

POSTER PRESENTATION

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Computation of the gradient-induced electric field noise in 12-lead ECG traces during rapid MRI sequences

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Background

Successful physiological monitoring using a 12-lead ECG during MR imaging is essential for safe conduction of cardiovascular interventions within a MR scanner. However, ECG artifacts induced by magnetic field gradients

severely affect the signal quality and fidelity. Previously, the gradient-induced artifacts were reduced by blocking ECG transmissions during all gradient ramps [1], which has been shown feasible while the method is not suitable for short-TR sequences. Theoretical and experimental

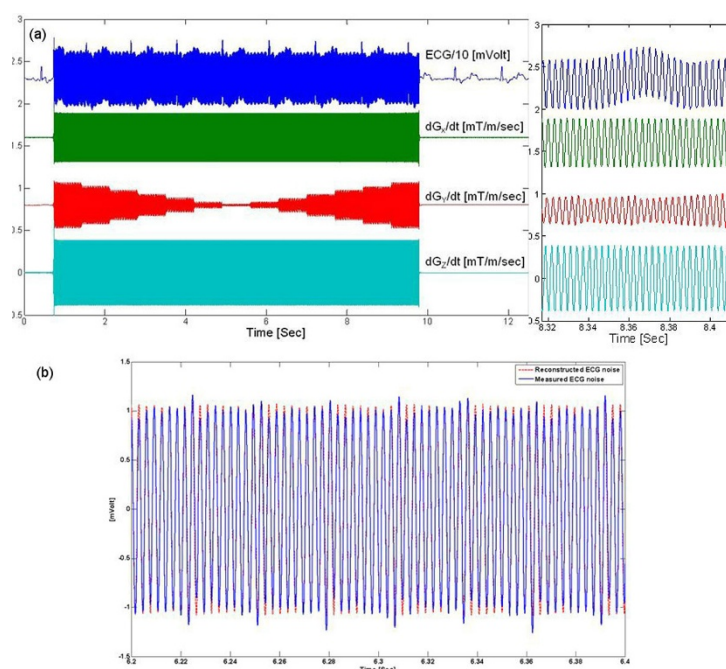


Figure 1 (a): One representative ECG trace (V5) and gradient waveforms derivatives from the X, Y and Z axes during a transverse (Z, or Superior-Inferior, slice encode) SSFP acquisition, with frequency encoding along x (Right-Left) and phase encoding along Y (Anterior-Posterior). A time domain magnification (right), shows the gradient derivative signals (only 0 to 500 Hz are shown). (b): Plots of measured ECG noise (solid blue) and computed ECG noise vector (dashed red) based on the fitted parameters. There is an 18% difference between the reconstructed and measured ECG noise.

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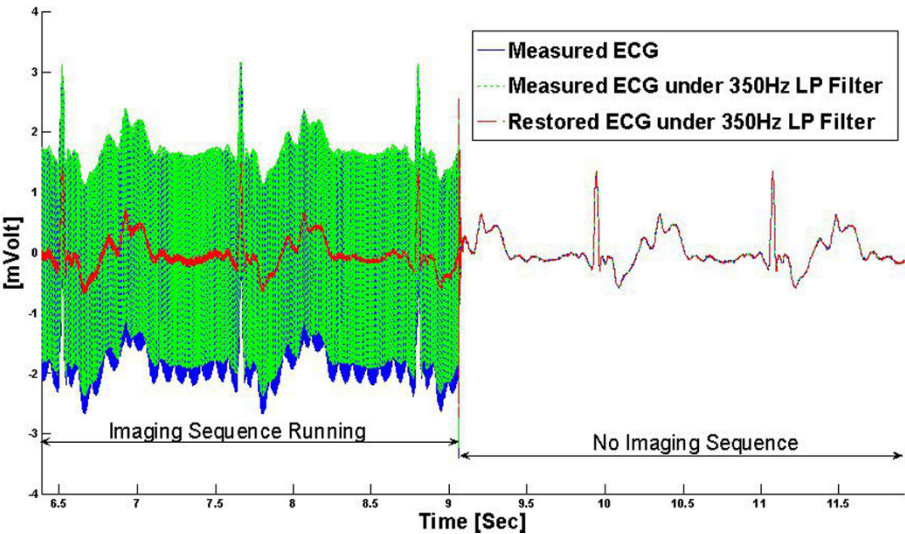


Figure 2 During Imaging, the restored ECG (red line) signal preserves the same signal shape as the ECG has in the absence of imaging (no gradient switching), while low-pass (LP) filtering (green dashed line) fails to clean the gradient-induced artifacts.

