Author's response to reviews

Title: Parallel Imaging: Is GRAPPA a useful acquisition tool for MR imaging intended for volumetric brain analysis?

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Author's response to reviews: see over
Title: Parallel Imaging: Is GRAPPA a useful acquisition tool for MR imaging intended for volumetric brain analysis?

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Authors reply to reviews:

Dear Editors

We gratefully received the comments of the two reviewers Jaroslav Tintera and Piotr Wielopolski in the Spring 2009. We must apologise for the delay in reply to the comments and the manuscript revision. We have answered each comment in turn and believe that the changes made improve the clarity of the paper and therefore thank the reviewers for their contribution. We state in each reply if changes have subsequently been made in the manuscript.

Best regards

Terri Lindholm

Reviewer’s report 1
Title: Parallel Imaging: Is GRAPPA a useful acquisition tool for MR imaging intended for volumetric brain analysis?
Version: 1 Date: 18 November 2008
Reviewer: Jaroslav Tintera
Reviewer’s report:

I have only some minor remarks and comments - Discretionary Revisions:

1. Increasing AF leads to the increase of SNR but higher noise (and artifacts) level is not uniformly distributed over images (as also stated in discussion). This can potentially lead to various results when calculating volumes in pre-selected regions because different noise level (speculatively this can lead to differences in affecting GM and WM volumes). Since the middle parts of images are the most affected by PI, in these regions the volumetry can have higher degree of inaccuracy and moreover the distribution of such problematic regions is hardly predictable. This fact should be perhaps more commented during discussion.

This exact issue is raised in the introduction section of the manuscript and is an important issue and was the reason for inclusion of repeated hippocampus volume measurement in this study. In response to this comment we have highlighted this issue in the discussion of the hippocampus volume measurement result (Discussion section, 2nd to last paragraph).

2. Authors use relatively low spatial resolution (1.3 x 1.3 x 1.3 mm3) but many others often voxel size of at least 1 x 1 x 1 mm3 which means less then half of SNR (voxel size of 2.2 against 1 mm3). Using AF of four in such higher resolution data would lead to more then four times lower SNR compared to author’s data without PI. I really doubt that in this case the quantification of the GM volume would be still acceptable. Therefore this context and potential limitation should be discussed.

The 1.3 x 1.3 x 1.3 mm resolution is considered high resolution for scanning at 1.5 T. Indeed at 3 T a resolution of 1.0 x 1.0 x 1.0 mm and higher is most commonly found. The resolution used in this study was that implemented by the well known ADNI study which uses 1.5 T without the use of parallel imaging. The voxel volume of course makes a significant difference to the SNR and the combination of the higher resolution and parallel imaging has not been investigated neither have we intended to recommend the combination in this paper. We have
edited accordingly statements in the discussion (paragraph 4) and conclusion (paragraph 1) sections of the manuscript to ensure the readers cannot misinterpret our intentions.

3. I can’t fully agree with the statement that also during longitudinal study the protocol can be changed to one with PI. Authors show that the use of PI and BET/Sienax leads to systematic decrease of GM and increase of WM volumes (table 1). However, just these changes could be highly interesting when studying progressive diseases as AD. On the contrary, changes in BPF can reflect the process of global brain atrophy with aging.

This statement was aimed towards volumetric measurement with the BMAP/Volstat software and was not clear in the text. However, it was a contentious statement to include and we were in some uncertainty as to include it in first submitted manuscript. After comments from the reviewer we have decided to remove this statement from the manuscript.

4. It seems that results are very dependant to algorithm used and according of table 1,2 the BMAP/Volstat gives much more stable results of GM/WM volumes when increasing AF. Is this fact specifically linked with PI or the algorithm is generally more robust for lower SNR data? Do you know whether also for higher resolution data this algorithm would be more stable?

