Feasibility of Ultrashort Echo Time (UTE) MR Imaging at 1.5 T in the Diagnosis of Skull Fractures

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Target audience: Researchers and clinicians interested in ultrashort echo time (UTE) MR imaging of skull structures and fractures

Purpose: Currently, CT is an essential imaging modality available for assessing skull fractures in craniocerebral trauma patients. However, the major drawback of CT is the ionising radiation and consequently, the risks of radiation-induced side effects [1, 2]. It is especially true in paediatric patients, in whom radioactive rays pose a great threat to actively mitotic cells and the risk of cancer is significantly higher than in adults [3]. Therefore, developing a non-radiation imaging method to take the place of CT is of great importance. In this study we investigate the feasibility of UTE MRI in diagnosing skull fractures using a clinical 1.5 T scanner.

Methods: The skull fracture specimens of 10 Bama pigs and 364 craniocerebral trauma patients underwent head CT (General Electric, Milwaukee, Wis, USA), 3D-UTE dual-echo (**Fig.1**) and conventional MRI sequences scans (Philips Medical Systems, Best, The Netherlands). An eight-channel SENSE head coil was selected. **UTE imaging parameters:** TR 8-12 ms; TE echo1/echo2 0.08-0.35/ 2.3-4.6 ms; trajectory delay 1-4 μs; FOV 256 mm × 256 mm × 140 mm; flip angle 25°; NSA 1; slice thickness 1/2 mm; slices 140/70; scanning time 16/8 min. **Post-processing:** The coronary, sagittal images of UTE MR and CT and three-dimensional surface shaded display (3D-SSD) images of CT were reconstructed at a GE AW_4.2 workstation (Advantage Windows 4.2 General Electric Medical Systems, USA) (**Fig.2b, 2c, 2e, 2f, 2g**). The length of linear fracture (LF) was measured using the technique of curved planar reconstruction (CPR) (**Fig.2h, 2i**), and the depth of depressed fractures (DF) was measured with a straight line on the same slice of UTE and CT images. The anatomical measurement (AM) under direct vision of skull fractures was performed to the specimens. AM and the measurements on CT images were taken as the gold standard. **Statistical analysis:** The accuracy of UTE in diagnosing skull fractures was analyzed by receiver operating characteristic curve (ROC), Mc Nemar test and Kappa value. The differences in measuring LF and DF were compared by one-way ANOVA and paired-samples T test.

Results and Discussion: UTE sequences clearly demonstrated the skull structures including the inner and outer tables, trabecular bone of diploe, cranial sutures and fractures both in the skull specimens, the paediatric and adult patients (**Fig.1c-1e, Fig.2**). We have further determined that UTE imaging can define the skull fractures clearly in terms of number, length, depth, dislocation and extending direction of fractures, which are not observable on conventional MRI. For the 10 skull specimens, 42 LF, 13 DF and 3 comminuted fractures (CF) were evaluated, with 2 LF missed by UTE. For the 364 craniocerebral trauma patients, 44 patients with skull fractures (31 males, 13 females; 27 adults, 17 children) were evaluated with UTE. There were 55 LF, 10 DF and 3 CF with one LF in the mastoid process of the right temporal bone that was missed. The accuracy, validity and reliability of UTE were excellent and the differences in expert reading were not statistically significant (AUC=0.94, $P>0.05$, Kappa=0.899). In the 42 LF and 13 DF of 10 specimens diagnosed by CT, UTE and AM, in the 55 LF and 10 DF of 44 patients diagnosed by CT and UTE, the measurement differences were not statistically significant, respectively ($P>0.05$) (**Table 1**).

Conclusion: UTE sequences is a feasible, non-radiational method for evaluating skull fractures in children and adults with a 1.5 T MRI scanner. Particularly, paediatric and pregnant patients will benefit from this study.

References: [1] Schmidt CW, Environ Health Perspect 2012; 120:A118-121. [2] Hall EJ, etal., Br J Radiol 2012; 85:e1316-1317. [3] Frush DP, Pediatr Radiol 2011; 41 Suppl 2:483-487.

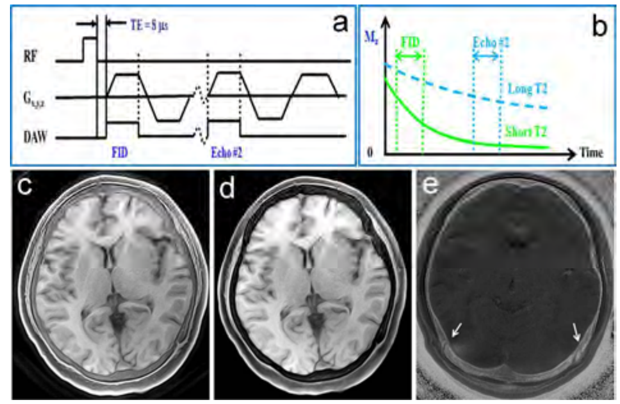

Fig. 1 a-b Pulse sequences diagram for 3D-UTE dual-echo imaging. **a** Contrast image for short T2 species was generated by acquisitions using dual-echo UTE, **b** The diagram showing the corresponding short T2 contrast for each approach. **c-e** UTE imaging of a volunteer. **c** 1st echo, **d** 2nd echo, **e** subtraction image, the trabecular bone of diploe and lambdoidal suture (*arrows*) are shown clearly. TE: echo time; RF: radio-frequency pulse; $G_{x, y, z}$: the gradient of x, y, z direction; FID: free induction decay

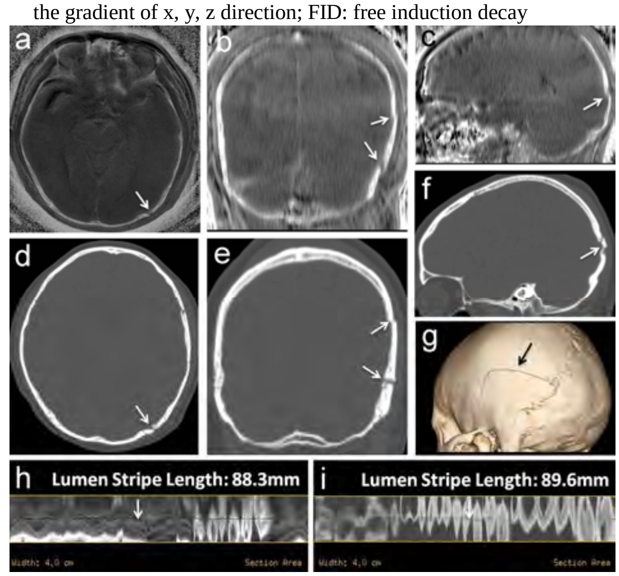

Fig. 2 Male, 68Y, falling to the ground from a 3-meter-high ladder. UTE images (a-c), CT images (d-f), CT 3D-SSD image (g) show the LF of the left temporal and parietal bones (arrows). The CPR images of UTE (h) and CT (i) show the length of LF.

Paired-samples T test	Y: CT (mm)	X: UTE (mm)	*T*	*P* value
Length of LF(*n*=55)	69.373±30.577	69.320±30.616	0.463	0.645
Depth of DF(*n*=10)	8.440±2.131	8.280±2.236	0.778	0.456

Table 1 Comparison of mean measurements of skull fractures between CT and UTE in 44 patients ($\bar{X}$ ± S)