Automated Identification of Minimal Myocardial Motion for Improved Image Quality in Coronary MRA at 3T

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INTRODUCTION

With the advent of 3T systems for cardiovascular use, the enhanced SNR offers promise to further improve spatial resolution in particular for coronary magnetic resonance angiography (MRA). However, to take full advantage of the higher magnetic field strength, residual cardiac motion needs to be further constrained. Therefore, the most accurate identification of the period of minimal myocardial motion is increasingly important. Heart rate dependent formulas and visual inspection on cine images have been used for that purpose but these methods are subjective and prone to errors. We hypothesized that a newly developed computer algorithm, FREEZE, for the automatic identification and prescription of the period of minimal myocardial motion, leads to an improved image quality in coronary MRA.

PURPOSE

The purpose of this study was to test whether the use of an automated software tool (FREEZE) for the identification of the most quiescent period of the cardiac cycle leads to an improved coronary MRA image quality when compared to visual assessment of that rest period.

METHODS

The image based correlation algorithm, FREEZE, was developed to identify the period of minimal myocardial motion (= trigger delay) on multi-heart phase cine images on a frame-by-frame basis. Preliminary phantom studies demonstrated successful results (Ustun et al, SCMR, 2005, Vol. 7:1, 194-95). In the present in-vivo study, 10 healthy adult subjects (9 men, 1 woman; mean age, 25; range, 21-32 years) underwent coronary MRA on a commercial 3T system (Gyroscan Achieva, Philips Medical Systems, Best, The Netherlands; 80mT/m, 200mT/m/ms) using a) a visually determined (on cine images) trigger delay (Tdv) and b) a trigger delay that was identified by FREEZE (Tdf). Tdv and Tdf were obtained from axial mid-ventricular 2D segmented k-space gradient-echo cine images (TR=2.7ms, TE=1.4ms, α=25°) with 50 frames/s. For coronary MRA (voxel size=0.7x1.0x3mm^3), navigator gated and corrected, double oblique 3D segmented k-space gradient echo imaging (TR=4.9ms,TE=1.7ms, α=20º, 3mm slice thickness, 512 matrix, FOV=36x27cm^2, 20 slices, fat saturation, adiabatic T2Prep (TE=50ms)) was used. Such volume targeted high-resolution 3D images of the left and right coronary arterial system were acquired with both the automatically identified trigger delay Tdf and the visually determined trigger delay Tdv. In one subject, coronary MRA at Tdf of a right coronary artery was performed with an acquired voxel size of 0.34x0.35x1.5mm^3 and with a reconstructed voxel size of 0.26x0.26x0.75mm^3 (TR=7.5ms, TE=2.3ms, α=20º, 1.5mm slice thickness, 800 matrix, FOV=27x21.6cm^2, 20 slices, fat saturation). Quantitative analysis of the thus obtained coronary MRA was performed using the 'SoapBubble' tool (Etienne et al, MRM, 2002, 48:658-66) by a blinded reader. Coronary MRA obtained at Tdv and Tdf were compared for vessel length, vessel sharpness, vessel diameter, signal-to-noise ratio (SNR) and contrast-to-noise ratio (CNR). In addition, a qualitative grading of image quality was performed by two blinded readers using a 1-4 scale (1=worst, 4=best) (McConnell et al, AJR, 1997, 168:1369-75).

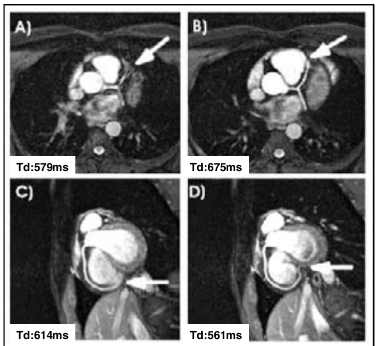

Fig 1: Improvement in vessel sharpness (A,B) and in vessel length (C,D). The images in the left column were obtained with visual assessment and those in the right column were obtained with FREEZE.

