Radiological and quantitative assessment of Compressed Sensing reconstruction of undersampled 3D brain images

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Target audience Imaging scientists interested in accelerated acquisition, image analysists, radiologists

Purpose Compressed Sensing (CS) promises to reduce scan time for many types of MR examinations[1]. However, very few reports of radiological assessment of CS images are available. Vasanawala et al[2] found that paediatric images reconstructed using CS techniques were rated more highly than those reconstructed with standard parallel imaging. In this study we implemented CS accelerated 3D brain imaging and evaluated its performance in healthy volunteers by radiological assessment of image quality and by quantification of brain volumes.

Methods The study was approved by the Local Ethics Committee and all volunteers (n=6) gave informed consent. Scanning was carried out at 1.5T using the manufacturer's 3D IR-prepared GRE sequence modified to acquire optimised centre-weighted random undersampling of k-space at different acceleration factors. Sequence parameters were TR/TE/TI=10/4/500 ms; flip angle = 8°; matrix 192×192×160 slices; isotropic 1.3 mm voxels. Undersampled k-space data were reconstructed using either translation invariant wavelets in the NESTA algorithm[3] (CS recon) or conventional least-squares (SENSE recon), and the resulting images transferred to a PACS system for viewing. Assessment was by an experienced neuroradiologist blinded to the details. Scoring (range 0 'unusable' to 29 'excellent quality') was based on a combination of diagnostic quality, spatial resolution and presence of artefacts[4]. As an example of quantitative evaluation, images were segmented (SPM8) into grey matter (GM), white matter (WM) and CSF to determine brain volumes.

Results Images (Fig. 1) were acquired from all volunteers at both accelerations. Radiological scores (Fig. 2) showed a clear preference ($p<0.001$) for the fully-sampled images over the accelerated ones (quality 28.0/17.3/13.7/13.8/9.3) for FULL/x4CS/x4SENSE/x6CS/x6SENSE respectively). Total brain volume (TBV, Fig. 3) was not different with acceleration. However, mean GM volume decreased ($p<0.05$) (701/686/680/680/673) ml and mean WM volume increased ($p<0.05$) (503/514/520/514/519 ml). For a given acceleration, CS recon gave higher quality images and more accurate volume estimates than the corresponding SENSE recon.

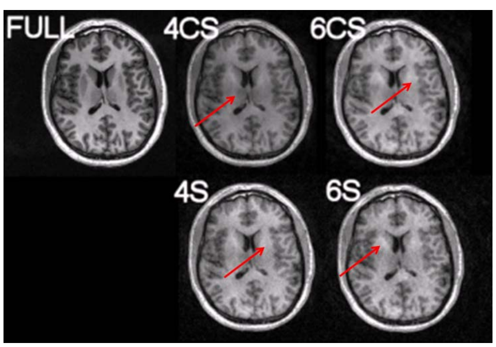

Figure 1. Images reconstructed from full, 4- and 6-times undersampled k-space with compressed sensing (CS) and SENSE (S). Arrows: artefactual brightening of deep GM.

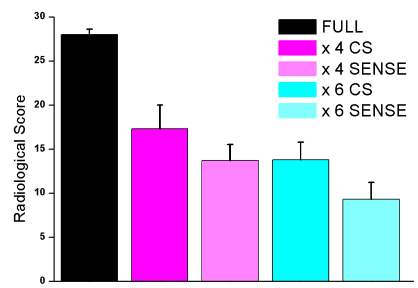

Figure 2. Radiological scores

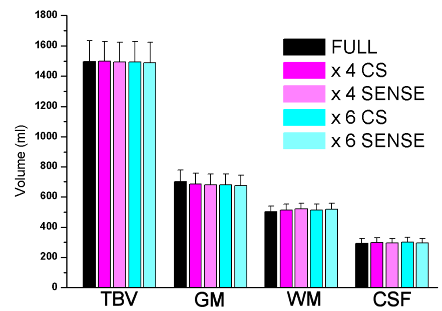

Figure 3. Brain volumes.

Discussion and conclusion

Reconstruction artefacts in many of the accelerated images made radiological interpretation of deep structures more difficult than peripheral structures, and would have obscured central pathology in patients. These artefacts brightened basal ganglia GM causing it to be misidentified as WM (arrows, Fig. 1) and leading to apparent differences in tissue volumes. **Despite using state-of-the-art methods, it is apparent that further work on undersampling and CS reconstruction algorithms is necessary before such methods can be applied in clinical practice.**

References

1. Lustig M. MRM 2007; 58: 1182-1195. **2.** Vasanawala SS. Radiology 2010; 256: 607-616.
3. Becker S. SIAM J Imaging Sciences 2011; 4: 1-39. **4.** Sirin S. Neuroradiology 2013; 55: 1241-1249.