Motion Artifact Suppression in ECG Ordered Breath Hold 3D Contrast Enhanced Magnetic Resonance Angiography

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Introduction Image quality in breath hold contrast enhanced magnetic resonance angiography (CE-MRA) in the thorax is compromised by blurring and ghosting artifacts due to the heart motion. These artifacts can be reduced by ECG gating but often at the expense of increased scanner time and total loss of the study when gating fails. We propose a robust ECG ordering of k-space for breath hold CE-MRA that acquires the central part of k-space in the diastolic phase of the cardiac cycle to minimize motion artifacts when ECG signal is available and fills in from the periphery of k-space when ECG signal is not available.

Materials and Methods *ECG view ordering* Before the CE MRA, one real-time scout scan and one 2D SSFP cine scan were performed to determine to the subject specific position and length of the mid-diastolic window within the cardiac cycle. The length of this window and the heart rhythm determined the total number N_C of views that could be acquired at minimal heart motion. Two view tables were set up: K_c (containing the N_C views closest to the center of k-space) and K_P (the rest). Within each of these sets, views were reordered according to a recessed elliptical centric view order (1). RF pulses were played out continuously but the views in K_C were only acquired during the mid-diastolic window in the cardiac cycle. At all other times, views from K_P were acquired (Fig. 1). If the acquisition took more than four heart beats longer than the normal duration, gating was turned off and the remaining views were acquired immediately. This was done to ensure a maximal scan time would not be exceeded.

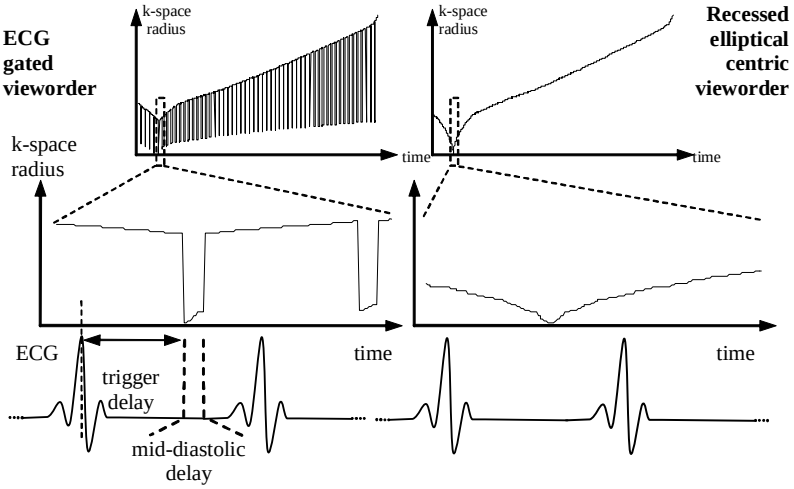

Fig. 1: In an ECG ordered CE-MRA the views closest to the k space center are acquired only within a fixed window in the cardiac cycle (left). In a recessed elliptical centric view order (right) the absolute center is acquired at approximately the same time.

An ungated *recessed elliptical centric view order* (1) where the absolute center of k-space was put at approximately the same position in time (see Fig. 1) and a *standard sequential view order* were included in all studies for comparison.

A CE MRA study including this ECG ordered MRA was performed on five healthy volunteers (age 18-26) with written consent. All experiments were performed on a Signa Excite 1.5T scanner using an 8 channel torso coil. 20 cc of Gd:DTPA (Berlex Laboratories) was administered at 1.5 cc/s. Scanning parameters were: FOV 36 cm, matrix size 512x192x30, interpolated to 512x512x60, TE/TR =1.1 ms/4.5 ms and 35°flip angle. Scan order was randomly changed from one volunteer to the next.

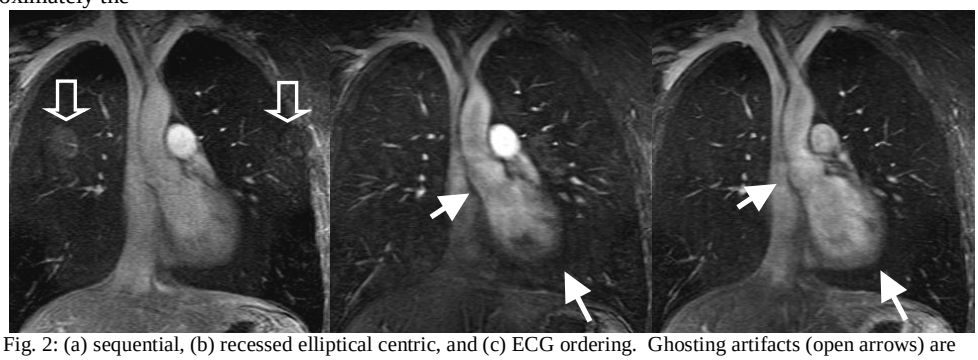

Fig. 2: (a) sequential, (b) recessed elliptical centric, and (c) ECG ordering. Ghosting artifacts (open arrows) are visible in (a). The aortic root and papillary muscles are progressively better defined (b,c, solid arrows). Pulmonary vessels are seen sharper due to the elimination of the cardiac motion artifact on ECG ordering.

Results Comparison of ECG ordered and sequential view ordering in the same volunteer is seen in Fig. 2 (source images). Suppression of heart motion and vascular pulsation artifacts is observed. In the ECG ordering (Fig. 2c) the ghosting artifact is clearly absent. A comparison of the the recessed elliptical centric view order (Fig. 3a) and ECG view ordering (Fig. 3b) shows that both succeed in removing major ghosting artifacts, most likely due to the fact that in both view orders, the absolute center of k-space was acquired at the same period of the cardiac cycle. With the ECG view ordering, pulmonary vessels, aortic root and papillary muscles are better visualized and sharper than in the recessed elliptical centric view order.

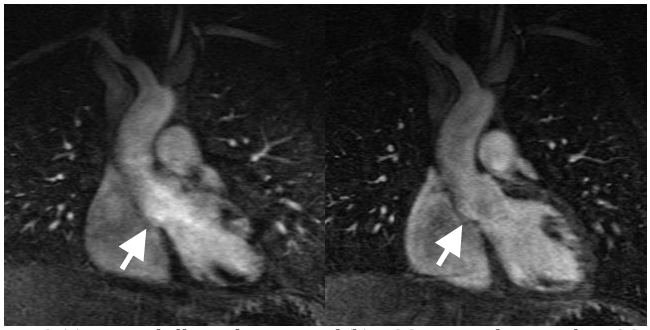

Fig. 3:(a) recessed elliptical centric and (b) ECG view ordering. The ECG view ordering allows for a better visualization of the cardiac structure.

Discussion The use of cardiac gating in TOF MRA was proposed earlier in (2, 3). However, when data are acquired only during a fixed window in the cardiac cycle, scan time is significantly increased and stops completely with loss of the ECG signal. Because of the necessity of a breath hold in chest MRA and the use of first pass contrast enhancement, this increase in total scan time is avoided by continuously acquiring data. This preliminary study suggests that acquiring just the absolute center of k-space at minimal heart motion is sufficient to remove ghosting artifacts in breath hold CE MRA. Cardiac ordered acquisition of a larger part of the center of k-space further reduces motion blurring and increases visibility of smaller structures.

Conclusion Three view orders for a breath-hold CE-MRA were compared: a standard sequential, a recessed elliptical centric and a new ECG ordered view order. The ECG view ordering was shown to significantly suppress ghosting and cardiac motion artifacts, and allowed for a better visualization of pulmonary vessels and cardiac structure.

References

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