Optimisation of 3D T1-Weighted Imaging of the Brain

D. J. Lythgoe[1], X. A. Chitnis[1], V. Ng[2], G. J. Barker[1]
[1]Institute of Psychiatry, London, England, United Kingdom, [2]South London & Maudsley Trust, London, England, United Kingdom

Introduction

In many institutions, including ours, three-dimensional inversion recovery prepared SPGR datasets are used for both clinical and research studies. In order to make these datasets compatible for comparison, it is imperative that they are acquired with the same optimised parameters. Previous studies have used a range of acquisition parameters, with inversion times in the range 300 – 650 ms and flip angles of 15°- 20° commonly used[1,2,3]. Since optimum parameters will differ depending on *what* is to be optimised, appropriate figures of merit must be used[4], and the purpose for which the images are being collected must be clearly defined.

Aim

Our aim was to devise an optimised SPGR dataset with good contrast and spatial resolution and an acceptable scan time .This must be appropriate both for visual assessment, and for tissue segmentation using packages such as FSL (http://www.fmrib.ox.ac.uk/fsl/). To increase subject compliance, an upper limit on scan time of six minutes was imposed. To allow for requirements of different processing packages, and for the images to be re-sliced to arbitrary planes for visualising and measuring various brain structures, isotropic voxels were deemed essential. The datasets were assessed on the following criteria: (1) performance of automated skull-stripping & segmentation routines (2) good visualisation of deep and cortical grey matter, (3) artefact.

Methods

IR prepared SPGR images of three subjects were acquired on an Excite Twinspeed 1.5 T scanner (General Electric, Milwaukee, USA). For this pulse sequence (which is optimised for speed of acquisition) only a restricted choice of echo times is available, and the repetition time is automatically set depending on the TE and bandwidth selected (here ± 15.63 kHz). Two echo times were used, minimum (1.7 ms; TR = 7.7 ms) and minimum full (5.1 ms; TR = 10.8 ms) with inversion time (TI) of 300 ms, 450 ms or 650 ms. For each combination of TE & TI, the excitation flip angle was varied in the range 10° - 25°.To meet the constraints on scan time and acquisition of isotropic voxels, a volume of 150 near axial (parallel to the AC/PC line) 'partitions' was prescribed in all cases, with a field of view (FOV) 28 x 21cm, acquisition matrix 256 ×160, and slice thickness 1.1 mm, giving 1.1mm isotropic voxels.

The white matter signal-to-noise (SNR) and grey to white contrast-to-noise (CNR) were measured. SNR was defined as the mean intensity over two regions of interest (ROIs) in frontal & occipital white matter divided by the mean intensity of an artefact free ROI outside the brain; CNR was defined as {mean intensity in a grey matter region (left caudate nucleus) – mean intensity in white matter} / noise.

Scans were investigated for quality of skull-stripping, and segmentation using freely available software tools (BET and FAST – part of the FMRIB Software Library (FSL)[5]. FSL was chosen since it is possible to perform the segmentation without using a priori information, *i.e.* the purpose was to assess the image acquisition, not the performance of the segmentation method. We were particularly interested in the quality of segmentation of deep grey matter structures, which are often identified poorly on T1-weighted images. Both the original images, and the segmentation results, were assessed by a radiologist (VN) and by an experienced image analyst (XC).

Results

Preliminary studies with TI = 650 ms (results not shown) produced high SNR & CNS, and skull-stripped well; however segmentation of the subcortical grey matter was very poor. For the rest of the study, more detailed comparisons were made for TI = 300 ms & TI = 450 ms.; SNR & CNR values for the different values of TR, TE & flip angle are given in tables 1 – 3 for TI = 300 ms & TI = 450 ms. Fig. 1 shows examples of image quality obtainable with different parameters. Figures 1a & 1b show example images (of the left superior temporal gyrus) for protocols with TE = 1.7 ms and TE = 5.0 ms, respectively (TI = 300 ms & a flip angle of 18°). Fig 1c & 1d show the grey matter partial volume maps produced by FAST from images with TE = 5.0 ms, flip angle = 18°, and TI 300 ms and 450 ms respectively.

Table 1: TI = 300 ms, TR = 7.7 ms, TE = 1.7 ms

FA	15	16	18	20	22	24	25
SNR	9.9	11.0	12.7	15.0	16.9	18.6	18.8
CNR	4.4	4.9	5.1	5.2	5.7	5.9	6.0

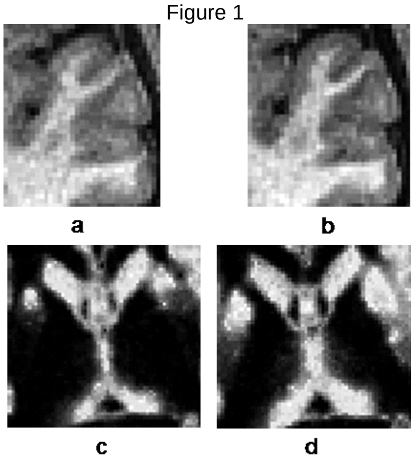
Table 2: TI = 300 ms, TR = 10.8 ms, TE = 5.0 ms

FA	15	16	18	20
SNR	7.4	8.4	10.2	11.6
CNR	3.8	3.9	4.4	4.7

Table 3: TI = 450 ms, TR = 10.8 ms, TE = 5.0 ms

FA	10	12	14	16	18
SNR	7.5	9.8	12.1	14.9	17.3
CNR	4.5	4.6	5.7	5.4	6.2

Figure 1


a b
c d

Discussion

SNR and CNR were higher with fractional echo acquisition compared with full echo acquisition; however, as can be seen in figure 1, acquiring a full echo produces a sharper boundary between grey and white matter. This probably reflects differences in the point spread function between the two acquisitions. Segmentation of the subcortical grey matter was best using a TI = 300 ms, and a flip angle of 18 °. This is illustrated in figures 1c & 1d, where the grey matter partial volume map obtained with TI = 300 ms shows better delineation of the putamen and thalamus than the grey matter partial volume map produced using TI = 450 ms. Again this is counterintuitive, since tables 2 and 3 show higher SNR & CNR at TI = 450 ms. It should be noted, however, that the radiologist scored the TI = 450 ms images higher in terms of visual appearance. The balance between clinical and research use of these datasets will determine the final parameters. In our case, although visual assessment was an issue, automated segmentation was more important, and we settled on an acquisition with TE = 5.0 ms (full echo), TI = 300 ms, and flip angle = 18°.

References

[1] Wetzel *et al*, Am. J. Neuroradiol., 2002, 23, 995 – 1002. [2] Woermann *et al*, J. Neurol. Neurosurg. Psychiatry, 1998, 65, 656 – 664. [3] Whitwell *et al*, Magn. Reson. Imaging, 2004, 22, 993 – 999. [4] Soltanian-Zadeh *et al*, IEEE Trans. Med. Imaging, 1994, 13, 161 – 175. [5] Zhang, Brady & Smith, IEEE Trans. Med. Imaging, 2001, 20, 45 – 57.