This is an interesting question however generally we would not expect any automated algorithm to give the same absolute tissue volumes with variable AF or resolutions as even slight changes in the imaging protocol can effect the volumetric results. We don’t have any comparative data between the two algorithms for higher resolution data than 1.3 × 1.3 × 1.3 mm and so would not like to comment further as to the reason for more stable volumetric measurement using BMAP/Volstat.

5. Despite the fact that the paper was published in Japanese language, authors should refer the following publication with similar results (Nakamura et al., 2006)

We would like to thank the reviewer for sending this reference since we were not aware of its existence. Although the parallel imaging technique and image analysis were not identical, our results are in agreement with those published by Nakamura et al. and is very encouraging. A relevant reference [11] has been made in the background section of the manuscript (2nd to last paragraph).
Reviewer’s report

Title: Parallel Imaging: Is GRAPPA a useful acquisition tool for MR imaging intended for volumetric brain analysis?
Version: 1 Date: 17 February 2009
Reviewer: Piotr Wielopolski

The introduction has been shortened as requested. The discussion of the use of shorter acquisition protocols for clinical drug trials has been moved to the discussion section of the manuscript.

2. There should be a “consistent” definition on what high resolution means for the authors. A 2.2 mm³ voxel size cannot be considered high resolution for brain studies and the choice should be defended more adequately. Is this the voxel size used initially in the ADNI study? Did the study in course at your site started with an older scanner that was not capable of parallel imaging (e.g. only a CP head coil) and the Siemens Avanto scanner offered the possibility to decrease imaging time at present?

The 1.3×1.3×1.3 mm³ voxel is indeed that used in the ADNI protocol. This resolution was chosen based on that recommended in the ADNI study which had investigated the optimal resolution for volumetry at 1.5 T. It is important to remember that this study was performed at 1.5 T and this was considered as ‘high resolution’ for such a system. This study was initiated after we installed a new Siemens Avanto scanner in with its parallel imaging capabilities which in 2005 became of interest to our longitudinal dementia studies.

3. When addressing the issue of parallel imaging and decreased SNR, would be adequate to state in general terms how much reduction in SNR is expected depending on the configuration that you are presently using. This can be considered a technical report and more concise numbers are envisioned.

This is indeed an important issue, however, the aim of our study was not to examine the effect of SNR per se but to examine the feasibility of parallel imaging for volumetric brain measurement. Since the use of parallel imaging results in a non-uniform SNR over the image its effect will depend greatly on the type of image analysis being performed. We feel in fact that the most relevant ‘SNR’ in brain volumetry studies is the reliability of volume measurement in repeated scanning. The investigation of the limitations of volumetry as a direct function of SNR is another interesting study in its own right and might be performed by comparing voxel sizes, coils of different channel numbers and indeed parallel imaging.

4. On what basis was 1.3x1.3x1.3 mm3 chosen? What are the SNR and CNR of the setup without parallel imaging? This should be reported as to lead the readers to the detrimental effects of parallel imaging, especially in the regions where noise with parallel imaging is enhanced (center of the brain).

This resolution was chosen based on that recommended in the ADNI study which had investigated the optimal resolution for volumetry at 1.5 T. We don’t have exact SNR and CNR for this sequence however it is considered as the ‘gold standard’ in AD studies due to its inclusion in the ADNI study. We feel that a sufficient discussion of the effects of the application of parallel imaging is made in the background section of the manuscript (paragraphs 5 to 8) as well as the unexpected results presented in this paper. We have made this clearer in the Discussion section regarding the hippocampus volume measurements (2nd to last paragraph). See also reply to questions 1 and 2 from reviewer 1.
5. The raw scanning time per volunteer was greater than 100 minutes. Could you please mention this and the total examination time including the removal and placing in the magnet? Was this performed all per volunteer in a single scanning session? Also mention the total scan time that the elderly underwent.

The repeatability scanning was divided into 2 scan sessions within a period of a week. Each scan session was approximately 1 hour in duration and included 3 acquisitions at each parallel imaging factor.

