangen, Germany), equipped with a 30-element receive coil. For the first two patients, acquisitions were performed during clinical routine scans, where contrast agent had been previously administered, while the dataset of the third patient was acquired without use of contrast agent. Data acquisition was performed with an ECG-triggered 3D radial bSSFP sequence that uses a previously described spiral phyllotaxis readout pattern [6] adapted for self-navigation, as described in [7]. T_2-preparation and fat saturation pulses were added prior to the acquisition of each k-space segment. Acquisition parameters: TR/TE=3.1/1.56ms, FoV=$(220mm)^3$, acquired voxel size=$(1.15mm)^3$, matrix size=192^3, excitation angle=115°. A total of ~12000 radial readouts were acquired either in 377 or 610 heartbeats (hb), depending on the heart rate of the subject. For the offline visualization of the CABGs, the 3D volumes were multiplanar reformatted using the Soapbubble tool [8]. The MR images were compared with X-ray angiographies of the CABG, when available. The first patient had an internal mammary artery (IMA) bypass on the mid left anterior descending (LAD) coronary artery, and a saphenous vein graft on the left coronary circumflex (LCX). The second patient had an IMA graft on the LAD and a venous graft on both the LCX and the posterior descending artery. This latter bypass was occluded on the level of the LCX anastomosis and had been treated with stent implantation. The third patient presented two IMA bypasses: one on the LAD and one on the right coronary artery (RCA), and one venous graft connecting to a marginal branch of the LCX.

Results: The three whole-heart SN acquisitions were all successfully completed. Scan times were 5:40 min (377 hb), 4:59 min (377 hb) and 6:37 min (610 hb). For the first patient the venous CABG on the LCX was very well defined in the MR volume and could be followed for its entire length (Fig.1A, side by side with the corresponding X-ray angiogram), while the IMA graft could not be clearly visualized. The IMA bypass of the second patient could be visualized for the entire length of 10 cm as shown in Fig.2A. However, in this case, only the distal part of the venous CABG was visible. The two IMA bypasses of the third patient could not be visualized while a very clear depiction of the venous graft was obtained (Fig.2B).

Discussion and conclusions: The results of this preliminary study demonstrated that SN whole-heart coronary MRA provides sufficient volumetric coverage and spatial resolution to visualize coronary artery bypass grafts with complex and tortuous anatomy. In these three first patients, 1 out of 4 IMA bypasses and 2 out of 3 venous grafts were successfully visualized. Artifacts from the sternal region, most likely coming from the surgical sternal wires, adversely affect the visualization of the CABGs, mainly the IMA ones. Moreover, the fact that only the distal part of the venous bypass of patient 2 was visualized is consistent with the presence of a stent in the more proximal part of this bypass as reported in the medical records. Based on these preliminary results, we can hypothesize that venous bypass grafts may be more easily visualized than internal mammary artery bypass grafts as sternal wires and stents lead to unwanted artifacts that degrade the relevant information. The high and isotropic resolution of the images could potentially enable the visualization of stenotic occlusions within the grafts. Even though respiratory motion correction is performed on the motion of the blood pool, the large FOV of the sequence allows for a good visualization of the grafts even in the distal portions with respect to the heart (Fig.2A). The effects of the motion correction on the surrounding regions still need to be investigated. Venous grafts are more easily assessed while sternal wires and stents are clear limitations. However, these preliminary results suggest that 3D radial SN whole heart CMRA is now ready to be applied in a larger patient cohort where it can be exploited to guide MR CABG flow measurements for graft patency assessment.

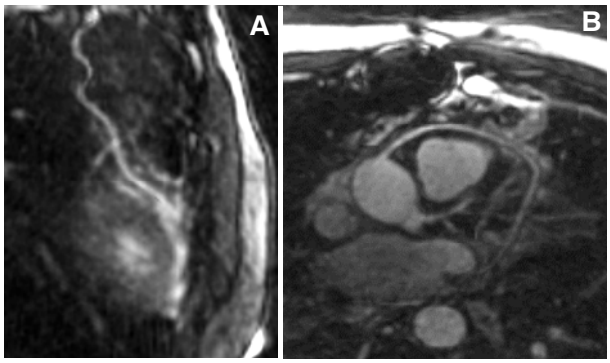

Figure 2: 2D reformat of the bypass grafts: IMA on the LAD of patient 2 (A); venous graft on LCX of patient 3, acquired without use of contrast agent (B).

References: **1.**Fitzgibbon et al. JACC 1996;28:616–26; **2.**Langerak et al. Circ 2003,107:1502-1508; **3.**Salm et al. JCMR 2005,7, 631–637; **4.**Hoppe et al. Interact Cardiovasc Thorac Surg. 2011,12,582-585; **5.**Stehning et al. MRM. 2005 54(2):476-80; **6.**Piccini et al. MRM 2011, 66(4):1049-56; **7.**Piccini et al. MRM 2012, 68(2) :571-9; **8.**Etienne A. et al, MRM 2002, 48(4):658-66.