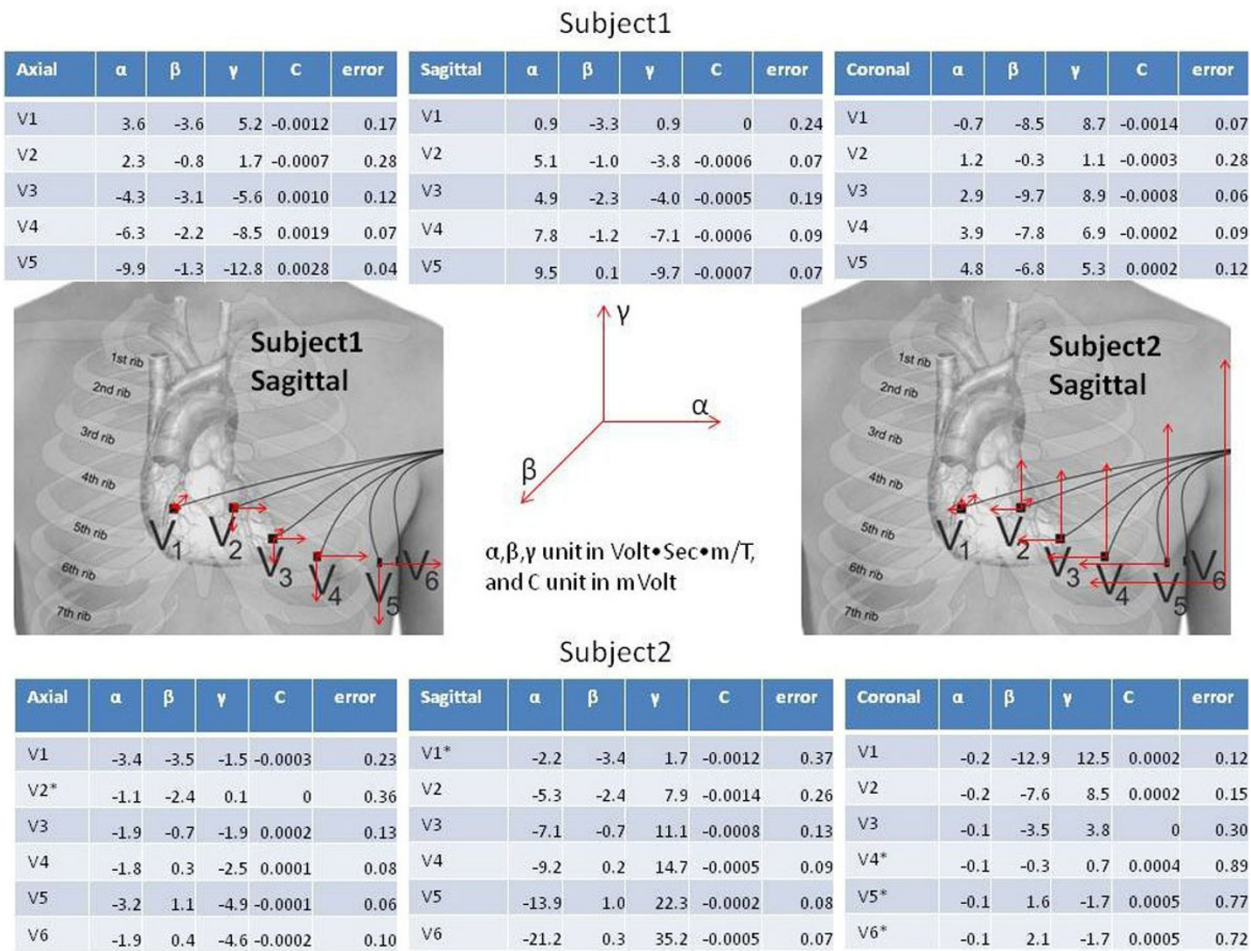


Figure 3 The fitted parameters for three SSFP acquisition orientations are listed for Subject 1 (top) and subject 2 (bottom). The 3D vector plots in the center illustrate graphically sagittal acquisitions in both subjects utilizing phase-encoding along Y (Anterior-Posterior) for the precordial electrodes V1-V6. A gradually increasing influence of the magnetic gradient fields on the ECG noise was observed from V1 to V6.

studies have shown a linear relationship between electric fields and the temporal derivatives of the magnetic field gradients [2,3]. We propose an algorithm to restore the true ECG signal by subtracting system response functions, based on the MR gradient signals, from ECG signals distorted by gradient interference.

Methods

Data Acquisition: An MRI-conditional 12-lead ECG system [1] was used to acquire data on two healthy volunteers inside a 3T MRI. Outside the MRI room, high-fidelity ECG traces, along with the x, y and z gradient waveforms were digitally recorded simultaneously at 62kHz. Balanced SSFP sequences with various slice orientations (axial, coronal, sagittal and oblique) were acquired. **Data Analysis:** The gradient-induced ECG noise was computed as the difference between aligned ECG traces with and without MR sequence running. The noise voltage (V_{ni}) at each electrode (i) was modeled as a linear combination of gradient derivatives and system factors, $V_{ni} = \alpha_i \cdot dG_x/dt + \beta_i \cdot dG_y/dt + \gamma_i \cdot dG_z/dt + C_i$, where α_i , β_i , γ_i and C_i are position-dependent. These parameters were then used to reconstruct the noise, for comparison with the measured ECG noise, and to further derive the restored ECG.

Results

The recorded ECG traces and low-pass filtered gradient derivatives are displayed in Figure 1a. The computed noise vector (V_{ni}) and the measured noise (Figure 1b) had differences of $21\% \pm 20\%$ in normalized Euclidean distance. The restored ECG signal was comparable to the clean ECG segments (Figure 2), providing higher signal quality and fidelity relative to low-frequency filtering of the ECG signal. Vectorial display of the fitted parameters (Figure 3) demonstrated systematic changes across the precordial leads, and varied in magnitude between subjects.

Conclusions

The gradient-derivative model closely fit the measured ECG noise, possibly allowing for efficient gradient-noise removal utilizing rapid calibration scans, combined with hardware blocking of extremely high noise intervals.

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