	VESSEL LENGTH(mm)		VESSEL SHARPNESS(%)		VESSEL DIAMETER(mm)	
	VISUAL	*FREEZE*	*VISUAL*	*FREEZE*	*VISUAL*	*FREEZE*
MEAN	65.2	83.1	43.8	46.3	2.9	3
SD	29.3	38.9	5.4	4.8	0.4	0.3
P VALUE	<0.01		<0.02		<0.04	
	SNR(a.u)		CNR(a.u.)		VISUAL GRADING(a.u.)	
	VISUAL	*FREEZE*	*VISUAL*	*FREEZE*	*VISUAL*	*FREEZE*
MEAN	29.5	32	21	23	2.5	3.3
SD	8.6	8.4	6.4	6.3	0.9	0.8
P VALUE	<0.02		<0.04		<0.01	

Table 1: Objective and subjective comparison of image quality from coronary MRA obtained with a visually identified (VISUAL) and a computer prescribed (FREEZE) trigger delay. SD=Standard deviation of the mean.

RESULTS

By the use of the FREEZE prescribed trigger delay Tdf, a significant quantitative and qualitative improvement in image quality was obtained when compared to images that were collected with the visually identified trigger delay Tdv (Table 1). In Fig 1 A & B, an improved image quality is readily apparent (B) using Tdf. On the right coronary system (RCA) shown in Fig. 1 C & D, the automated identification of the trigger delay led to the visualization of a longer contiguous segment of the RCA. Furthermore, in subjects with high heart-rates, the automated tool found periods of minimal myocardial motion at end-systole (Fig. 2, arrows) leading to better image quality as shown in Fig 2B, while diastolic trigger delays were identified in these cases by visual inspection. Finally, the use of FREEZE supported 3T coronary MRA with a voxel size as low as 0.34x0.35x1.5mm as shown in Fig. 3, where a long segment of the right coronary artery is visualized together with smaller diameter branching vessels and an excellent visual vessel border definition.

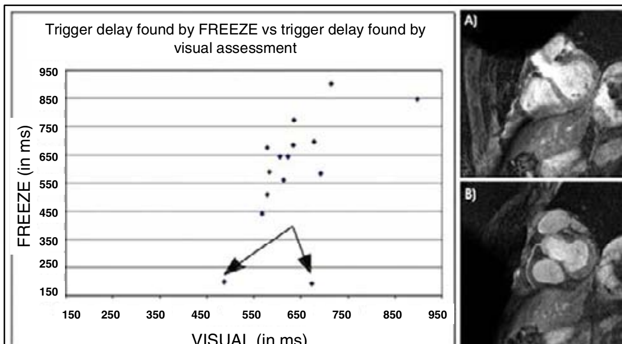

Fig 2 Left: Trigger delay calculated by FREEZE vs visual assessment. In two subjects (arrows), FREEZE found end-systolic Td whereas the visual inspection led to a diastolic acquisition interval in the same subjects. A and B: Images obtained in one of these two subjects A) Visual Assessment B) FREEZE.

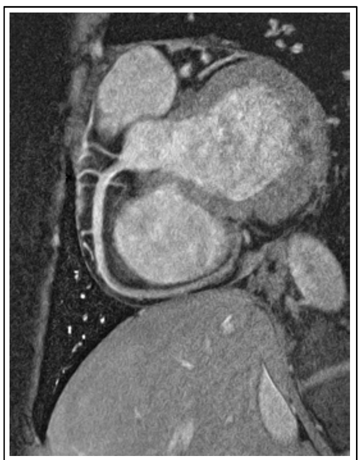

Fig 3: 3T Coronary MRA with FREEZE. Image acquired during the minimal myocardial motion interval computed by FREEZE (Resolution:0.34x0.35x1.5)

CONCLUSION

This study demonstrates that an automated algorithm (FREEZE) for the identification of the most quiescent period of the cardiac cycle significantly improves objective and subjective image quality in coronary MRA when compared to a more conventional visual inspection of the optimal trigger delay. Periods of minimal myocardial motion can be found objectively and operator dependent variations can be minimized. FREEZE supports 3T imaging at very high spatial resolution and may contribute to an overall improved image quality and reproducibility of coronary MRA in general.