

Coronary MR Angiography at 3T During Diastole and Systole

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Introduction:

A major technical challenge in coronary magnetic resonance angiography (MRA) is blurring due to cardiac motion[1]. The blurring is minimized by acquiring image data during the quiescent mid-diastolic period of the cardiac cycle[2]. This period occurs at approximately 75% of the cardiac cycle, after relaxation of the ventricles. Depending on the subject's heart rate, the diastolic period can be as short as 66ms or as prolonged as 330msec, with an average length of 187msec in patients [1]. After ventricular systole, at ~35% of way through cardiac cycle, there is another quiescent period that lasts on average 118msec (range 0-223msec)[1]. It is useful to note that both of these periods have an inverse relationship with the heart rate, that is, they both shorten as heart rate increases [1]. However, the duration of the end-systolic period and its relative position within the cycle are less affected by heart rate variability than that of diastole. For these reasons, we hypothesize that end-systolic imaging may be an alternative with which the adverse effects of RR variability can be minimized.

The abbreviated systolic rest period necessitates image data collection in a very short acquisition window, which may prolong scanning time, putting the acquisition at risk of failure due to patient motion or diaphragmatic drift. In the present study, we used parallel imaging in the form of sensitivity encoding (SENSE) [3] at 3T to abbreviate the systolic image data acquisition window to ~40ms without increasing the total scan time with respect to conventional diastolic imaging. The purpose of this study was to investigate the impact of end-systolic imaging on the quality of right coronary MRA in comparison to diastolic. Simultaneously, the effect of RR interval variability on image quality was studied for both end-systolic and mid-diastolic acquisitions.

Methods and Materials:

The right coronary artery (RCA) of 10 normal volunteers (3 males, 23-45 years old) was imaged on a 3T Intera scanner (Philips Medical System, Best, The Netherlands) using a 6 element cardiac coil. Initial scout scans were performed as previously described by Stuber et al [4]. An axial mid-ventricular ECG-gated balanced SSFP sequence was used to determine the quiescent periods (TR=3.6msec, TE=1.8msec, 45°, 50 cine phases). The cine phases analyzed using FREEZE tool (research software,[5]) to automatically identify optimum end-systolic and diastolic quiescent period with a duration of 35ms (~5 TRs). A 75msec quiescent period during diastole was also identified. A 3D navigator-gated sequence [4] was used to scan the RCA of each subject three times, in random order: (1) End-systolic short acquisition (SS): ~40ms window at end-systole (TR=7.6ms, TE=2.2ms, 20°, turbo factor or lines per heartbeat = 5, SENSE factor=2). (2) Diastolic short (DS): mid-diastolic acquisition with the same imaging parameters as SS. (3) Diastolic long (DL): ~80ms diastolic window with the same imaging parameters except using a doubled turbo factor of 10. In 9 of the 10 subjects, the vectorcardiogram (VCG) of each scan was recorded to analyze RR interval variability. The RR variability was measured as the standard deviation of the RR interval length over all coronary scans performed. The Soapbubble tool [6] was used to quantify vessel sharpness, and vessel length of the reformatted RCA images. The reformatted images were also randomized and evaluated by two blinded readers for assessment of image quality. A score of 1-4 was assigned to each image (1=worse and 4=best) by each reader individually and as a consensus read. A paired student's t-test with Bonferroni correction was used to compare vessel sharpness, and vessel length, while a Wilcoxon test was used for statistical comparison of the image quality scores. A linear regression analysis was used to correlate R-R variability in msec to these three parameters.

Results:

The RCA was imaged successfully in all 10 subjects using a short acquisition window during diastole and systole, and a prolonged acquisition window during diastole. The average vessel length, vessel sharpness and consensus score for each technique is shown in Table 1. No statistically significant difference was found when comparing these three approaches. The subjects' heart rates ranged from 55-95 bpm with a mean RR variability ranging from 42-91 msec. None of the qualitative parameters showed a statistically significant correlation with RR variability. However, there was a trend for reduced vessel length as a function of RR variability for diastolic RCA imaging.

Conclusion and Discussion:

This study demonstrates the feasibility of imaging the RCA at 3T using free-breathing during the end-systolic rest period. The use of a shortened acquisition window was made possible by taking advantage of the increased performance of SENSE and the increased SNR available at 3T. Using such a short acquisition window, imaging during the abbreviated quiescent end-systolic period does not have a significant detrimental effect on image quality. Although, there is no statistically significant effect of R-R variability on all three techniques, imaging during end-systole appears to be least affected by such variability (Fig 2).

Imaging during the mid diastolic period has been successful enough that it is an integral part of both MR and CT angiography strategies. Breaking away from the standard of imaging only during diastole can potentially improve in tachycardic patients with short RR intervals or in patients with high heart rate variability. Another potential application is simultaneous imaging during both periods in a single scan to acquire, for example, the RCA slab during end-systole and LAD during diastole. Further studies using a larger subject population would be beneficial to further identify any potential advantages of imaging during end-systole.

References:

1. Johnson KR, Patel SJ, et al. *J Cardiovasc Magn Reson* 2004;6:663-673
2. Wang Y, Watts R, Mitchell I, et al *Radiology* 2001;218:580-585
3. Pruessman et al *MRM* 1999 42(5):952
4. Stuber M, Botnar RM, Fischer SE, et al. *Magn Reson Med* 2002;48:425-429
5. Ali O Ustun et al. In: *SCMR*. San Francisco, CA, USA, 2005
6. Etienne A et al, *MRM* 48(4):658 2002



Figure 1: Coronary MRA of the RCA obtained in the same subject in diastole using a long (left image) and short (middle image) acquisition window. (Right image) Image acquired using a short acquisition window at end-systole.

	DL	DS	SS
Vessel Length	109mm	112mm	111mm
Vessel Sharpness	39%	39%	35%
Image Quality Score	2.4	2.4	2.7

Table 1: Mean vessel length, sharpness and image quality score for the three different acquisition. DL=diastolic & long acquisition window; DS=diastolic & short acquisition window, SS=systolic & short acquisition window.

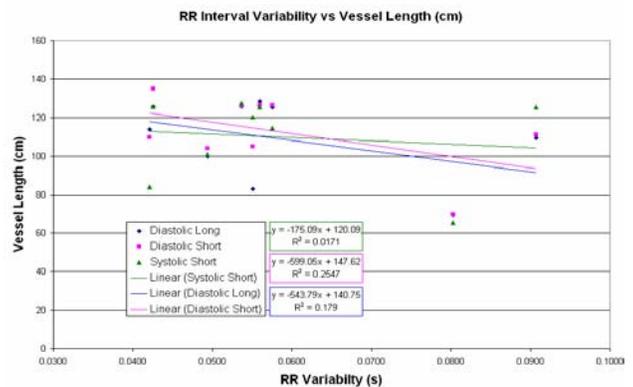


Figure 2: Linear regression fits for vessel length compared to R-R variability. There is a trend for end-systolic short window (SS) acquisitions to be more robust in the face of RR interval variability than diastolic acquisitions.