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Supplemental material

Development of an ultrafast brain MR neuronavigation protocol for ventricular shunt placement

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Supplemental Materials

Purpose Statement

These supplemental materials are intended for researchers interested in (1) deploying the fast image guided surgery (IGS) scan we developed, (2) evaluating IGS registration accuracy. The PICO parameters are provided and should allow implementation at any institutions with a modern 3T clinical scanner. A supplemental spreadsheet is provided to facilitate calculations of registration error should researchers wish to confirm the accuracy of PICO within their own institution or to test derivative scans. Our goal is that other imaging centers may deploy PICO or improved alternatives, measure the accuracy and reproducibility of the sequences in situ, and compare the quality of other new IGS images they might propose.

Deploying Fast IGS scans: Protocol Development and MRI Parameters

Five established methods were implemented to accelerate the MRI acquisition, include (i) modification of k-space readout direction (i.e. spiral acquisition),[1] (ii) partial k-space acquisition, (iii) sparse sampling of k-space (i.e. compressed sensing; CS),[2,3] (iv) variation of in-plane spatial resolution, and (v) variation in slice thickness. **Table 1** presents parameters from 13 T1-weighted MRI sequences that we used to evaluate these methods. We avoided any hardware-specific acceleration methods which include, (i) improved gradient strength, (ii) improved gradient slew-rate, (iii) multichannel coils, (iv) higher field strength. These hardware-specific methods are not readily deployed at other institutions without capital infrastructure investments.

Phantom pilot experiments allowed preparation of 13 potential scan protocols (including the unmodified baseline sequence S1), which were interrogated with regard to scan duration, ability to achieve accurate surface rendering, and registration accuracy. For baseline comparison, acquisition times of standard practice MR sequences are supplied (**Supplemental Table 1).**

Supplemental Table 1. Acquisition times for standard sequences used for brain imaging.

	T1	**T2**
	Acquisition Time (seconds)	
Limited	90	30
Vendor Standard	204	122
Stealth (IGS)	279	323
PICO (IGS)	25	-

Supplemental Table 1 Legend: Acquisition times for standard sequences used for brain imaging. IGS, image-guided surgery; PICO, Presurgical Imaging with Compressed SENSE for time Optimization.

Evaluating IGS Performance: Calculating Distances and Performing Statistical analysis

To perform the Bland-Altman analysis, location was obtained from a single fiducial in real space, and the difference in distances were calculated to neighboring fiducials in real and image space. This analysis was performed similarly for all fiducials over all participants, with the calculation one pair of fiducials shown:

$$Sj_{distance} = \sqrt{\left(X2_{Sj} - X1_{Sj}\right)^2 + \left(Y2_{Sj} - Y1_{Sj}\right)^2 + \left(Z2_{Sj} - Z1_{Sj}\right)^2} \quad (1)$$

$$IGS_{distance} = \sqrt{(X2_{IGS} - X1_{IGS})^2 + (Y2_{IGS} - Y1_{IGS})^2 + (Z2_{IGS} - Z1_{IGS})^2} \quad (2)$$

$$Bias = Sj_{distance} - IGS_{distance}, Distance = (Sj_{distance} + IGS_{distance})/2, \quad (3)$$

Where j refers to the sequence, i.e. j=1 or j=5, and IGS refers to the instrument, and X, Y and Z are the coordinate locations in mm. The Bland-Altman bias and mean distance were plotted and used to determine overall bias using an unpaired two-tail t-test. Significance was defined as a p-value less than 0.05 throughout. A supplemental spreadsheet (Supplemental TRE Calculator) is supplied to facilitate calculations of TRE, RMSE, and bias.

Supplemental References

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