Self-navigated 100µs echo time 3D radial whole-heart coronary magnetic resonance angiography: a feasibility study.

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Target Audience: Basic and translational researchers interested in cardiovascular and coronary imaging.

Purpose: Ultrashort echo time (UTE) magnetic resonance imaging (MRI) allows identification of plaque calcification in carotid arteries [1] and also has been shown to be a robust tool for plaque calcification detection in ex-vivo for coronary arteries [2]. Moreover, UTE imaging provides robustness against magnetic field susceptibility and helps minimizing both motion and flow artifacts [3,4]. These characteristics make UTE a very appealing technique for coronary magnetic resonance angiography. Furthermore, in recent years, respiratory self-navigation has been demonstrated to significantly improve the ease of use and time efficiency of whole-heart coronary magnetic resonance angiography [5,6]. The goal of this study was therefore to integrate the advantages of the UTE acquisition with the efficiency of self-navigated 3D radial whole-heart imaging for in vivo coronary visualization and to test its feasibility in a group of healthy adult volunteers.

Methods: The acquisition protocol was approved by the local ethics committee and (n=4) healthy adult volunteers provided written informed consent. Data were acquired on a 1.5 T clinical scanner (MAGNETOM Aera, Siemens Healthcare, Erlangen, Germany) with a 18 channels body and 12 channels spine array coil for signal reception. A free-breathing whole-heart UTE sequence with a center-out k-space readout and golden-angle based 3D radial phyllotaxis [7] trajectory was implemented. ECG signal was used to trigger data acquisition to the diastolic cardiac resting period. Sequence parameters included: TR/TE=3.04/0.1ms, FOV=$(250mm)^3$, voxel size=$(1.3mm)^3$, matrix size=192^3, radiofrequency excitation angle=11°, heart beats (data segments)=890, lines per heart beat=22, total acquired radial lines=19580. Each data segment was preceded by CHESS fat saturation. The acquisition protocol was repeated twice for each subject. The first time no magnetization preparation pulse (except for fat saturation) was performed. The second time a T_2 preparation (T_2-prep) of 30ms preceded each data segment, to increase the contrast between the coronary arteries and the myocardium, as it is performed in standard gradient echo coronary imaging [8]. The interleaved golden-angle spiral phyllotaxis acquisition allows arbitrary extraction of subsets of data in k-space. This keeps an overall high pseudo-uniformity in the spatial distribution of the radial k-space signal readouts, thus limiting undersampling artifacts. To compensate for respiratory motion, an algorithm that extracts the respiratory signal from the center of k-space, and which includes sub-image co-registration was implemented [9]. In brief this algorithm works as follows: the k-space center amplitude is extracted from the first line of each data segment and for all channels. From such recordings, a component related to respiration is extracted via independent component analysis (ICA) [10] and directly used to bin data in 11-14 sub-images from different respiratory phases. For motion detection, each sub-image is registered to a previously selected reference sub-image with 3D rigid transformation. From this registration, the superior-inferior respiratory displacement of the heart is extracted and is used to correct for motion directly in k-space [5]. After the reconstruction of the two datasets (without and with T_2-prep), multiplanar reformatting was performed to visualize the coronary arteries.

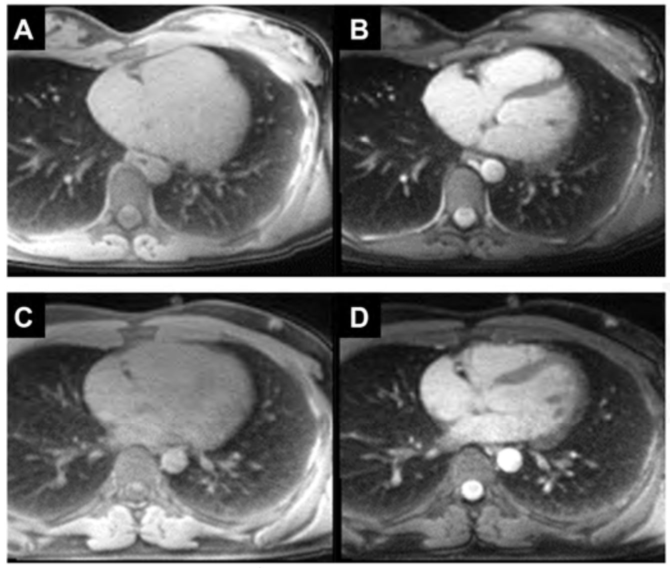

Figure 1: Transversal view from volunteer 1 (A,B) and volunteer 2 (C,D) from the UTE acquisition without (A, C) and with (B,D) T_2 preparation.

Results and Discussion: The self-navigated 3D radial ECG-triggered, whole-heart UTE acquisition was successfully performed in all volunteers (Figure 1). The preliminary results shows that coronary visualization is indeed feasible, as can be observed from the multiplanar reformats in Figure 2. As expected, the use of T_2-prep (Figure 2 B,D) increases the contrast between the coronary vessel and the surrounding tissue, compared to the non-T_2-prep acquisition (Figure 2 A,C), thus improving the vessel depiction.

Conclusions: A self-navigated 3D radial, ECG-triggered, whole-heart imaging sequence was adapted to perform ultrashort echo time acquisitions. Preliminary results in healthy volunteers show the feasibility of applying this method for the visualization of the coronary arteries in vivo. This technique may support the visualization of coronary artery plaques with magnetic resonance angiography. From this study we also observed that T_2 preparation increase coronary conspicuity, but the extent to which the T_2-prep affects the potential visualization of calcifications still remains to be investigated.

***References:* *1.* *Chan et al. JCMR 2010, 12:17;* *2.* *Károlyi et al. JACC Cardiovascular Imaging 2012, 6(4):466;* *3.* *Hoerr et al. JCMR 2013, 15:59;* *4.* *Nielsen et al. MRM 1999, 41:591;* *5.* *Stehning et al. MRM.2005,54(2):476;* *6.* *Piccini et al. Radiology 2014, 270(2):378;* *7.* *Piccini et al. MRM 2011, 66(4):1049;* *8* *Botnar et al. Circulation 1999, 99:3139;* *10*. *Hyvärinen, IEEE Transaction on Neural Networks 10(3):626;* *9.* *Bonanno et.al ISMRM 2014, abs# 0936.*

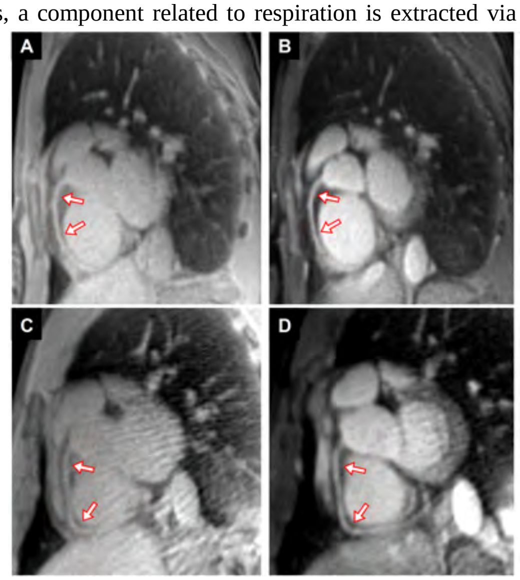

Figure 2: Multiplanar reformat of the right coronary artery from two volunteers (top and bottom rows) with the UTE acquisition without (A,C) and with (B,D) T_2 preparation.