Localization of US Focal Spot in In Vivo Tissue Using 3D Acoustic Radiation Force Impulse Imaging

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PURPOSE: The 3D MRI pulse sequence presented here for performing Acoustic Radiation Force Impulse imaging (ARFI) would be especially beneficial for easily and safely localizing the ultrasound focal spot in all three dimensions before an MR guided HIFU treatment. This 3D sequence builds on 2D MR-ARFI techniques [1–3] and provides large volumetric coverage, thus increasing the confidence that the peak beam intensity has been captured. This abstract evaluates the effectiveness of the 3D-ARFI technique when applied *in vivo*.

METHODS: A 3D Spin Echo segmented EPI pulse sequence was modified to include a pair of unipolar motion encoding (ME) gradients and flyback readout (figure 1). An optical trigger is output at the start and end of the first unipolar ME gradient lobe which synchronizes the firing of an ultrasound burst. Experiments were performed *in vivo* in goat udder using a breast-specific transducer system with integrated 11 channel RF coil. The 3D ARFI maps were acquired in a 256x160x24mm volume at 2x2x2mm resolution and zero-fill-interpolated to 1x1x1mm voxel spacing. TR = 250ms, TE = 50ms, EPI factor = 9, BW = 752 Hz/px, FA = 90°, ME_{amp} = 30 mT/m, ME_{dur} = 20 ms, acquisition time = 62 sec, US power = 100 W, δ = 10.2 ms. A second set of experiments were performed measuring temperature over the same volume using a 3D segmented EPI thermometry sequence in order to investigate whether 3D ARFI could predict the location of peak heating. For the heating experiments, TR = 34 ms, TE = 10 ms, EPI factor = 9, BW = 752 Hz/px, FA = 10°, acquisition time = 4.3 sec/meas, US power = 62.5W, heat duration = 30 sec. The 3D ARFI and 3D temperature datasets were compared and the error between the position of peak ARFI phase difference and location of peak temperature change was quantified.

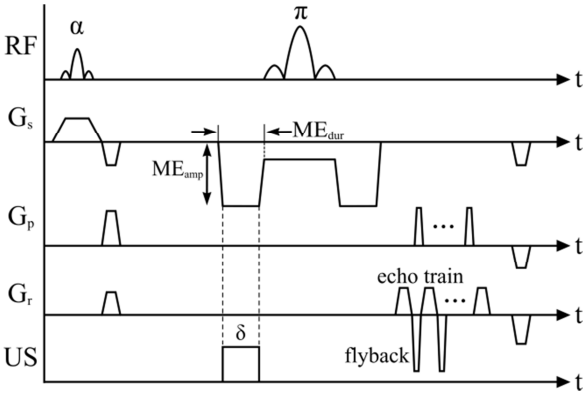

Figure 1: 3D ARFI pulse sequence diagram

RESULTS & CONCLUSION: Figure 2a shows an anatomical image of the goat udder through a coronal plane. Figure 2b (left) shows transverse and coronal slices through the point of maximum ARFI phase signal, while figure 2b (right) shows transverse and coronal slices through the point of maximum temperature. Figure 2c shows the magnitude of the ARFI and temperature measurements through the maximal row of each dataset (row 129). Analysis of the 3D volumes show that the peak ARFI signal occurs at voxel position (129, 68, 20), while the peak temperature occurs at (129, 70, 18) demonstrating that peak ARFI is correlated with peak temperature to within 2mm (1 voxel) in all three dimensions. Thus, *in vivo* testing of the 3D spin echo unipolar ARFI sequence confirmed that it can localize the focal spot in all three dimensions in a single scan.

REFERENCES: [1] N. McDannold, "Magnetic resonance acoustic radiation force imaging," *Med. Phys.*, vol. 35, p. 3748, 2008. [2] J. Chen, "Optimization of encoding gradients for MR-ARFI," *MRM*, vol. 63, pp. 1050-1058, Apr. 2010. [3] E. A. Kaye, "Rapid MR-ARFI method for focal spot localization during focused ultrasound therapy," *MRM*, vol. 65, pp. 738-743, Mar. 2011.

ACKNOWLEDGEMENTS: This work is supported by the Mark H. Huntsman Endowed chair, NIH grants R01 CA87785 and R01 CA134599, The Ben B. and Iris M. Margolis Foundation, NSF IGERT Award# 0654414, and the Focused Ultrasound Surgery Foundation.

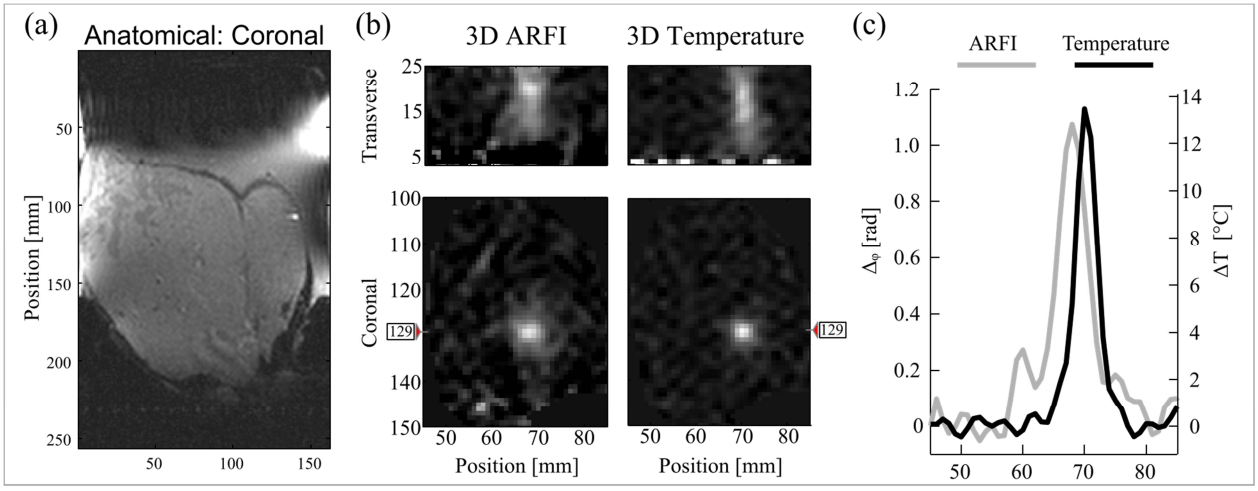

Figure 2: (a) anatomical image of in vivo goat udder (b) ARFI & MR thermometry maps (c) plot through row of maximum ARFI & Temperature