Fast and high resolution scans for clinical and neuro-anatomical volumetry studies: sub-millimeter, isotropic-3D MP-RAGE sequence using SENSE in 5 minutes at 3T

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Introduction

The recent arrival on the market of clinical high field (3T) systems with multiple-channels and parallel-imaging capabilities has opened up many new possibilities for clinical imaging. In particular, it is now possible to fully utilize the gain in signal-to-noise ratio provided by the increased field strength to increase the spatial resolution of anatomical scans suitable for quantitative morphometry, while keeping the total acquisition time within clinically relevant limits. This is especially important in patient studies, in which long scan times and small voxel size can become a source of potential failure due to motion-related corruption of the data set. In this study, we optimized a 3D magnetization-prepared rapid acquisition with a gradient echo (MP-RAGE) [1] sequence for use at 3T with an isotropic whole-brain sub-millimeter acquisition ($0.9 \times 0.9 \times 0.9 mm^3$) in only 5 minutes using SENSE. As a demonstration of principle, we performed volumetry of both right and left hippocampi in healthy volunteers and epileptic patients, using both SENSE (axial) and non-SENSE (coronal) MP-RAGE data for comparison of quality.

Methods

Experiments

All sequences were implemented on a clinical 3.0T imager (Philips Medical Systems, Best, The Netherlands) with parallel imaging capabilities. An axial 5min14s-long SENSE-MP-RAGE scan, as well as a 10min14s-long conventional coronal sequence were performed on 5 healthy controls (3 males, 2 females; mean age 35.4±7.2) and 5 epileptic patients (2 males, 3 females; mean age 46.8±23.6), with their informed consent.

MR sequence

A compromise between regularization of the point-spread-function in the second phase-encoding direction, gray-white matter contrast and speed of acquisition was obtained by using a linear phase-encoding Look-Locker-like [2-3] associated with relatively long inversion times in an axial acquisition. The use of axial acquisition allowed in particular increasing the bandwidth to compensate for the short acquisition time obtained using SENSE. A repeated sequence in a more conventional coronal acquisition without SENSE was also acquired. The optimized MR parameters were the following: For the coronal scan, TR = 6.7 ms, TE = 3.0 ms, FA = 8°, Inter-shot time = 3000 ms, FOV =230 mm, 256 z-phase encoding steps acquired (in AP), 204 reconstructed, linear profile acquisition order, 0.9 mm slice thickness, TI = 850 ms, matrix = 256 x 204, rFOV = 80%, 1 average, BW per pixel =300Hz, for a total scan duration = 10min14sec. For the axial scan, the parameters were identical except the following: TR = 8.4 ms, TE = 3.8 ms, 192 z-phase encoding steps acquired (in FH), 150 reconstructed, BW per pixel =190Hz, total scan duration = 5min14sec, SENSE factor 2 (in LR). The long inter-shot time allowed for signal recovery and better suppression of the CSF, therefore increasing the contrast-to-noise ratio [3].

Data Analysis

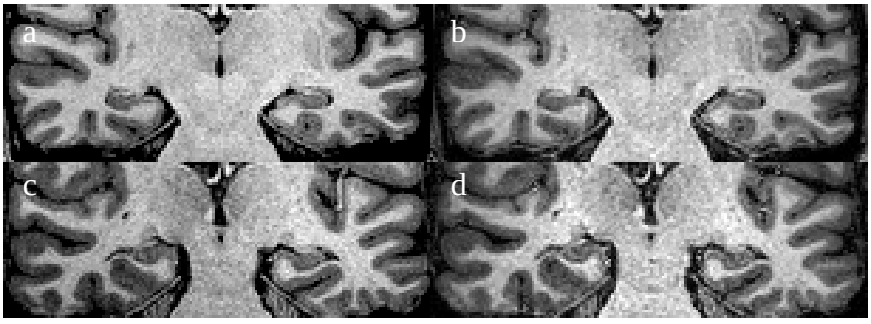
Scans were post-processed and analyzed using MRreg v.1.6.2 software [4] on a SUN Sparc 10 workstation (SUN Microsystems, Mountain View, CA). The axial scans were reformatted in the coronal plane. Delineation of the hippocampus was done manually by an experienced reader blinded to both subject and right-left anatomic status. A 2-way mixed-plot ANOVA was performed in SPSS v.11 (SPSS Inc., Chicago, IL) with original scan modality (axial or coronal) as the repeated factor and subject group (patient or control) as the between-subjects factor. Main effects were determined for both factors.

