Zero TE bone imaging

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INTRODUCTION:

In this abstract we investigate the feasibility of zero TE imaging[1-3] for depiction of cortical bone in the head and the pelvis. Proton density weighting in combination with a logarithmic image scaling is used to highlight bone structures and differentiate them from soft tissues and background air. Different from prior art, no long T2 suppression methods[4] (like echo subtraction or saturation pre-pulses) are required, rendering the presented method fast, robust and effective. In-vivo volunteer experiments indicate excellent 3D cortical bone depiction as required for instance for PET/MR attenuation correction and MR-based radiation therapy planning.

METHODS:

RUFIS-type zero TE imaging was implemented in the form of non-selective RF excitation followed by 3D center-out radial sampling[1]. The readout gradient active during excitation, limits the RF pulse width to a few microseconds only, generally leading to small flip angles (few degrees dependent on imaging bandwidth) and natural proton density contrast. The pulse sequence demonstrates unique imaging characteristics including a nominal TE=0 and minimal gradient ramping in between spokes leading to sub-millisecond TR and virtually silent scanning. Image reconstruction was performed using standard 3D gridding followed by gradwarp and RF shading correction. In order to highlight bone structures and differentiate them from soft-tissue and background air a logarithmic image scaling operation (i.e. -log(image)) was used. Zero TE imaging was performed in healthy volunteers on a Discovery MR750w 3.0T scanner using GEM coil arrays (GE Healthcare, Waukesha, WI). Imaging parameters used are described in the corresponding figure captions.

RESULTS:

Figure 1 shows zero TE images in linear and -log(image) scale in the head and the pelvis. The logarithmic scaled images appear CT like with uniform soft tissue being cold and bone mid-tempered against a hot noise (/air) background. High resolution and SNR, uniform PD contrast in combination with a logarithmic image scaling leads to excellent cortical bone depiction even at challenging regions like the sinuses in the head. Outside the body otherwise invisible plastic components of the RF coils and table are visible as well.

Figure 2 compares axial zero TE images acquired at three different imaging bandwidths of ±125kHz, ±62.5kHz, and ±31.25kHz. The highest bandwidth (±125kHz) with the fastest k-space sampling (4μs dwell time) provided the most uniform soft-tissue contrast and sharpest bone signal response with least amount of off-resonance blurring. This is also evident from the image histogram distributions showing two distinct peaks corresponding to soft-tissue (lower peaks) and noise/air (upper peaks), which become distorted at lower imaging bandwidths (cf. red curve for ±31.25kHz). Conversely, the bone signal response is distributed over a wider range in between the two peaks indicating larger variations in proton density and relaxation times as well as partial volume effects.

Figure 3 shows three-class (air, soft-tissue, bone) segmentation results obtained for the ±62.5kHz zero TE dataset shown in Fig.2. Segmentation was performed using two threshold values automatically derived from the center and full width half-maximum of the signal and noise peak of the corresponding image histogram.

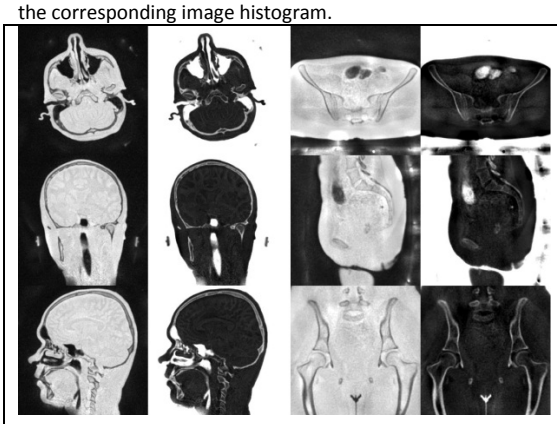

Figure 1: Head and pelvis zero TE scans in linear and -log(image) scale. Bone, soft-tissue, and air can be clearly differentiated in the logarithmic scaled images. Head protocol: FOV=32cm, res=1mm, FA=0.8°, BW=±125kHz, 409600 spokes, ~8min. Pelvis protocol: FOV=40cm, res=1.6mm, FA=0.6°, BW=±125kHz, 262144spokes, ~4min.

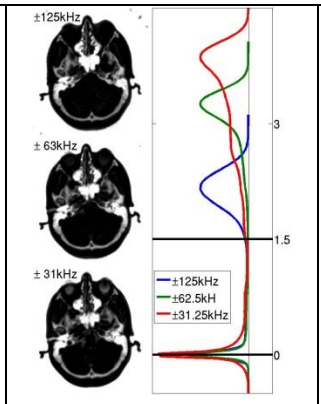

Figure 2: -log(image) scaled axial views (FOV=26cm, res=1.4 mm, 147456 spokes, ~3-5mins) comparing three different BWs (left) and image histograms and window level [0, 1.5] (right).

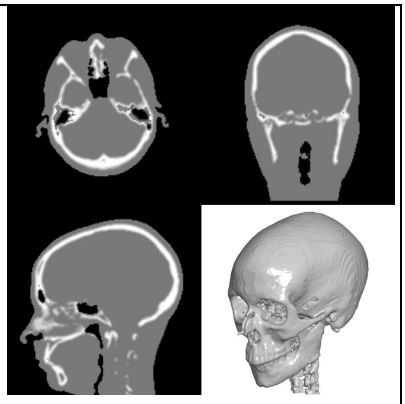

Figure 3: Three-class (air, soft-tissue, bone) segmented zero TE images and 3D rendered volume projection derived from BW=±62.5kHz dataset shown in Fig. 2 (FOV=26cm, res=1.4 mm, FA=1.2°, 147456 spokes, scan time 2:53).

DISCUSSION / CONCLUSION:

Excellent 3D cortical bone depiction in the head and pelvis was achieved using zero TE imaging in combination with an inverse logarithmic scaling. Proton density weighting provides a flat uniform image contrast, favorable for simple threshold based image segmentation. In contrast to prior art no long T2 suppression methods (like echo subtraction, or pre-pulses) have been used, rendering the presented method fast, robust and effective. As a next step, the method will be investigated in patients and compared relative to gold-standard CT.

REFERENCES: [1] Madio et al, MRM 34 (1995); [2] Weiger et al, MRM 66 (2011); [3] Grodzki et al, MRM 67 (2012), [4] Du et al, MRI 29 (2011).