MR Single Shot Fast Spin Echo ARFI

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Introduction: MR acoustic radiation force imaging (ARFI) has been shown to be a means of visualizing a high intensity focused ultrasound (HIFU) focus without the need for applying extensive energy with a thermal test spot. Much work has been performed to improve the speed of MR-ARFI images, although primarily these faster pulse sequences have been EPI-based. While EPI can be sensitive to off-resonance and geometric distortions, fast spin echo sequences are relatively immune to both and can provide even better registration of a HIFU spot to the desired target location. The purpose of this work was to develop and test a modified single shot fast spin echo pulse sequence for ARFI visualization.

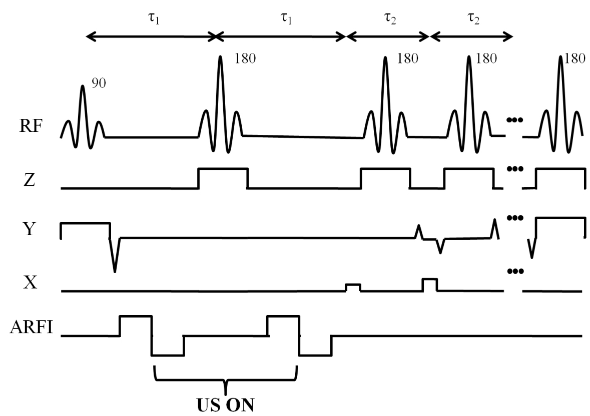
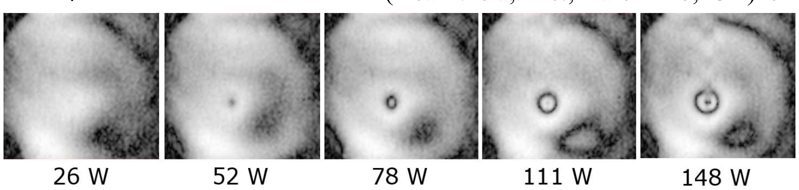


Figure 1: MR-ARFI representative ssFSE pulse sequence with a reduced field of view. Ultrasound is on during the time surrounding the first 180° RF pulse. Small motions due to the acoustic force result in encoded phase. Gradient areas, including crushers, are determined as described in [1-3].

Methods: ARFI experiments were performed on a gel phantom (CIRS, Inc, Norfolk, VA) with the following acoustic properties: speed of sound 1533 m/s, attenuation 0.48 dB/cm/MHz, elasticity 8.5 kPa. Using an extracorporeal 550 kHz Conformal Bone System transducer with 1000 elements (InSightec, Ltd, Tirat Carmel, Israel), an ssFSE rFOV MR-ARFI pulse sequence was created using RTHawk, a real time imaging platform (HeartVista, Inc., Palo Alto, CA) on a 3T GE Signa Excite magnet (GE Healthcare, Waukesha WI). The sequence was similar to DIET sequences previously proposed [1-3], but with the longer TE portions towards the beginning of the pulse sequence. A 20cm by 8cm field of view was performed with outer volume suppression was performed with the first 90 exciting a slab along the phase encode direction, and the subsequent 180s along the slice direction. A partial k-space factor of 0.60 was used, with TE = 93ms. The ultrasound power was on during the second half of the first bipolar encoding pulse through the first half of the second bipolar encoding pulse. MR-ARFI images were acquired both perpendicular and parallel to the HIFU focus location. The HIFU power was varied from as low as 26 acoustic Watts to close to 150 acoustic Watts, the maximum output power for the transducer. In addition to ARFI experiments, images of the ssFSE sequence were taken of a grid in a non-ablation phantom, and compared to the original 30 cm FOV GRE sequence images and those of SE-fbEPI rFOV MR-ARFI pulse sequence[4].

Figure 2: Perpendicular images of the focus with increasing applied HIFU power.



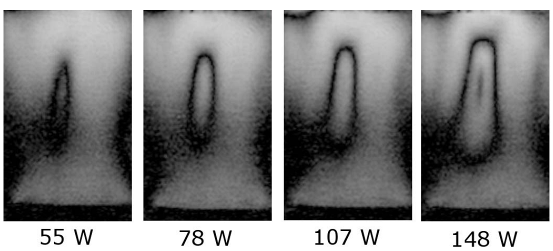


Figure 3: Parallel ARFI images with increased HIFU power.

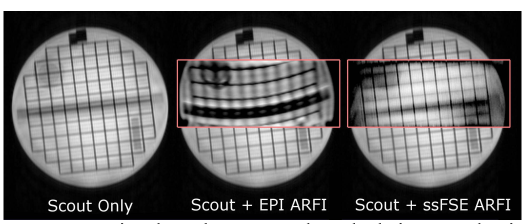


Figure 4: Comparison of 2DFT conventional large FOV scout image to SE-fbEPI rFOV MR-ARFI and the proposed ssFSE rFOV MR-ARFI sequences, shown as overlays. While the slice thicknesses are slightly different, the geometric distortions are reduced in the ssFSE case.

Results: Figure 2 and 3 show magnitude images from the ssFSE ARFI experiments. As the ultrasound power is increased, FSE signal cancellations begin to appear in the phantom, thus helping to depict the focal location. This is expected, as phase errors will periodically cause CPMG violations, leading to periodic signal destruction [5]. Finally, Figure 4 highlights the reduced geometric distortion of the ssFSE pulse sequence compared to a similar EPI trajectory. The ssFSE image's geometric distortions are identical to the acquired larger FOV scout sequence.

Discussion: The images shown here show the feasibility of using ssFSE rFOV MR-ARFI imaging as a means of localizing a HIFU focus. Especially when applying larger powers, the spot can be visualized directly on the magnitude images, with only a single shot (compared to other ARFI methods which utilize repeated scans). The fast spin echo sequence allows for a more accurate representation of the focal location, without potential geometric distortions that can occur with EPI based techniques.

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References: **1**. Kanazawa H. et al. Contrast naturalization of fast spin echo imaging: A fat reduction technique free from field inhomogeneity, in, Proc, SMR, 1994. 474. **2**. Butts K. et al. Dual echo "DIET" fast spin echo imaging, in, Proc, SMR, 1995. 651. **3**. Stables L. et al. Analysis of J coupling-induced fat suppression in DIET imaging. JMR. 136(2); 1999. 143-51. **4**. Holbrook, et al. In vivo MR acoustic radiation force imaging in the porcine liver. Med Phys. 38; 2011; 5081-5089. **5**. Bastin M et al. On the Application of a Non-CPMG Single-Shot Fast Spin-Echo Sequence to Diffusion Tensor MRI of the Human Brain. 48; 2002. 6-14.