Results

Figures 1a and 1c show 10min native coronal scans while Figures 1b and 1d show 5min coronal-reformatted axial scans through the hippocampus of a control and an epileptic patient respectively. A slight broadening of the point-spread function can be seen on the reformatted scans (blurring), with ratio of the SNR values close to the theoretical limit of 1.39, given by the reduction in acquisition time (see Table 1). As expected, hippocampal volumes measured using the 10min native-coronal ($\bar{x} = 1.98 \pm 0.27 cm^3$) or 5min reformatted-axial scans ($\bar{x} = 1.91 \pm 0.24 cm^3$) of the subjects were not significantly different (F=3.23, d.f.=8, p=0.11). When looking at hippocampal volumes acquired with different scan modalities, slightly larger discrepancies appeared within patient scans than in controls (see Figure 2). Overall, controls and patients had similar mean hippocampal volumes ($\bar{x}_{controls} = 1.97 \pm 0.28 cm^3$ vs. $\bar{x}_{patients} = 1.93 \pm 0.25 cm^3$, not statistically significant (F=0.04, d.f.=1, p=0.84)). Using a laterality index of (L-R)/(L+R), both controls and patients demonstrated slight right hippocampal asymmetry of –0.02 and –0.01 respectively.

Discussion

In this study, we show that sub-millimeter whole brain volumetric analysis can be performed at 3.0T using parallel-imaging in a clinically relevant scan time of about 5min. No significant differences in hippocampal volumes were seen between scan modalities and also between subject groups, bearing in mind the small number of subjects. Discrepancies between the native-coronal or the reformatted-axial scans were slightly larger for patients than for controls, possibly due to greater movement in patients in between and/or during scans, again highlighting the need for faster acquisition times. This new method offers the advantage of reducing overall scan time, thereby reducing the potential for motion artifacts, while achieving a high spatial resolution suitable for quantitative morphometry.



Figures1: Examples from 1 patient (a – coronal; b – reformatted-axial) and 1 control (c – coronal; d – reformatted-axial)

	SNR_{WM}	SNR_{GM}	CNR
Coronal	35.7	17.3	18.4
Axial	27.3	13.2	14.0
Ratio	1.308	1.305	1.310

Table 1: Mean SNR/CNR in the above scans, calculated as: SNR = Mean(signal) / Std(noise) and CNR = (Mean($signal_1$)- Mean($signal_2$)) / Std(noise)

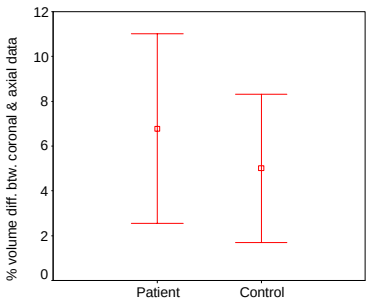


Figure 2: Mean & range of discrepant hippocampal volumes (in percent) between scan modalities in patients & controls.

References:

1. Mugler III, J. P., and Brookeman, J. R. (1990). *Magn. Reson. Med.* **15:**152–157.
2. Mugler III, J. P., Epstein, F. H., and Brookeman, J. R. (1992). *Magn. Reson. Med.* **28:**165–185.
3. R. Deichmann, C. D. Good, O. Josephs, J. Ashburner, and R. Turner (2000). *NeuroImage* **12**:112-127.
4. Lemieux L, Liu RS, Duncan JS (2000), *Magn Reson Imaging*; **18**(8):1027-1033