# Parallel Imaging in 3D MP-RAGE for Consistent Brain Volume Imaging

**E. T. Tan[1], C. R. Haider[1], R. C. Grimm[1], J. L. Gunter[1], C. P. Ward[1], D. A. Reyes[1], M. A. Bernstein[1], C. R. Jack[1], and S. J. Riederer[1]**

[1]Mayo Clinic, Rochester, MN, United States

## Introduction

Serial brain volume measurements can detect small changes in brain morphology that are attributable to pathologic progression of Alzheimer's disease [1]. However, the long scan time of pulse sequences used for this application, for example T1-weighted magnetization prepared rapid gradient echo (MP-RAGE) [2], increases the probability of motion artifacts and decreases throughput. Parallel imaging (PI) can be applied to reduce scan time if consistent volume measurements can be made. This work hypothesizes that a combination of PI with acceleration factors up to six can be applied with a centric view order in the 3DFT acquisition to obtain smaller than 0.5% deviation in brain volume with respect to an un-accelerated acquisition taken to be the "gold standard".

## Methods and Materials

The parameters tested to optimize the acquisition protocol were the view order and the PI method. The view orders used were sequential, elliptical-centric (EC), and recessed EC [3]. The inversion time (TI) was chosen to optimize white vs. gray matter (WM, GM) contrast and cerebrospinal fluid (CSF) suppression, and that was dependent on the view order used. The PI methods were i) self-calibrated sensitivity encoding (SENSE) and ii) generally-autocalibrated partially-parallel acquisitions (GRAPPA). Controlled-aliasing sampling patterns with the lowest noise amplification were used [4].

A phantom with regions matched to T1s of WM, GM and CSF, was imaged. PI was done in either one or two dimensions with acceleration factors of $R$=1 (un-accelerated) 2, 3, 4 and 6. Two separate GRAPPA reconstructions with different kernel sizes were compared against SENSE. Volume, edge sharpness, signal and contrast-to-noise ratio between WM and GM (SNR, CNR) were measured. WM and GM regions were segmented using a histogram-based threshold method. Volume ratios were taken with respect to the un-accelerated scans of the respective view order. Non-linear fitting of error-functions to edges was used to determine edge sharpness. All images were acquired at 3 Tesla (General Electric, Signa 14.x), with an 8-channel head coil, and a 3D MP-RAGE pulse sequence with adiabatic inversion pulses (TI /MP-RAGE TR / TR / TE = 800-900 / 2300 / 6.6 / 2.8ms, flip angle=8$^o$, sagittal, sampling matrix=256×240×172, imaging resolution =1×1×1.2mm$^3$).

**Table 1: Instances of PI Reconstructions with Better Image Quality Measurement (paired t-test, p=0.05)**

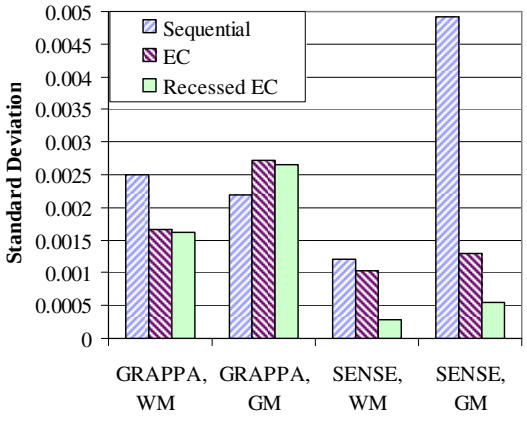
| Measure/View Order | | Seq. | EC | Rec. EC |
|---|---|---|---|---|
| Unity Volume Ratio# | WM | 1/12 | 10/12 | 10/12 |
| | GM | 0/12 | 10/12 | 10/12 |
| Higher Sharpness in Y-direction* | WM | 16/24 | 0/24 | 12/24 |
| | GM | 0/24 | 0/24 | 9/24 |
| Higher Sharpness in Z-direction* | WM | 0/24 | 0/24 | 24/24 |
| | GM | 0/24 | 8/24 | 23/24 |
| Higher SNR* | WM | 17/24 | 0/24 | 12/24 |
| | GM | 10/24 | 0/24 | 24/24 |
| Higher CNR* | | 21/24 | 9/24 | 0/24 |

#Compared to un-accelerated scans (4 acceleration factors × 3 reconstructions = 12 comparisons) ; *Pair-wise comparisons between view orders (12 × 2 comparisons per view order = 24 comparisons)

## Results

Both centric view orders resulted in the most instances of equivalence to unity volume ratio in the phantom (Table 1). Overall, the sharpest edges were formed with recessed EC. Recessed EC had better SNR but sequential had better CNR. All view orders produced volume (standard) deviations of smaller than 0.5% (Fig.1). In particular, the volume deviations of recessed EC with SENSE were smaller in both WM and GM (<0.06%) by about an order of magnitude compared to the view order with the largest deviation.

**Fig. 1: Standard Deviation of Volume Ratios of Four Accelerated Reconstructions (R=2,3,4,6)**




## Discussions and Conclusions

Centric view orders disperse k-space modulation due to the transient MP-RAGE signal, which might account for the more consistent volume measurements and higher sharpness. This effect was pronounced in the Z-direction because it was the only direction modulated in a sequential view order. The results also suggest that higher volume consistency is not necessarily directly related to better SNR and CNR measurements.

An imaging protocol for accelerating consistent brain volume imaging using MP-RAGE was optimized using phantom experiments. The volume analysis demonstrates the potential for highly consistent (<0.06% deviation) volume measurements of recessed EC view order with PI. The volume measurement consistency of this protocol would be evaluated in future volunteer studies.

## References

[1] Preboske, G.M. et al, *NeuroImage* **30**:1196-1202 (2006).
[2] Mugler, J.P, Brookeman, J.R., *Magn Res Med* **15**: 152-157 (1990).
[3] Lin, C., Bernstein, M.A., *Magn Res Med* (in press).
[4] Breuer, F.A. et al, *Magn Res Med* **55**:549-556 (2006).