Preclinical Evaluation of a 3D Technique for Whole-Heart Water-Fat Imaging: Comparison with CT

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Target audience: Scientists and clinicians with an interest in cardiac imaging.

Purpose: Accurate measurement of the aortic root is essential for surgical planning and assessment of aortic abnormalities. Further, high resolution cardiac imaging is important for morphological characterization in a wide variety of applications, including congenital heart disease and evaluation of cardiac masses. A 3D chemical-shift-encoded pulse sequence for water-fat-separated cardiac imaging during free breathing[1] has recently been developed to provide high-resolution end-diastolic fat-suppressed morphological images of the whole heart. This sequence should allow improved delineation of the aortic root. The purpose of this work was to evaluate the accuracy of this MRI technique for morphological measurements, using CT angiography (CTA) as the reference standard.

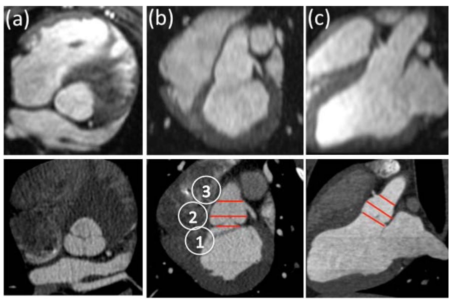

Figure 1: Axial (a), OS (b) and OC (c) LVOT reformats of 3D MR (top row) and CTA datasets (bottom row). Note: 1. annulus; 2. Max. diameter across sinuses; 3. ST junction.

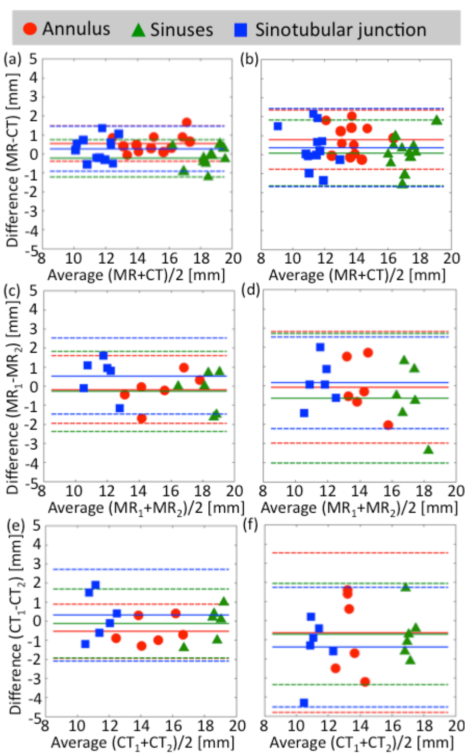

Figure 2: Bland-Altman plots for accuracy (a,b) and repeatability (c-f) of MR with respect to CTA using OS (a,c,e) and OC (b,d,f) LVOT reformats.

Methods: In this work we performed aortic root measurements at three different locations (aortic annulus, maximum diameter across the sinuses and sinotubular (ST) junction) from oblique-sagittal (OS) and oblique-coronal (OC) LVOT (left ventricular outflow tract) reformats. Accuracy with respect to cardiac CTA and repeatability of MR relative to CTA were evaluated in 6 dogs.

Animals: Six healthy dogs (beagles, mean weight = 11.1kg) were scanned twice, on two separate occasions (2-3 days apart) after obtaining approval from our Institutional Animal Care and Use Committee (IACUC).

Imaging: On both occasions each dog underwent an MRI (3T GE MR750, Waukesha, WI) and a low-dose CT exam (GE CT750HD, Waukesha, WI). The MRI protocol included a 3D RF-spoiled gradient echo pulse sequence with chemical-shift-encoding, navigator gating and ECG gating[1]. A T_2 preparation pulse (effective TE=48ms) was played out every R-R to improve contrast between the blood and the myocardium. Four echoes (TE_1=1.3ms; ΔTE =1ms) were acquired in two interleaves with fly-back gradients. A true spatial resolution of $0.94\times0.94\times2.2mm^3$ interpolated to $0.47\times0.47\times1.1mm^3$ through zero filling was achieved in 179 R-R intervals using an ARC acceleration factor of 4. A segmented acquisition with center-out view ordering within each segment (TR=6.3ms; acquisition window duration ~10% R-R interval) was used. Water-fat separation was performed using complex fitting and a Graph Cut algorithm for field map estimation[2]. MR images were acquired ~10 minutes after injection of 0.1mmol/kg of gadobenate dimeglumine (Multihance).
The CTA exam was based on a clinical cardiac CTA protocol with retrospective cardiac gating (pitch = 0.625:1, slice thickness = 0.625mm, 200mA without dose modulation, 80kV) and images reconstructed through systole and diastole. Images were acquired during a 20ml bolus of iodixanol-300 (Vispaque, GE Healthcare, London, UK) injected at 2ml/s timed to the aortic root using standard fluoro-triggering.

Analysis: The diameter of the aortic annulus, the maximum diameter across the sinuses and the aortic diameter at the level of the ST junction were measured on both MR and CTA images (Fig. 1). All measurements were performed on OS and OC LVOT reformats. Accuracy of the MR measurements with respect to CTA, which served as the reference, was evaluated using the method described by Bland and Altman[3], which accounts for repeated measurements on each subject. Conventional Bland-Altman plots were used to assess repeatability of both MR and CTA.

Results and discussion: The best agreement between MR and CTA was found for measurements performed on OS LVOT reformats (cf. Fig. 2a vs. Fig. 2b). The maximum diameter across the sinuses had the smallest bias (-0.22mm) and the narrowest limits of agreement (LOA) ([-1.21; 0.76]; range=1.97mm). The same measurement performed on OC LVOT reformats had a negligible bias (0.08mm) but larger LOA ([-1.65; 1.82]; range=3.47mm). Similarly, repeatability of both MR and CT was best when OS LVOT reformats were used (cf. Fig. 2c (OS) and 2d (OC) for MR and Fig. 2e (OS) and 2f (OC) for CT). Bias and LOA for repeatability of MR and CTA measurements performed in OS LVOT reformats are reported in Table 1.

Conclusion: Accurate aortic root measurements with similar repeatability to CTA-based measurements are possible using a 3D, free-breathing, chemical-shift-encoded MRI method without the need for ionizing radiation or iodinated contrast agents.

References: [1] Taviani V. et al. ISMRM 2012; p. 1226; [2] Hernando D. et al. MRM 2010; 63:79; [3] Bland J.M. Journal of biopharmaceutical statistics 2007; 17: 571.

	Annulus [mm]	Sinuses [mm]	ST junction [mm]
MR	Bias = -0.18 LOA = [-1.96; 1.59]	Bias = -0.27 LOA = [-2.37; 1.83]	Bias = 0.53 LOA = [-1.47; 2.54]
CT	Bias = -0.53 LOA = [-1.96; 0.89]	Bias = -0.12 LOA = [-1.92; 1.69]	Bias = 0.32 LOA = [-2.09; 2.72]

Table 1: Repeatability of MR and CTA measurements in OS LVOT reformats.