The patient scanning session began with the volumetric acquisitions (MPRAGE and 3D T2 SPACE) with the addition of a 3D FLAIR and two spectroscopy sequences for a wider study. The volumetric scanning was approximately 13 minutes in total including the MPRAGE at acceleration factors 2 and 4 as well as the 3D T2.

Appropriate additions have been made to the manuscript text in the Methods section under ‘healthy young volunteer’ (paragraph 1) and ‘Elderly patient group’ (paragraph 2).

6. The MPRAGE sequence description should be described more adequately (provide additionally TR (inter-RF spacing), TE, readout bandwidth). In fact, a table should be included with the parameter used for all the sequences applied. This is adequate as the SPACE sequence was also used as input in one of the segmentation algorithms evaluated.

Table 1 has been included and referenced to in to the Methods section under ‘Magnetic resonance imaging’ (paragraph 4).

7. When making reference to manufacturers and software, please consistently list city and country of origin.

Appropriate corrections have been made to all first time references of product/software manufacturers.

8. A diagram would be most adequate demonstrating the two segmentation procedures and the steps that followed in the evaluation. As noted by the authors, comparison cannot be made regarding volume outputs but most importantly the repeatability of the segmentation and resulting numbers with patient/volunteer rescanning with/without inclusion of parallel imaging.

A table has been added (table 2) to summarize the two segmentation procedures side by side.

9. Could you comment on the minimum SNR and CNR necessary to successfully have good study repeatability? This will be important in case higher resolution images are planned in the future. How robust are the segmentation algorithms in the presence of worst SNR figures despite the artifacts that parallel imaging may introduce with higher acceleration factors.

The findings of this study were, surprising to us, that even with an acceleration factor of 4 acceptable reliability of automated whole brain volumetry was found. So from that perspective our data cannot provide any cut-off for SNR and CNR related to volumetry. For higher resolution imaging using for example at 3 T, separate studies are needed to further evaluate the relationship between parallel imaging, resolution, SNR, CNR and reliability of brain volumetry.

10. There could be a sentence included that illustrates the possibility of a higher acquisition bandwidth readout for MPRAGE to reduce imaging time. In this case, it is not necessary to acquire calibration data. Newer scanners have better antennas.
and received circuitry and the additional SNR could be used also in this scenario. Parallel imaging has its benefits, such as decreasing the amount of RF pulses applied (SAR) and increasing the effective k-space sampling speed.

Of course increasing the bandwidth would allow a shorter TE and normally this would contribute to a shorter scan time (at a cost of reduced SNR) but in the case of the MPRAGE sequence the dominating time factor in the sequence is the inversion time which is in the order of 1000 ms and not the TE which is approximately 3 ms. Perhaps with a 3D T1-weighted sequence without magnetization preparation this could save significant time and with modern scanners without the comparative loss of too much SNR. This might be an alternative method of shortening scan time for such a sequence rather than using parallel imaging. However this type of sequence is known as not giving as high T1 contrast as the MPRAGE.

11. Discussion on 3.0T scanning is not adequate here and far from speculative with regards to increase in image resolution. At best, only a factor of 2 in SNR is possible and authors must be cautious. B1 inhomogeneities are greater at higher field strengths and local changes in CNR have not been well determined.

Since our plans have changed after the installation of our 3 T scanner we have removed this statement.

12. Figure 1: awkward figure caption. It should be re-written. Example: comparison between MPRAGE images acquired with and without parallel imaging. Columns demonstrate coronal, axial and sagittal multi-planar reconstructions with increasing acceleration factors, left most column acquired without parallel imaging compared to factors of 2 and 4 ......

The figure caption has been clarified.

13. Figure 2: Inadequate description. The left top image is a segmented brain slice from the normal non-parallel imaging. It looks as if the slice has been heavily filtered.

The figure caption has been clarified. The MPRAGE image has not been filtered.