A Comparison Study of Four Navigator Gating Techniques in Free-Breathing Steady-State Free Precession 3D Coronary MR Angiography

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INTRODUCTION Navigator technology is an effective approach to overcome respiratory motion in high-resolution 3D coronary MRA (CMRA). Diaphragmatic motion information is used to select a motionless data set for image reconstruction, either before data acquisition (prospective gating) or after (retrospective gating). The retrospective gating algorithm (RETRO) (1) is simple to implement but inefficient and may not completely eliminate motion at the k-space center. Prospective gating algorithms, including accept/reject (A/R) (2), diminishing variance algorithm (DVA) (3), and phase ordering with automatic window selection (PAWS) (4), can provide improved motion suppression, but require real-time navigator processing capability from the scanner hardware. The A/R algorithm is available on commercial scanners, but it is less efficient than the DVA and PAWS algorithms if respiratory drift occurs. The PAWS algorithm provides the most effective motion suppression by smoothing motion within the gating window through view ordering. While the performance of these techniques had been investigated separately (5,6), a comprehensive pairwise comparison of all algorithms in a single study is lacking. The objective of this work was to compare the performance of RETRO, A/R, DVA and PAWS algorithms using free-breathing steady-state free precession (SSFP) imaging, the state-of-the-art sequence for 3D CMRA (7).

MATERIALS AND METHODS

The four gating algorithms were implemented on a 1.5T GE Excite 14M4 commercial scanner (no additional hardware required). For prospective gating, a custom program was developed to collect navigator data, extract motion information, and control data acquisition in real time. The RETRO, DVA and PAWS algorithms were fully automated and the A/R algorithm only required graphically setting the gating window. All image reconstructions were performed online by the scanner hardware. The four algorithms were incorporated into an ECG-triggered SSFP 3D CMRA sequence consisting of a pencil-beam navigator placed on the right-hemidiaphragm, a fat saturation pulse to suppress the epicardial fat, followed by a 6 Kaiser ramp-up magnetization preparation to drive spins into steady state for subsequent SSFP imaging. Experiments were performed in 10 volunteers (8 men, 2 women, mean age of 35 ± 14 years) without breathing coaching. The typical imaging parameters were: TR/TE/FA/rBW = 4.0 ms/1.5 ms/60°/±62.5 kHz, resolution = 1.0x1.0x3.0 mm^3, 32 partial echoes per heartbeat. A gating window of 5 mm was used for A/R, DVA and PAWS. A maximum data overscanning factor of 3 (corresponding to a 33% navigator efficiency) was used for DVA and RETRO gating to keep the total study time reasonable. The RCA and the LAD were randomly selected for imaging (both vessels were imaged if time permitted). The four gating algorithms were performed in randomized order. Vessel signal, vessel contrast and motion suppression were scored visually by the consensus of two experienced observers blinded to the gating algorithms using a five-point scale (0=very poor, 1=poor, 2=fair, 3=good, 4=very good). The scores were then averaged to obtain an overall image quality score.

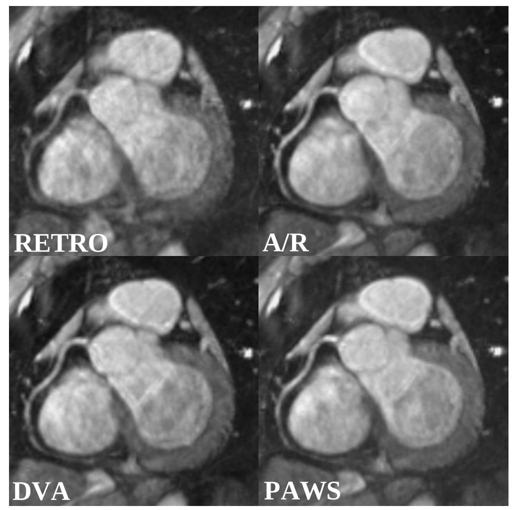

Fig.1. RCA images obtained with four gating algorithms.

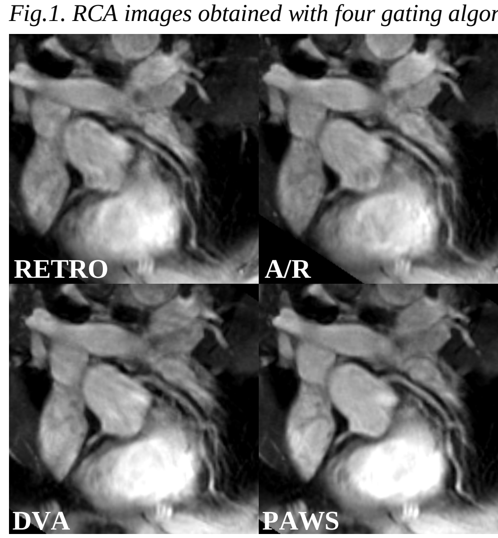

Fig.2. LAD images obtained with four gating algorithms.

RESULTS

All scans finished succesfully and a total of 15 vessels were imaged (9 RCA and 6 LAD). Table 1 summarizes the performance comparison of the four gating algorithms averaged over all vessels. PAWS provided significantly better image quality than A/R (P=0.02), DVA (P=0.01) and RETRO (P=0.002). While the quality difference between A/R and DVA was not statistically significant, both algorithms yielded better image quality than RETRO. PAWS and DVA were the most efficient algorithms, providing an approximately 20% and 41% higher navigator efficiency compared to A/R (P=0.01) and RETRO (P<0.001), respectively. Fig.1 illustrates a case where prospective gating provided superior visualization of the RCA compared to that of retrospective gating. Fig.2 shows PAWS more effectively suppressing motion artifacts than the other three algorithms, leading to the best depiction of the LAD and the best overall image quality.

	Image quality score	Efficiency (%)	Scan time (s)
RETRO	2.5 ± 1.0	33 ± 0	320 ± 61
A/R	3.0 ± 0.7	39 ± 10	290 ± 106
DVA	2.9 ± 0.8	47 ± 11	238 ± 74
PAWS	3.3 ± 0.7	46 ± 10	243 ± 73

Table 1. Overall comparison of gating algorithms (N=15).

CONCLUSION Prospective gating provided better 3D SSFP CMRA than restrospective gating in less scan time. The most efficient and effective PAWS gating algorithm is recommended for free-breathing 3D CMRA.

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