A fully automated selection of the optimal data acquisition window in coronary MRA eliminating the need for user-interaction

X. Bi[1], Y-C. Chung[1], R. M. Setser[2], M. Desai[2], P. Weale[1], V. Deshpande[1], S. Zuehlsdorff[1], G. McNeal[1], D. Li[3], and R. Jerecic[1]

[1]Siemens Medical Solutions, Chicago, Illinois, United States, [2]the Cleveland Clinic Foundation, Cleveland, Ohio, United States, [3]Northwestern University, Chicago, Illinois, United States

Introduction: Coronary motion during a cardiac cycle is subject-dependent (1). To achieve the optimal image quality especially in whole heart coronary MRA, an appropriate data acquisition window needs to be carefully positioned within the resting period of the cardiac cycle, which is different for each subject. The determination of the resting period is typically done by visual assessment of coronary artery motion on previous acquired cine data. Such a procedure is highly subjective and induces high operator variability in image quality.

Post-processing methods previously proposed to derive cardiac motion information were semi-automatic (e.g., (2)) and still require user interaction. In this work, a fully automated method was developed to determine the optimal data acquisition window in coronary MRA based on cardiac cine imaging with no user intervention. The recommended acquisition window is displayed inline on the imaging console together with the motion curve. The efficacy of this fully automated, objective method was retrospectively validated in healthy volunteer and patient studies.

Method: The automated window detection method was integrated to a retrospectively-ECG-gated 2D TrueFISP cine sequence, acquired with 40 cardiac phases. For each measurement, the correlation coefficient (CC_i) between signal intensities of the i^{th} and $(i+1)^{th}$ cine phases was calculated. The maximal (CC_{max}) and minimal (CC_{min}) coefficients were identified and neighboring phases of the CC_{max} within a user-defined threshold value α were defined as cardiac diastasis if $CC_i > (CC_{max} - \alpha \cdot (CC_{max} - CC_{min}))$. The correlation curve was generated inline as part of the reconstruction routine of the Image Calculation Environment (ICE, Siemens, Erlangen, Germany) and instantly available for display (Figure 1) as separate DICOM image.

Healthy volunteer validation: To determine the appropriate acceptance threshold α and optimize the imaging protocol, fourteen healthy volunteers were scanned on a 1.5 T scanner (MAGNETOM Sonata, Siemens, Erlangen, Germany) to compare the automatically determined acquisition window with the results from a conventional visual inspection by two experienced readers independently. The reader determined cardiac resting phases with minimal coronary motion by visual assessment of the motion of the cross-section of RCA in the 4-chamber view. Four different imaging protocols were used with the following settings: breath-holding/free-breathing, and 1.3×1.3×6/1.7×1.7×6 mm^3 resolution. For automated determination of cardiac diastasis, the algorithm described above was applied offline to cine images with threshold values of 1%, 5%, 10%, and 15%. The mid-point and width of the calculated diastasis from the CC were compared to those visually determined by the reviewers using paired t-test.

Patient study: Nineteen patients with known or suspected congenital cardiovascular abnormalities were imaged on a 1.5 T scanner (MAGNETOM Avanto, Siemens, Erlangen, Germany). The image quality of coronary arteries was assessed subjectively using a 4-point scale by 2 experienced readers. For subjects with good image quality (average score ≥ 3.0), the cardiac diastasis was retrospectively calculated from the 4 chamber cine images and compared to the value used in the study, assuming appropriate data acquisition windows were applied in these cases, resulting in sharply depicted coronary arteries.

Results: *Healthy volunteer study:* The selected acquisition window from two reviewers agrees with each other (p-values = 0.38 / 0.08 for the mid-point / width). The comparison results of the observed (by reviewers) and automatically calculated data acquisition window from volunteers are summarized in Table 1. Although α = 0.01 yields results in agreement with the reviewers (p-value > 0.05 for both the mid-point and width of the window), the acceptance window is small (mean width = 44 msec) and not practical as it would result in unacceptable long scan times. With α = 0.05, good correlation between visual assessment and automatic selection is achieved with reasonable acquisition window width (mean value = 107 msec).

