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12-lead ECG in a 1.5 Tesla MRI: Separation of real ECG and MHD voltages with adaptive filtering for gating and non-invasive cardiac output

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Introduction

The Magneto-Hydro-Dynamic (MHD) effect arises when conductive blood flows in the MRI magnetic field (B_0). MHD generates a voltage which distorts the real electrocardiogram (ECG_{real}), especially during the S-T segment where flow from the left ventricle (LV) into the aorta contributes to a large MHD voltage [1]. A dominant QRS and undistorted S-T segment are important for MRI gating and physiological monitoring for ischemia during cardiac imaging/interventions [2].

Purpose

We hypothesized that adaptive filtering could separate between MHD and ECG_{real}, and that the MHD signal could non-invasively estimate cardiac output.

Methods

MRI-compatible 12-lead ECGs were acquired with a modified ECG-recording system [3] from three healthy volunteers and one patient with idiopathic outflow tract Premature Ventricle Contractions (PVCs) (Ejection Fraction 20-25%, LV wall thickening, mitral regurgitation). Three sets of 20-sec breath-held ECGs (Fig. 1), were measured in a 1.5 scanner with subjects placed (i) outside the scanner with their head-in ($ECG = ECG_{real}$), (ii) at iso-centre with their head-in ($ECG = ECG_{real}+MHD_{head\text{-}in}$), and (iii) at iso-centre with their feet-in ($ECG = ECG_{real}+MHD_{feet\text{-}in}$), which reverses B_0 polarity ($MHD_{feet\text{-}in} \sim -1 \times MHD_{head\text{-}in}$). Data processing (Fig. 2) involved application of an adaptive Least-Mean-Square filter to (ii) and (iii), whilst (i) was used to train the filter to decouple the MHD signal from ECG_{real}.

Results

Fig. 3(a-d) show processing of the patient's V6 ECGs in positions (ii) and (iii). MHD signals are effectively

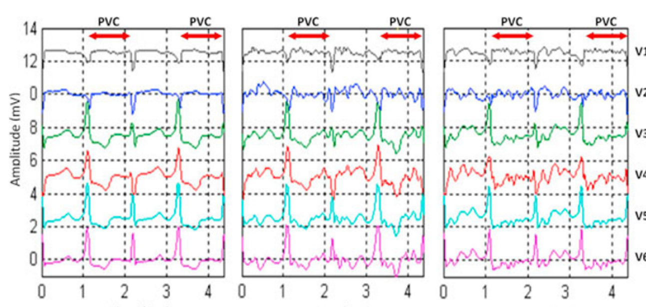

Figure 1
Unprocessed PVC patient ECGs.

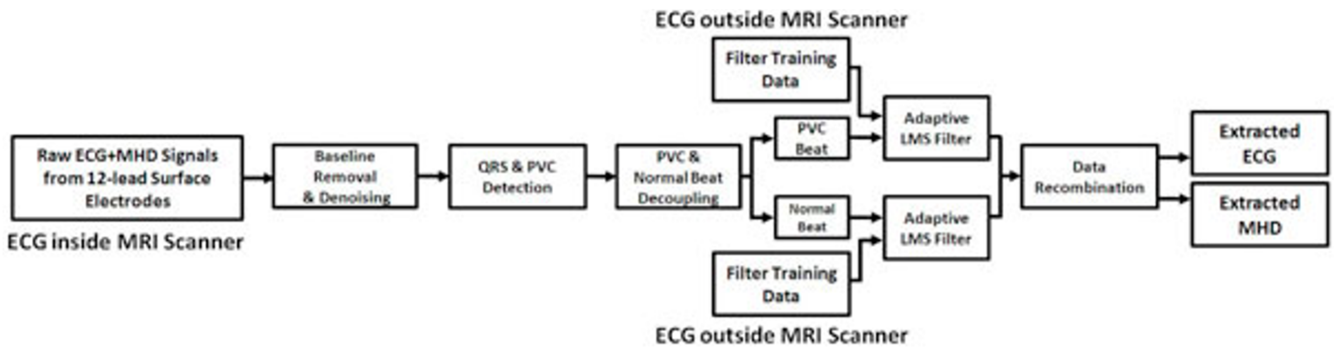

Figure 2
Adaptive filtering procedure.

