Application of 3Dcones Sequence for Ultra-Short Echo Time Imaging

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Introduction:

Ultra-short echo time (UTE) imaging has been proposed as a method for visualizing short T2 relaxation components in the head and has demonstrated the ability to visualize structures such as the dura mater, falx cerebri, bone marrow and short T2 white matter compartments [1]. Previous work has demonstrated UTE imaging using 2D radial [1], 2D spiral [2] and 3D stack-of-spiral [3] imaging approaches. Recently the 3D Cones technique [4] has been presented that combines ultra-short TE capability with an efficient, isotropic 3D acquisition strategy. This work presents preliminary feasibility work for applying the 3D Cones technique in UTE imaging of the human head.

Methods:

3D Cones UTE imaging was performed on a 1.5T MR scanner (Signa HDx, GE Healthcare) using an 8-channel head coil for signal reception. A doped-water QA phantom was used to test the feasibility of the 3D Cones sequence (Figure 1) for UTE imaging of the head and to calibrate sequence-timing parameters. Delays between the start of data acquisition and the onset of the gradients was determined by acquiring additional data samples and evaluating the output signal from the digital receivers and the effects of time shifting the data used in the 3D gridded reconstruction to detect the actual onset of the gradient encoding. Once the appropriate delay was determined, it was used for all subsequent phantom and in vivo studies using the same receive coil. A simple fat-sat preparation prior to the non-selective RF excitation pulse was used to

Figure 1, 3Dcones sequence schematics. The acquisition starts right after the RF pulse and produces a non-Cartesian k-space trajectory.

control for off-resonance blurring of fat. Short-T_2-selective UTE images were obtained through the subtraction of interleaved, two-echo data acquired in an RF-TE1-RF-TE2 scheme. Two echo times (0.1 ms and 1.0 ms or 5.0ms) were acquired. Other sequence parameters were: TR=29 ms, FOV=26x26x26 cm, isotropic 2mm resolution, RBW=125kHz for a total scan time of 90 sec (TE1=0.1ms, TE2=1.0 ms) or 104 sec (TE1=0.1ms, TE2=5.0 ms).

Results:

The cylindrical plastic shell of the QA phantom has very short T_2 and is normally invisible to conventional imaging sequences. Figure 2 shows the images obtained with the interleaved-echo 3D Cones sequence illustrating the decay of the short T2 shell in the late TE (5ms) image. The inner sphere has a longer T2 behaviour and hence in the short-T_2-selective UTE (subtraction) image it is suppressed. Figure 3 illustrates preliminary 3D Cones UTE images of a human volunteer brain illustrating three representative slices, each acquired at TE=0.1ms (left), TE=5ms (center) and the subtraction between these two (right). Many short T2 structures are seen in the short-T_2-selective UTE (subtraction) image including the dura mater, bone marrow of the skull and some signal from the brain parenchyma.

Discussion and Conclusion:

These preliminary results suggest that the 3D Cones acquisition method is feasible for UTE imaging of the human head. Its efficient, isotropic 3D sampling may have scan time advantages over previously reported UTE imaging methods that required 8 min per slice [1], 3.5 min for a 6 cm slab [2] or 2.5 min for a 15 cm slab [3] all with 5 mm through-plane resolution. The isotropic 3D nature of the 3D Cones data may be useful for characterizing the morphology of more complex short T2 structures in reasonably short scan times. More precise gradient delay characterization, gradient compensation blips (as in [2]) and long-T2 suppression pre-pulses [5] are being investigated as means of improving image quality.

References:

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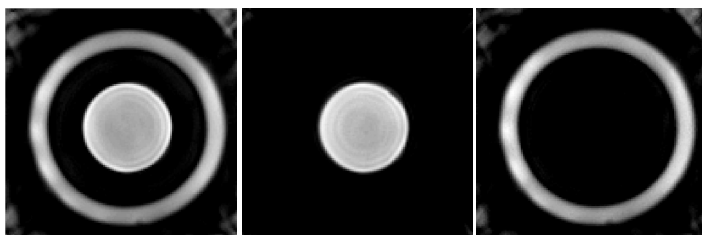
Figure 2, Images of the scan room QA phantom with plastic shell. Left: TE=0.1ms, middle: TE=5ms, Right: UTE subtracted image showing short T_2 plastic shell.
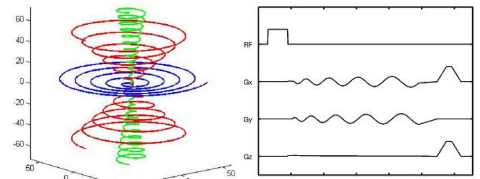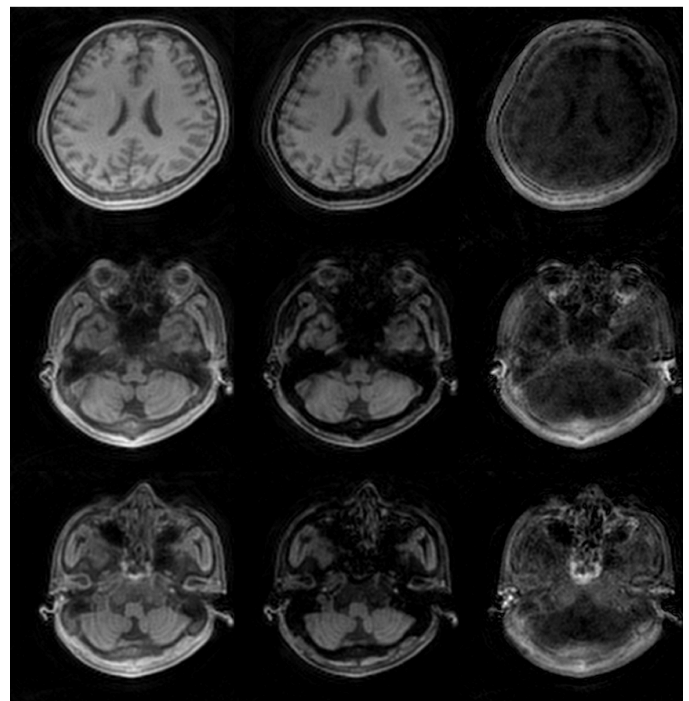

Figure 3, UTE human head images obtained with 3D Cones sequence. Left: TE=0.1ms images; Middle: TE=5ms images; Right: Subtracted Short-T_2 images; 2mm isotropic resolution over 26x26x26 cm volume acquired in 104 sec.