Non-linear Bayesian suppression of Magnetohydrodynamic effect for accurate Electrocardiogram analysis during MRI.

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Target audience: The development of MRI guided surgery and intra-cardiac electrophysiology is currently limited by the unavailability of diagnostic value Electrocardiogram (ECG) traces within MRI [1,2]. The cardiovascular status of the patient undergoing such procedures needs to be assessed to enhance the patient safety as well as utilize the ECG to diagnose disease sources and monitor the effectiveness of therapy.

Purpose: ECG is highly distorted inside the MRI bore by the MagnetoHydroDynamic (MHD) effect, which is caused by the flow of electrically charged particles in the blood in the presence of the high static magnetic field and whose main contribution arises from the blood ejection through the aortic arch [3]. This effect thus superimposes on the ECG signal and is strong in the ECG's ST segment and T wave, which are used for the detection of ischemic events or pathological repolarization. The aim of this study was to develop an accurate MHD suppression technique in order to provide diagnostic quality ECG.

Methods: A non-linear Bayesian filtering has recently been proposed for the suppression of the MHD effect [4]. This technique relies on *prior* knowledge of the dynamics of both the ECG and MHD contributions, which have been modeled as a pseudo-periodic sum of Gaussian functions. This technique has been quantitatively assessed on sets of synthetic data simulating pathological ventricular repolarization with accurate QT interval measurements and T wave inversion detection [4].

Three sets of ECG data were acquired on two patients within a 1.5T MRI scanner for both and a 3T for the second (General Electric, Wawkesha, Wi, USA). The recordings were performed with an experimental MRI conditional 12-leads ECG system [5]. For each set of data three 20s recordings were acquired in the supine position, the first acquisition was performed outside the MR bore, while the second and third recordings were performed inside the MR bore with the patient feet-first and head first respectively. The first two recordings were used for parameter initialization by extracting the ECG and MHD templates and for estimation of the Gaussian parameters. The Bayesian MHD suppression technique was then applied to the third recording.

This proposed technique was compared with an Independent Component Analysis (ICA) method, which is a standard method for blind source separation, which was previously proposed for ECG denoising [6]. ICA may benefit from the recordings of 12 leads, as more sources can be extracted relative to commercial intra-MRI ECG acquisitions in where only 4 leads are available.

Results: The results of the denoising by both methods on the three datasets are depicted in figures 1 to 3. These figures show the raw ECG trace of lead V5 inside the MRI on the top right, with the template computed outside the MR bore on the top left and the signals denoised by ICA (bottom left) and by the Bayesian MHD suppression method (bottom right).

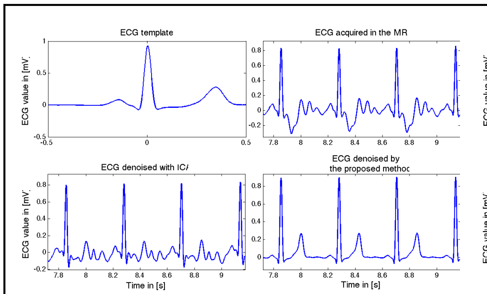

Fig. 1: Results of denoising on first dataset (1.5T)

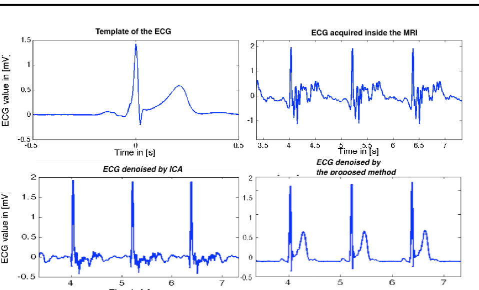

Fig. 2: Results of denoising on second dataset (1.5T)

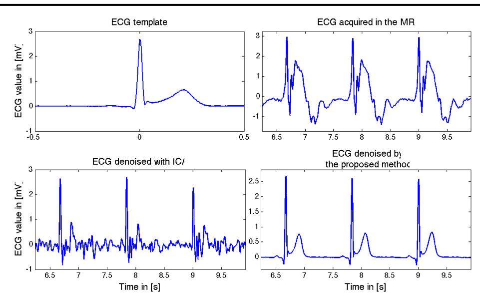

Fig. 3: Results of denoising on third dataset (3T)

Discussion: Visual comparison of the denoised signals with the ECGs acquired outside the MRI demonstrates that the Bayesian MHD suppression technique offers a signal whose morphology is closer to the ECG template than that resolved from ICA. The characteristic waves of an ECG signal can be delineated and thereafter analyzed on the signal whereas this is not true for the signal denoised by ICA. A quantitative analysis of the denoised ECG can nevertheless not be conducted since the ground-truth of the ECG morphology is not available. Experiments with real ECG acquisitions for the assessment of pathologic rhythms detection have still to be designed since quantitative comparison is essential before applying the method in clinical conditions.

Conclusion: The Bayesian MHD suppression approach seems very promising for providing ECG signals with diagnostic quality. Its application on real data showed no unpredicted behavior of the technique but quantitative quality assessment has still to be performed before the method can be used in clinical practice for safer MRI-guided surgery, cardiac catheterization and intra-cardiac electrophysiology.

References: [1] Lederman, *Circulation,* 112 (19): 3009-17, 2005. [2] Sommer *et al., Europace,* doi: 10.1093/europace/eus230, 2012.
[3] Keltner *et al., MRM,* 16 (1): 139-149, 1990. [4] Oster *et al., in Proc. of Workshop on BSI (Como),* 7: 97-100, 2012.
[5] Tse *et al., Journal of CMR,* 14 (suppl. 1): 213, 2012. [6] He *et al., Neural computing and applications,* 15 (2): 105–116, 2006.