Quantification of coronary artery motion using cardiac fat navigator echo

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INTRODUCTION

Motion of the coronary arteries is a major challenge for coronary MR angiography (CMRA). Currently the electrocardiogram (ECG) is used to gate CMRA by limiting data acquisition to mid-diastole, the period of minimal cardiac contraction. The delay time from the ECG trigger is typically estimated from a cine scout scan or calculated using empirical formulas (1-3). Since these techniques were not based on the knowledge of actual cardiac motion that occurs during data acquisition, substantial motion may occur under ECG guidance. Direct quantification of cardiac motion has been studied using X-ray angiography (4) and electron beam tomography (5), but these techniques cannot be applied to CMRA exams. Recently cardiac fat navigator echo has been proposed to measure 3D bulk translation of the proximal coronary tree by selectively exciting the epicardial fat that surrounds and moves together with the coronary arteries (6). The present study employs this technique to quantify the motion of the coronary arteries.

METHODS

Experiments were performed on healthy subjects (n=5) using a 1.5 T GE Signa CV/i MR scanner. A 5-inch circular surface coil was positioned on the anterior chest wall for signal reception. Cardiac fat navigator parameters are as follows: slab thickness = 70 mm, slab FOV = 140 mm, 1-4-6-4-1 type I spatial-spectral RF pulse, flip angle = 40°, rBW = ±15.63 kHz. Cardiac fat navigator echo was acquired every 33 ms in a 10 heartbeat breath-hold.

The ECG signal was sampled every 4 ms and simultaneously with the navigator acquisition using a digital oscilloscope. The gradient switching in the navigator sequence caused spurious spikes in the ECG record, which were used to co-register the navigator and the ECG signal in time. These spikes were later filtered out to obtain the true ECG waveform.

Displacements were extracted from the navigator data using an image-space least-squares algorithm and interpolated to 4 ms temporal resolution using a cubic interpolator. The rest period of the coronary arteries was defined as the duration during which the detected motion in all three orthogonal directions (superior-interior, anterior-posterior, right-left) was less than 1 mm, corresponding to a maximum displacement of √3 mm in any direction. For comparison, optimal delay times were calculated using empirical formulas (1,2) and also by visual inspection of axial cine images acquired at the ventricular level.

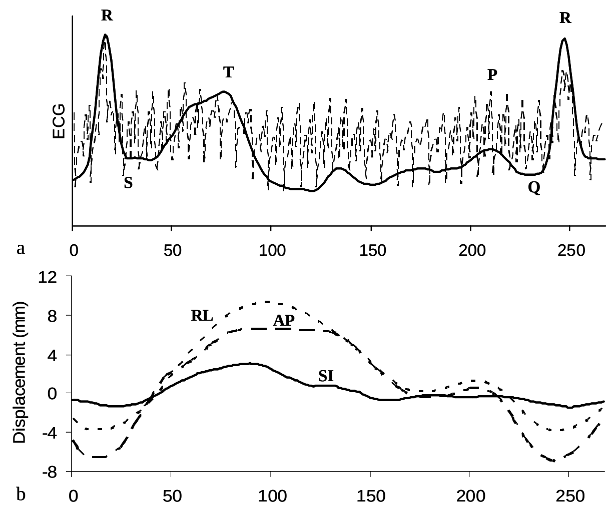

Fig. 1. Example of the recorded and filtered ECG signal (a), and corresponding 3D coronary motion (b) acquired over one cardiac cycle.

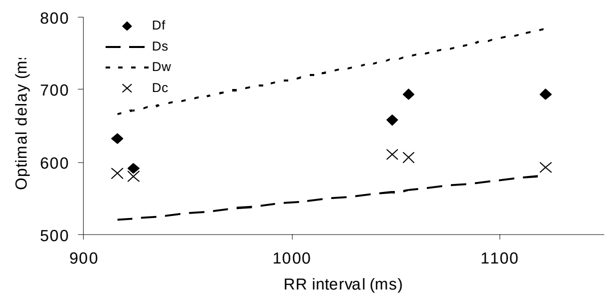

Fig. 2. Optimal delay times calculated using fat navigator (Df), Stuber formula (Ds), Weissler formula (Dw) and cine scan (Dc).

RESULTS

Fig. 1 illustrates the ECG signal (a) and the detected 3D bulk cardiac motion (b) over one cardiac cycle. Two rest periods can be observed, one starting during late systole at the onset of the T wave (start of ventricular repolarization) and another occurring during mid-diastole before the P wave (start of atrial depolarization). In all subjects, the delay from the QRS complex and the duration of the late-systolic rest period was 293±32 ms and 90±39 ms, respectively. The delay and the duration of the mid-diastolic rest period was 654±43 ms and173±41 ms, respectively. The R-R intervals were 1013±90 ms. Fig. 2 shows the scatter plot of optimal mid-diastolic delay times determined with cardiac fat navigator, two empirical formulas and cine scan. Note that Ds and Dw consistently underestimated and overestimated the delay time.

DISCUSSION

The cardiac fat navigator echo provides a direct measure of coronary motion and may replace the ECG signal as a more effective guide to suppress motion artifacts in coronary MRA. A short late-systolic period and a long mid-diastolic rest period in the cardiac cycle are accurately identified using the cardiac fat navigator.

REFERENCES

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