Navigator-Gated Whole Heart Coronary MRI: Comparison of 3D TrueFisp Cartesian and Radial Acquisitions

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Introduction

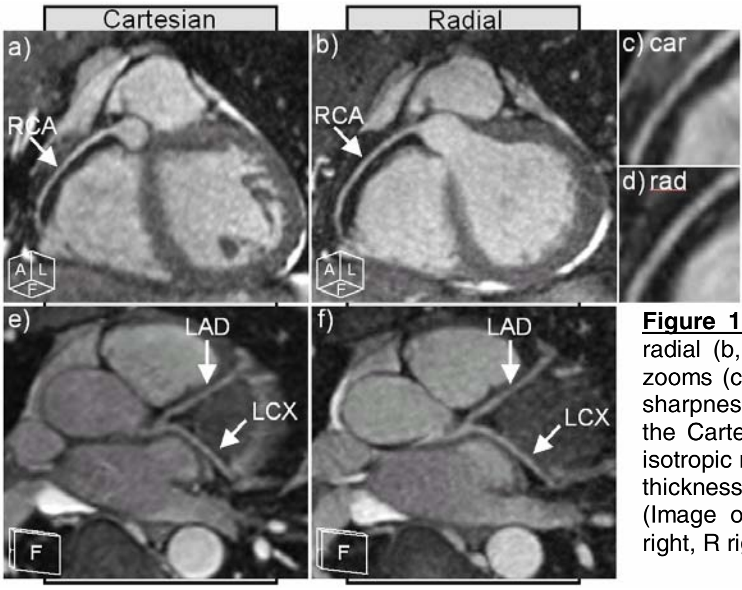
Coronary MRA provides a non-invasive approach for the detection of coronary artery disease. Previous works have shown that whole heart 3D techniques simplify the scanning procedure with no compromise in image quality [1-3]. Compared to Cartesian acquisitions, radial acquisitions are less sensitive to motion [1] and allow for smaller FOVs and undersampling, which do not result in ghosting, but lead to streaking artefacts and decreased SNR [1-3]. Therefore, radial sampling is potentially useful for coronary MRA. In this work a navigator-gated isotropic 3D radial TrueFISP sequence was compared to a standard Cartesian technique for coronary MRA in terms of SNR, CNR and vessel sharpness.

Materials and Methods

The sequences and reconstruction algorithms were implemented on a clinical scanner (1.5 T, MAGNETOM Avanto, Siemens AG Medical Solutions, Erlangen, Germany) equipped with a cardiac 12-element matrix coil. 3D radial sampling was achieved by rotating the scan plane orientation of the Cartesian TrueFISP Kernel for each projection, following a spiral path on the surface of a sphere from the pole to the equator. A gradient delay correction and a correction for the timing shift between data acquisition and reference signal were implemented as described in [4]. To achieve instantaneous reconstruction of the radially acquired data sets, an online reconstruction program consisting of a Kaiser-Bessel gridding algorithm (window width = 3 and $\beta = 4.2054$) was implemented in the standard image reconstruction environment of the scanner. Sampling density precompensation was achieved with a rho filter modified to plateau toward the outer part of k-space to correct for undersampling. An isotropic data set was obtained after 3D FFT. The following sequence parameters were used: TR/TE = 3.3/1.8 ms, $\alpha = 90°$ and BW = 830 Hz/pixel. Fat saturation and T_2 preparation pulses were included to improve image contrast [5]. The average acquisition time T_{acq} = 10-13 min with 33 lines per cardiac cycle and voxel size = $(1.1\ mm)^3$ were achieved by acquiring 64 slices (interpolated to 128) × 192 lines × 192 samples/line (FOV = 220 mm) for Cartesian sampling and 16384 projections × 128 samples/projection (FOV = 146 mm) for radial sampling. The spatial resolution was $1.1 \times 1.1 \times 1.1\ mm^3$ for radial sampling and $1.1 \times 1.1 \times 2.2\ mm^3$ (interpolated to $1.1 \times 1.1 \times 1.1\ mm^3$) for Cartesian sampling. Four healthy volunteers were examined and the resulting images were evaluated in terms of SNR, CNR and vessel sharpness of the coronary arteries as described in [6].

Results

Figure 1 shows reformatted views of 3D volume data sets of the heart of a healthy volunteer by Cartesian and radial sampling, which depict the right coronary artery (RCA) (Fig.1a, b) with respective zooms (Fig.1c, d), left anterior descending (LAD) and left circumflex (LCX) coronary arteries (Fig.1e, f). Table 1 shows the comparison between Cartesian and radial techniques in terms of SNR, CNR and vessel sharpness. Although the Cartesian images (Fig.1a, c, e) show slightly improved SNR and CNR, the radial images (Fig.1b, d, f) show superior sharpness. These results can be explained by the fact that while the radial data has true isotropic resolution of 1.1 mm^3, the Cartesian data has 2.2 mm slice thickness interpolated to 1.1 mm. The thicker measured slice (2.2 mm) of the Cartesian data leads to higher SNR and CNR but lower vessel sharpness than the radial data.



Mean±SD	Cartesian	Radial
SNR	17.0 ± 3.0	14.0 ± 2.0
CNR	7.5 ± 1.2	6.8 ± 1.3
Sharpness	0.27 ± 0.05	0.35 ± 0.12

Table 1. Comparison of Cartesian and radial images in terms of SNR, CNR and sharpness of the coronary arteries.

Figure 1. Selected views reformatted from Cartesian (a, c, e) and radial (b, d, f) volumetric 3D data sets. RCA (a, b) with respective zooms (c, d) and LAD and LCX (e, f) are depicted. The RCA vessel sharpness of the radial method (b, d) is clearly improved over that of the Cartesian method (a, c) because the radial data set has a true isotropic resolution of $(1.1\ mm)^3$ and the Cartesian data set has a slice thickness of 2.2 mm.
(Image orientation: A anterior-posterior, P posterior-anterior, L left-right, R right-left, H head-feet and F feet-head views).

Discussion

Free-breathing navigator-gated 3D images of the whole heart with an isotropic resolution of $(1.1\ mm)^3$ have been acquired with radial sampling on a clinical scanner with a total scan time of about 10-13 min. Although Cartesian images have higher SNR because of the thicker slice, radial images have better spatial resolution and greater vessel sharpness, which can potentially improve the detection of coronary artery disease. Isotropic resolution with radial sampling is particularly important for image reformatting to view images from different angles because coronary arteries are highly tortuous. Both sampling techniques can benefit from parallel acquisition for reduced imaging time, radial techniques could potentially reduce scan time further via vast undersampling or smaller FOVs at the expense of SNR and streaking artefacts, while Cartesian sampling is limited by ghosting artefacts. A large patient study should be performed in order to quantitatively evaluate their clinical value.

Bibliography **1.**Stehning C. et. al. MRM 52:197-203 (2004) **2.**Stehning C. et. al. MRM 54:476-480 (2005) **3.**Bi X. et. al. MRM 54:470-475 (2005) **4.**Speier P. Trautwein F. ISMRM 13:2295 (2005) **5.**Brittain JH. et. al. MRM 33:689-696 (1995) **6.**Li D. et al. Radiology 219:270-277 (2001)