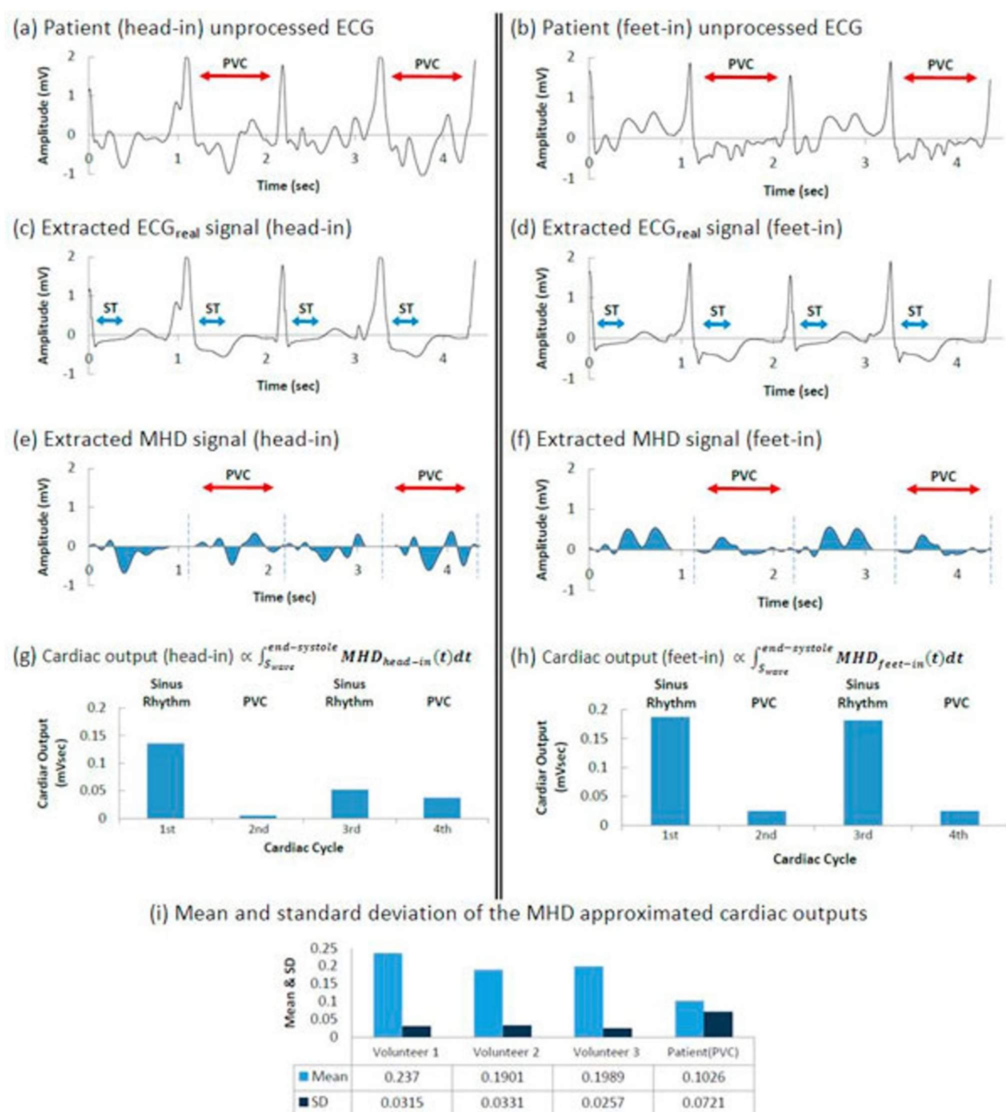

Figure 3
(a-h) PVC patient ECGs at iso-centre. (i) Cardiac outputs of healthy volunteers versus the patient.

removed in Fig. 3(c-d), showing ECG_{real} with the S-T seg ment preserved. The MHD signals, Fig. 3(e-f), are maximal during the S-T segment. Oscillating positive and negative MHD voltages during systole in each PVC cycle can be explained by flow eddies, consistent with the patient's mitral regurgitation. Fig. 3(g-h) show the cardiac output, calculated from the systolic time-integrated MHD. Cardiac output during PVC cycles is much smaller than during normal beats. Fig. 3(i) indicates that the PVC patient's average cardiac output is 44-54% of the healthy volunteers', due to less effective PVC beats.

Conclusion

The filtering procedure separates the ECG_{real} and MHD signals in 12-lead ECGs acquired within the MRI. The QRS complex becomes dominant, as required for good MRI gating, while preserving S-T segment fidelity for physiological monitoring during imaging/interventions. MHD signals allow for non-invasive monitoring of beat-to-beat cardiac output.

References

1. Gupta : *IEEE Trans BioMed Eng* 2008.
2. Haberl : *ECG pocket, Borm Bruckmeier Publishing*; 2006.
3. Dukkipati : *Circulation* 2008.