Full Wave 3D Inverse Scattering Transmission Ultrasound Tomography: Breast and Whole Body Imaging

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Background, Motivation and Objective

Beginning with early work by Greenleaf and Johnson at the Mayo Clinic in 1974-1980, ultrasound tomography (UST) has developed into a useful modality for breast imaging. Original work by Johnson's group at the University of Utah led to high contrast and spatial resolution images in 2008, which were steadily improved at QT Ultrasound, resulting in FDA clearance for a clinical grade scanner in 2017, the only FDA-cleared modality for 3D transmission ultrasound. Clinical breast data is now being acquired throughout the US. This success has led to our objective of extending UST to more difficult whole body imaging, in the presence of bone and air.

Statement of Contribution/Methods

The ultrasound scanner consists of a plane wave transmitter, a 2048 element receiver array, and 3 adjunct reflection arrays in a water bath. We have developed a fully 3D inverse scattering algorithm that incorporates the 3D nature of the acoustic field, and a concomitant refraction corrected (3D) reflection algorithm that incorporates the speed of sound (SOS) map generated by the inverse scattering reconstruction. We have generalized the reconstruction protocols used for breast imaging to achieve high resolution, speed of sound and reflection images of the whole body. We have quantitatively imaged soft tissue that does not generate an MR signal, near mature bone, and in the whole body of neo-natal piglets.

Results/Discussion

Fig. 1 shows the 3D reconstructions of the SOS of the breast, neo-natal piglets, and the fused speed of sound and reflection images of a human knee. We show the quantitative accuracy and stability of the reconstructions in the presence of bone and air, and contrast and spatial resolution of the SOS and reflection images. We achieve quantitative accuracy of tissue in knee and piglet images, and complete femur/tibia separation with 'volumetric bone reconstruction' protocols. Cartilage and ligaments interior and close to the Femur-Tibia (F-T) space are imaged. The SOS and reflection image of the neo-natal piglet show intestines, internal organs, kidneys, liver, and vertebrae. to high resolution and accuracy, and trans-cranial imaging of the brain tissue.

Conclusion: Transmission ultrasound imaging has high spatial/contrast resolution and is safe for broadly applicable human medical imaging.

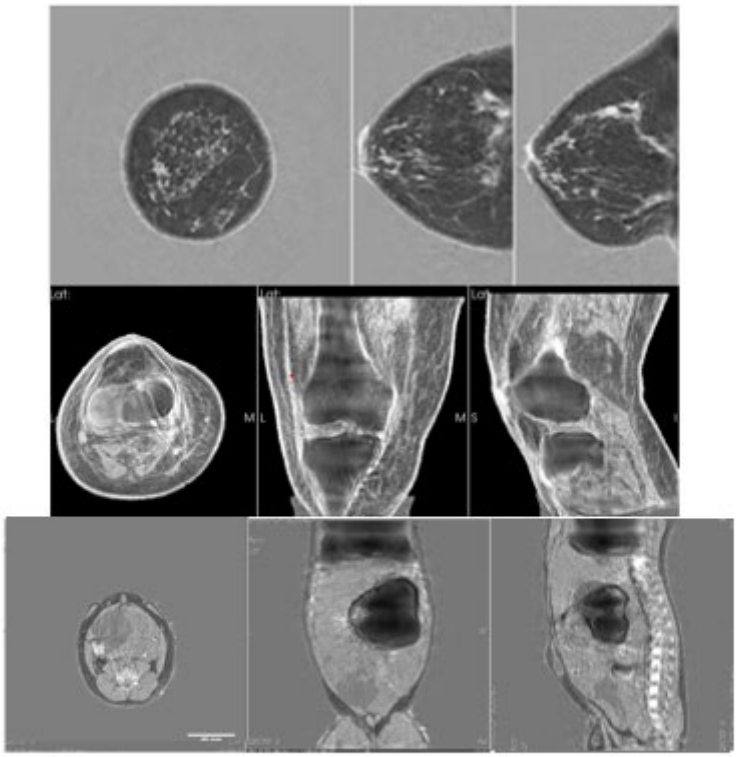

Fig. 1. Top row: coronal, axial and sagittal views of the transmission ultrasound 3D speed of sound map. Second row: axial, coronal, sagittal views of fused SOS and reflection image of mature human knee. Bottom row: axial, coronal and sagittal views of the neo-natal piglet.