Patient study: The average image quality as scored by the two readers was 2.83 ± 0.68. For 12 out of the 19 patients image quality was scored > 3.0. Within this group the retrospective determination of the acquisition window was in excellent agreement with the actually chosen window by the operator based on visual inspection (p-values = 0.14 / 0.07 for the mid-point / width). Image data with less than 3.0 score were excluded in this analysis as other reasons such as irregular breathing patterns or heart rates could have a more dominant effect on image quality and it was not possible to determine the reason in retrospect.

Discussion: The study demonstrates the feasibility of extracting cardiac motion information from conventional cine images. Such method can potentially be used to optimize data acquisition in imaging techniques (e.g., CT, MR) that requires data acquisition at the appropriate time of the cardiac cycle. Expansion of this technique to automatically transfer the extracted temporal information to following scans would be a further step towards an more automated and objective approach with benefits in improving robustness and reducing the need for "expert" operator. This method may also have uses in analysis of other motion related data, for example, filling rates and ejection rates where signal is primarily modulated by cardiac motion - this needs further investigation.

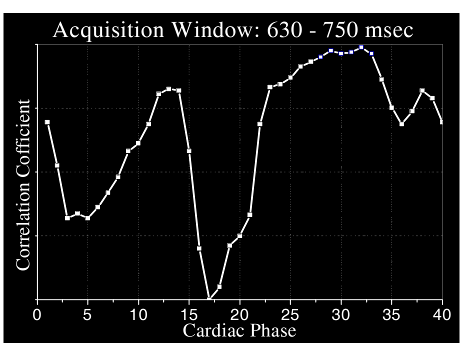

Figure 1. Inline display of the correlation curve: the recommended data acquisition window is displayed without the need for manual cropping or user intervention. For this subject, cardiac phase number 28 to 33 were identified as diastasis, corresponding to an acquisition window from 630 to 750 msec.

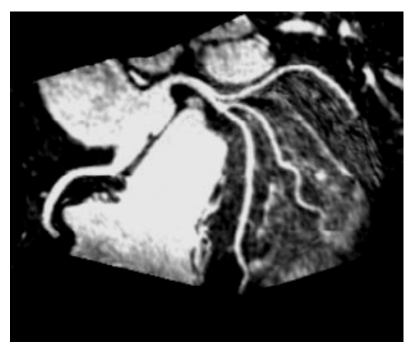

Figure 2. Example coronary artery image from a patient study. Data acquisition window based on visual assessment (812 – 904 msec) was in good agreement with that calculated using automatic window selection algorithm (776 – 904 msec). The average R-R interval was 1146 msec.

Table 1: Correlation results (p-value) of the selected data acquisition window (mid-point and width) based on visual assessment by reviewers and automatic calculation with different imaging protocols and acceptance thresholds α. Note α value of 0.05 yields results in good agreement with the visual assessment.

breath-hold/ free-breath	In-plane resolution	p-values with various acquisition window thresholds (α)							
		α = 0.01		α = 0.05		α = 0.10		α = 0.15	
		mid	width	mid	width	mid	width	mid	Width
breath-hold	1.3×1.3	0.27	1.00	**0.28**	**0.99**	0.01	0.23	0.01	0.01
	1.7×1.7	0.27	1.00	**0.05**	**0.99**	0.01	0.78	1E-5	0.01
free-breathing	1.3×1.3	0.33	1.00	0.02	0.99	7E-5	0.63	2E-5	8E-5
	1.7×1.7	0.49	0.99	**0.06**	**0.96**	9E-6	0.02	3E-6	1E-5

References:

1. Wang Y. et. al. Radiology 213: 751, 1999
2. Jahnke C. et. al. JCMR 7: 395, 2005