MULTIMODALITY REGISTRATION AND VISUALIZATION OF MR AND ULTRASOUND VOLUMES FOR LONGITUDINAL TRACKING OF OCULAR STRUCTURES
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INTRODUCTION
The long-term objectives are to develop multimodality volume registration methods of in-flight ultrasound scans with pre- and post-flight MR ophthalmic scans and to enhance the ability to longitudinally track ocular structural alterations in response to microgravity and correlate these ocular structural changes with elevated ICP and visual acuity changes. Volumetric ultrasound imaging has the potential to improve the reliability of in-flight ocular measurements, as well as decrease crew time and reduce ground guidance required for image capture. The current ISS ultrasound hardware does not support 3-D imaging, but prototype hardware to retrofit Ultrasound 2 with volumetric imaging capability has been developed and is currently being tested in vitro on ultrasound imaging phantoms.

METHODS
The approach consists of first registering coordinate frames for MR and ultrasound volume scans acquired under similar conditions, as would be part of the pre-flight evaluation scans, assuming a rigid model for the ocular structure between the two pre-flight scans. Then multiple in-flight ultrasound volumes are registered with each other and with the pre-flight ultrasound volumes through a deformable model of the ocular structure. Finally, the last in-flight ultrasound scan is registered with post-flight ultrasound scans using a deformable model and the post-flight ultrasound and MR scans are registered using a rigid model.

In addition to the multimodality registration of the MR and ultrasound volumes, techniques are being developed for offline analysis of the volumetric ultrasound data to visualize and measure ocular structures in 3-D. The current work includes side-by-side display of co-registered slices through the MR and ultrasound volumes and a simplified interactive rendering of a virtual 2-D ultrasound imaging plane within the volume to identify the slice orientation for optimal visualization of the optic nerve sheath. A multi-platform, open source software platform for medical image visualization and analysis (3D Slicer from www.slicer.org) serves as the development platform for the offline 3-D visualization tool.

RESULTS
The initial development of the rigid body multimodality registration and interactive rendering has been conducted using in vitro and MR data. The multimodality volumetric registration has been tested on MR and ultrasound volumes collected on a near field ultrasound imaging phantom (CIRS Model 050, Norfolk, VA) with several nonspherical inclusions of known volume, while the interactive rendering of the optic nerve has been developed using MR data from an ocular exam. The ultrasound volumes were acquired using a prototype mechanical 3-D ophthalmic ultrasound probe and the Ultrasound 2 platform (Vivid q portable ultrasound system from GE Healthcare, Milwaukee, WI). The prototype ultrasound hardware is undergoing safety testing prior to in vivo ophthalmic scanning.

Years 2 and 3 of the grant will include in vivo evaluation of the volumetric ophthalmic imaging. The in vivo evaluation includes demonstration of the multimodality rigid-body registration and ultrasound deformable model registration with ocular scans; development of 3-D ocular metrics for the optic nerve sheath size and posterior globe flattening from the ultrasound volumes; tracking acute changes in the ocular structure for mildly elevated ICP during tilt table experiments; and comparison of the sensitivity of current 2-D and new 3-D anatomical metrics for mildly elevated ICP in human subjects and significantly elevated ICP in an animal model.