Segmented Multi-Echo MPRAGE Acquisition for Accelerated T1-weighted Brain Imaging

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Intended Audience

Pulse sequence designers and those who use structural brain imaging in clinical research settings.

Introduction

This work explores the feasibility of exploiting the SNR gains obtained using coil arrays and higher B0 fields to substantially reduce scan times in high-resolution structural MR brain protocols. Especially in clinical settings, shortened scan times are desirable because they reduce motion artefacts and improve patient comfort. To this end, a segmented EPI-type [1] multi-echo scheme is used to reduce scan times for high-resolution T1-weighted brain MP-RAGE imaging [2] using the ADNI protocol [3]. As opposed to parallel imaging techniques, this approach fully samples the k-space and does not rely on the coil design. Results show that even a 4.0-fold accelerated (2:20 min) acquisition provides image quality meeting diagnostic requirements.

Materials and Methods

All experiments were performed on a standard clinical 3T MRI (Magnetom Trio a Tim System, Siemens, Germany) equipped with a 32-channel head coil array. Six healthy subjects (age = 26.7 ± 4.5 yrs; 5 male) were imaged after obtaining written consent. The measurement protocol comprised two (reference, repeat) standard 3D MP-RAGE with ADNI-1 [3] protocol parameters (BW=240 Hz/pixel) using no acceleration (TA=9:14 min) and one GRAPPA R=2 (TA=5:12 min) acquisitions. A modified MP-RAGE sequence allowed acquiring multiple echoes with bipolar gradient readouts. Between the readouts, phase encoding blips were inserted so that different portions of k-space were sampled after a single excitation as illustrated in Fig 1. Using this scheme, 2-, 3- and 4-fold accelerations ("turbo factors") were achieved. In all turbo acquisitions, the echo-spacing was kept similar as in the ADNI-1 protocol to avoid introduction of additional T1-blurring due to a prolonged readout train. The employed bandwidths were: 580 Hz/pixel (turbo=2, TA=4:38 min), 1150 Hz/pixel (turbo=3, TA=3:10 min) and 1150 Hz/pixel (turbo=4, TA=2:20 min). A phase correction algorithm adapted from EPI was applied to all k-space lines to reduce inconsistencies between odd and even echoes. The order the scans were acquired in was randomised between sessions. For qualitative analysis and comparison with the standard protocol, all data were graded by an experienced, blinded observer participating in the ADNI trial to grade the images with respect to artefacts and to rate them within session on a 1-6 relative scale (1: best, 6: worst). Grades were averaged across the subjects. Image volumes of one session were spatially normalised with respect to the non-accelerated MP-RAGE images serving as a best-case reference. Subsequently, a root mean square error (RMSE) of the difference from the unaccelerated MP-RAGE was computed. Additionally, volumetric measurements were performed using the framework described in [4]. Taking the volumes of the non-accelerated MP-RAGE scans again as reference, the mean absolute volumetric error was computed across the subjects and standard deviations were used as an error estimate.

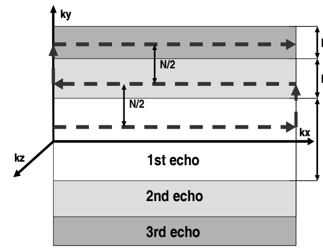

Fig. 1 Example of a turbo=3 acquisition scheme. The dashed line illustrates a k-space trajectory traversed after a single excitation.

	MPR Repeat	GRAPPA	TURBO=2	TURBO=3	TURBO=4
HP (%)	1.8±0.95	2.7±1.3	1.76±1.3	2.5±1.1	2.6±0.77
GM (%)	0.49±0.14	1.44±0.53	0.84±0.43	1.6±0.81	1.6±0.61

Table 1 Volumetric % difference to the MPRAGE reference scan: error estimates of total hippocampus (HP) and grey matter (GM) volumes.

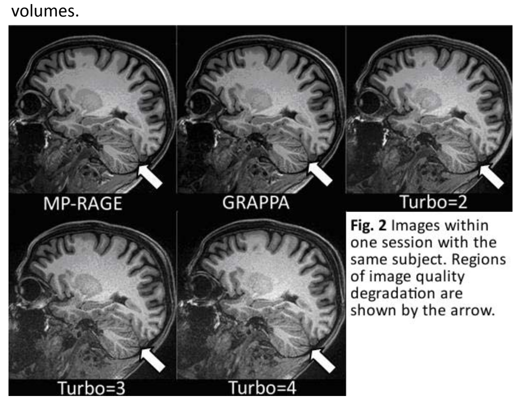

Fig. 2 Images within one session with the same subject. Regions of image quality degradation are shown by the arrow.

Results and Discussion

Qualitative observations confirm the expected increase in noise with the segmented acceleration but still show good GM/WM contrast even at turbo-4 (Fig. 2). Images exhibited in some cases mild ringing artefacts in the segmented acquisitions, largely arising from hyperintense signals from abundant fat in the neck. Nevertheless, all images were considered to be clinically useful and of high quality or with only mildly affected image quality. Fig. 3 shows RMSE and observed within-session rankings indicating that the turbo acceleration results in measureable and observable degradation of image quality, primarily originating from the reduced SNR (higher bandwidth) as well as from artefacts due to phase and magnitude inconsistencies between k-space segments. Qualitative ratings confirm that the presented method accelerates MP-RAGE scans and provides clinically useful image quality. The quantitative analysis indicates that the measures increasingly deviate from the reference MP-RAGE, but are well within acceptable limits of the methodology. In summary, the presented concept could be used when parallel imaging methodology can be applied only with caution, e.g. acceleration of the readout trains after the magnetization preparation RF-pulse in high resolution MP-RAGE scans.

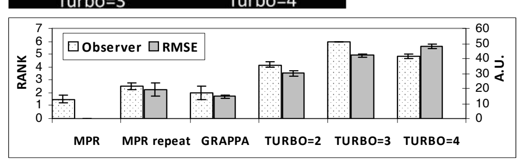

Fig. 3 Observer ranking and RMSE (with respect to the MPR) of the different scans averaged across subjects. Error bars show standard deviation as error estimation.

References

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