Real-Time Adaptive Motion Correction for Coronary MR Angiography

M. Henningsson[1,2], S. A. Uribe Arancibia[1], A. J. Wiethoff[1,3], P. G. Batchelor[1], and R. M. Botnar[1]

[1]Division of Imaging Sciences, King's College London, London, United Kingdom, [2]NIHR Biomedical Research Centre at Guy's & St Thomas' Hospital and King's College London, London, United Kingdom, [3]Philips Healthcare, Reigate, United Kingdom

Introduction: Artifacts due to residual coronary motion remain an impediment to diagnostic coronary MRA in a small but substantial amount of patients. Wang *et al.* [1] have shown that for the general population a linear relationship between the diaphragmatic and cardiac motion can be assumed. The study also shows that the principal motion of the heart can be compensated for by using the so called Wang factor (WF) of 0.6 in the superior-inferior direction. By placing a pencil beam navigator on the right hemidiaphragm the position of the imaged slice can be tracked by multiplying the WF with the navigator output. However, there seems to be large variance within the general population with respect to this factor [2]. Even within a single scan the factor may have some variance due to respiratory drift or changes in the duration and depth of the respiratory motion. The purpose of this study was to investigate a method that determines a patient specific correction factor which continuously updates throughout the course of the scan.

Materials and methods: All experiments were carried out on a commercial 3T Philips Achieva system (Philips Healthcare, Best, the Netherlands) using a 32-channel cardiac coil and a steady state free precession (SSFP) sequence. Imaging parameters included TR/TE/FA=5.5 ms/1.59 ms/20°, FOV=320x320x30 mm^3, 1 mm spatial resolution, 0.53 mm after reconstruction, and 3 mm slice thickness reconstructed to 1.5 mm. The acquisition was ECG-triggered and a navigator gating window of 5 mm was used for motion correction. The imaging sequence was preceded by T2prep and fat suppression (SPIR) prepulses for myocardial and epicardial fat suppression.

The real-time adaptive factor (AF) was calculated by means of a linear regression using two pencil beam navigators performed immediately before the acquisition phase in the cardiac cycle, one positioned on the free wall of the left ventricle and the other on the dome of the right hemidiaphragm. The linear analysis was based on the last *n* navigator positions within the gating window and as such updated for every heart cycle using a sliding window approach. As the AF depends on the value of *n*, several sliding window sizes were tested: 8, 12 and 16. Additionally, a third method was investigated in which a navigator was placed on the wall of the left ventricle of the heart using a "heart factor" (HF) of 1.0 (in this case the gating window was 2.5 mm). The HF was included in the study to investigate whether the heart navigator by itself was sufficient to correct for respiratory motion.

Results: Images of the left coronary artery were acquired in 7 healthy volunteers (28.7 +/- 4.3 years) using the AF, HF and WF methods to compensate for respiratory motion. Vessel wall sharpness (VWS) for the left anterior descending (LAD) and left circumflex (LCX) artery were measured using the "Soap-Bubble" software [3] and the results (mean+/- std. dev.) are shown in Table 1. As the AF with sliding window size 8 resulted in slightly better image quality this was used for the statistical comparison with the other methods. Furthermore, a visual score was given by an expert to grade the vessel visibility of the LAD and LCX according to the following scale: poor (1), good (2), very good (3) and excellent (4), the results of which can also be found in Table 1. Both the VWS measurements and visual score show a trend towards better coronary artery visibility for the AF, particularly for the LAD where the VWS score was better than that of WF in 100% of the cases, and HF in 86%.

