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ENHANCING ULTRASOUND WITH ELECTRICAL IMPEDANCE TOMOGRAPHY FOR DEEP SPACE MEDICAL IMAGING

Abstract

A critical medical capability lacking for deep space and long-duration missions is the ability to monitor and diagnose tissue injury within physical spacecraft constraints and communication limits. Ultrasound is the medical imaging system used on the International Space Station, but this complex technique often requires telemedical support for proper acquisition and interpretation, making it a challenging solution for crews isolated in deep space. Significantly higher contrast at injury sites can be obtained using electrical impedance tomography (EIT) to image the bioelectric properties of tissue, as these are sensitive to cellular content, blood flow, tissue type, and tissue injury. EIT is a low resource, non-invasive, non-ionizing imaging technique capable of detecting a range of acute injuries and monitoring physiological effects of long-duration space travel (e.g. internal bleeding, tissue injury, muscle atrophy, thoracic function, cancer presence). Enhancing ultrasound with EIT (US-EIT) can provide high-contrast images for more effective acquisition and interpretation without the need for additional equipment or expertise. An integrated US-EIT system will provide a low cost, low-resource imaging solution that can accurately characterize internal injury while meeting space travel constraints, allowing isolated crews to independently diagnose injury and monitor medical risks associated with deep space exposure.

An FPGA-based multi-channel, multi-frequency EIT data acquisition (DAQ) is being developed for integration with the Vivid E95 Flexible Ultrasound System (FUS) as a space-deployable US-EIT system. The DAQ hardware was evaluated using discrete resistors, and benchtop tests are being performed to assess key specifications, including signal-to-noise ratio, measurement accuracy, power limits, and bandwidth. A 16-channel electrode array was designed to fit the FUS C1-6 transducer for an integrated US-EIT probe capable of imaging (and detecting) deep internal bleeding within the abdomen. US-EIT imaging experiments performed on non-biological phantoms with varying impedance profiles validate probe functionality and demonstrate image accuracy and sensitivity. Software developed in MATLAB overlays the EIT conductivity map on top of the ultrasound image, in a sense “highlighting” the injured tissue or phantom. Real-time US-EIT image reconstruction will be integrated directly with the FUS software as an enhancement to ultrasound acquisition. This system will ultimately be used to validate US-EIT for internal bleeding detection on a porcine model.

Coupling EIT with state-of-the-art ultrasound equipment will provide a space-compliant medical imaging system that can accurately distinguish internal pathologies, enabling crew members to be proactive in the event of injury on long-duration deep space missions.