PhD Thesis Title: 'Magnetohydrodynamics Present in Physiological Signals and Real-Time Electrocardiography during Magnetic Resonance Imaging'

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ABSTRACT:

The Electrocardiogram (ECG) is a clinical standard for monitoring patient heart activity. Several issues in obtaining high-fidelity ECGs have been studied that arise during Magnetic Resonance Imaging (MRI), reducing the ability of the ECG to be used for (1) cardiac Magnetic Resonance (MR) gating/synchronization, and (2) physiological monitoring during conventional MR imaging, interventional procedures, and cardiac stress tests.

This dissertation examines Magnetohydrodynamic (MHD) and MR Gradient Switching induced voltages known to result in low-fidelity ECG recordings, and aims to (1) develop a system to deliver clean ECG traces inside the MR scanner, (2) improve the state of cardiac MRI-ECG gating, and (3) derive blood flow information from extracted MHD signals intra-MRI. Through this study, this dissertation endeavors to enhance ECG-gated MRI scans, and improve patient physiological monitoring during imaging and interventional procedures, especially for high-risk patients who may have stroke and ischemic history, who are intubated, and those who might be currently excluded from MRI due to lack of real-time physiological monitoring.

The MHD effect is a physiological phenomenon that occurs due to the interaction of the strong magnetic field of the MRI with blood plasma electrolytes that are rapidly ejected into the aortic arch during the systolic phase of the cardiac cycle. This effect is studied through induced MHD voltages in 12-lead ECG recordings, revealing differences in signal envelopes of induced MHD voltages, cardiac arrhythmias, and the true ECG.

The inherent relationship of induced MHD voltages with cardiac blood flow leads to the further expansion of the current body of literature by examining potential applications of extracted MHD signals. MHD-derived blood flow and Stroke Volume metrics will allow for increased information to be obtained by overseeing physicians during a typical clinical workflow, which can be processed and displayed to the end-user in real-time during imaging and interventional procedures, allowing for improved patient monitoring.

This dissertation expands upon the current body of literature to provide methodology for the delivery of high-fidelity ECGs intra-MRI, and prove clinical relevance of MHD distortions found in these ECG recordings; further allowing for the reduction of patient complications associated with conventional MRI clinical workflows and interventions.

References to author publications that relate specifically to the dissertation:

Peer-Reviewed Journal Articles

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[3] T. S. Gregory, K. J. Wu, J. Yu, J. B. Box, R. Cheng, L. Mao, et al., "Magnetohydrodynamic-Driven Design of Microscopic Endocapsules in MRI," IEEE/ASME Trans. Mechatronics, Vol. 20(6) pp 2691-2698, 2015.

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