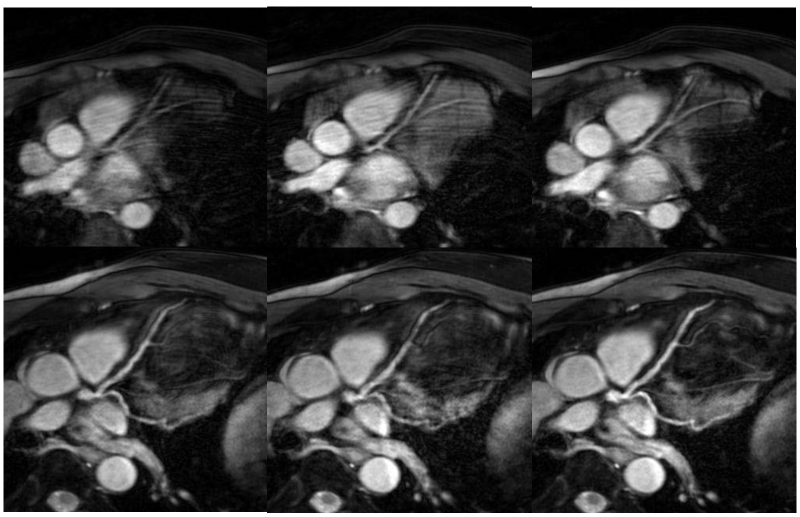

Figure 1.Reformatted images of the left coronary artery of two healthy volunteers (top and bottom) using different motion correction methods: WF (left), HF (middle) and AF (right), sliding window size 8.

Figure 1 contains two examples where the AF (right) showed improved image quality over the WF (left). The calculated adaptive factor for the cases in Figure 1 was plotted over time and shown in Figure 2 (top case in fig.1 is green in fig.2, and bottom case is blue). Although the relationship between diaphragm and the heart over the entire scan (0.72 and 0.77) is close to the Wang factor (0.6), the variation of the AF throughout the scan is large (std. dev. = 0.22 and 0.21).

Conclusion: The improvement of image quality with the AF compared to the WF suggests that the calculated factor reflects true changes in the relationship between the heart and diaphragm. The reason AF performs better than HF in most cases could be related to the fact that the navigator on the heart is rather unreliable. The AF is a combination of the heart navigator with the more stable navigator on the diaphragm, as well as calculated over several cycles which means that the AF is less sensitive to noise. Because the AF with sliding window size 8 resulted in the best images (compared to window size 12 and 16) the AF seems to change fast. Validation of the adaptive method is however needed to determine to which extent the factor changes over time.

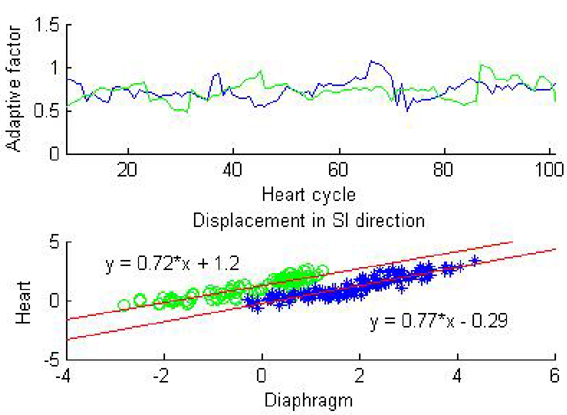

Figure 2. (Top) plot of AF over time (sliding window size 8) for two volunteers (green and blue), (bottom) diaphragm vs. heart displacement in SI direction.

	Visual score$_{LAD}$	Visual score $_{LCX}$	VWS$_{LAD}$	VWS$_{LCX}$
WF	2.3+/-0.5	1.5+/-1.2	35.9+/-4.3	32.0+/-5.8
HF	2.3+/-0.8	1.5+/-0.5	36.5+/-3.9	31.1+/-4.3
AF	3.0+/-0.6	2.2+/-0.8	39.4+/-4.5	34.0+/-6.6

Table 1. Vessel wall sharpness and visual score measurements (mean+/-std. dev.) for the three motion correction methods.

References:

[1] Wang Y. et al. Magn Reson Med 1995; 33: 713-19
[2] Taylor A.W. et al. J Cardiovasc Magn Reson 1999; 1: 131-38
[3] Etienne A. et al Magn Reson Med 2002; 48: 658-66