Comparison of GRAPPA Acquisition Methods for Whole Body Diffusion Weighted Imaging

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Introduction: Whole-body magnetic resonance diffusion-weighted imaging (WBDWI) is gaining popularity as an oncological tool for detecting skeletal lesions [1]. Single-shot echo planar imaging (ss-EPI) is currently the most widely used technique employed. EPI is also used to acquire the auto-calibrating signal (ACS) lines from which WBDWI images are reconstructed [2]. Despite the fact that this method allows high-contrast images to be obtained within a clinically relevant time frame, WBDWI images tend to be heavily affected by EPI-specific artifacts. In this work, we evaluate an alternative to ss-EPI, a fast multi-slice 2D gradient echo (GRE) prototype sequence to acquire ACS lines for diffusion images [3]. We investigated how the technical differences between ss-EPI(R=2), FLASH(R=2) and FLASH(R=3) visually manifest themselves in the context of WBDWI imaging, where R denotes the reduction in the number of phase encoding steps. More specifically, we analyzed the geometric distortion, SNR, overall image quality, and inter-station registration in an effort to identify which is best suited for a WB diffusion protocol appropriate for diagnosing skeletal lesions.

Methods: Protocol: T1-VIBE, sagittal TSE, and 3 acquisitions each of ss-EPI(R=2), FLASH(R=2), and FLASH(R=3). This protocol was performed on 5 volunteers on a 1.5T MRI scanner (MAGNETOM Avanto, Siemens AG, Healthcare Sector, Erlangen, Germany). All of the volunteers were scanned in the head/neck station because it has been identified as particularly distortion-prone station [4] and 2 volunteers underwent additional scans in the thoracic station. The parameters for the DWI scans (with the exception of R) were held constant for each volunteer (Matrix/Partial Fourier/TE/TR/Ref lines/Bandwidth/b-values = 150x144/6/8 /77.2-85.2ms/14.6-14.8s/33 or 45 (R3) 34 or 44 (R2)/1389 Hz/px /50 and 900s/mm^2). DWI *Image Distortion:* Image distortion in the A-P phase-encoding direction was quantified using image registration in OsiriX. 10-11 points were placed on the spinal cord corresponding to the center of the vertebral bodies from C2 to T4-T5 on both T1 and DW sequences for each volunteer. The point placements were repeated 5 times per volunteer to quantify user repeatability. After translational registration, the Euclidean distance between corresponding points was calculated, and the mean was taken of these distances to yield the average Euclidean distance (AED). A small AED indicates a close match between the T1 and the DW images, thereby signifying a greater level of geometric fidelity. *Image quality:* The image quality of each method was assessed by a radiologist who rated 21 MIP images based on the severity of artifact presence, and the quality of: neck, organs, lymph nodes, and overall image quality on a 4 pt Likert scale. *Patient Scan*: A WB FLASH(R=3) protocol was employed to obtain the image data in Figure 2.

Results: Figure 1 shows the differences in image distortion between the GRAPPA acquisition methods. The spinal cord of the FLASH(R=3) DW image is better aligned with the T1w compared with the other DW methods. **Figure 2** demonstrates the clinical potential for using a FLASH(R=3) protocol. SNR calculations show that R=3 has a predictably lower SNR than the R=2 methods, although this reduction is not statistically significant. **Figure 3** shows that the AED between T1w and DW registration points is significantly lower in FLASH(R=3) than the other R=2 methods, thereby quantifying the phenomenon observed in Figure 1. The difference in AED between the R=2 methods is not statistically different. The overall MIP quality of FLASH(R=2) rated higher than ss-EPI(R=2) in the radiologist reading.

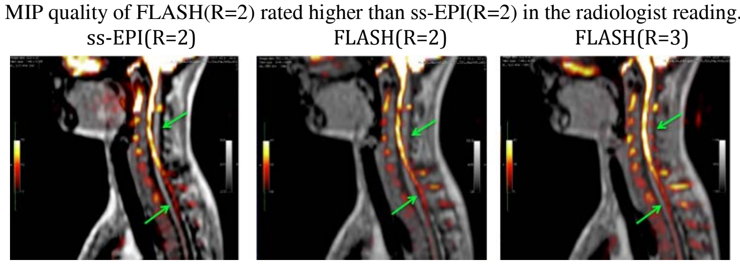

Figure 1: Image fusion in OsiriX after 10-point registration, where the grayscale image is T1w-VIBE, and the color map image is a DW image. Green arrows indicate spinal-cord distortions.

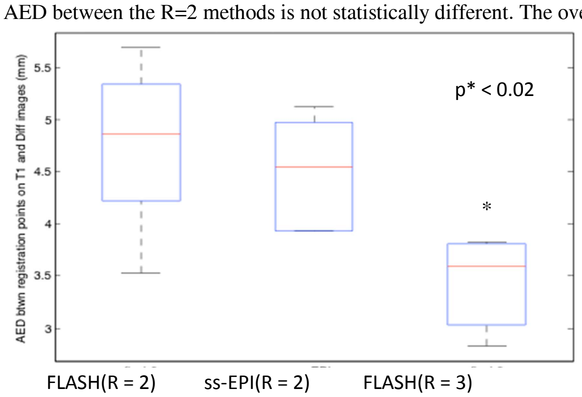

Figure 3: AED between the 11 registration points of T1w and DW images for the upper station (n = 5).

Discussion: Preliminary results indicate that FLASH(R=3) ACS has higher geometric fidelity than FLASH(R=2) ACS and ss-EPI(R=2), as shown visually and quantitatively. This difference is likely to be due to the increase in R from 2 to 3 rather than the type of pre-scan, as there is no detectable difference between FLASH(R=2) and ss-EPI(R=2) with respect to geometrical distortions. Previously, there was a concern that the difference between the reference data and the acquired image data would result in increased artifact and distortion [3]. In our practice, we have not observed this; we attribute the difference to an improved EPI phase correction algorithm that preserves the relative phase between individual coil elements. Our observations (exemplified by Figure 2) suggest that FLASH(R=3) can be used diagnostically, as it has few artifacts, good inter-station registration, and high geometric fidelity. Additionally, FLASH(R=3) shows low susceptibility to differences in the centre frequency, as there is an absence of station misalignment in the patient scan. However, the advantages of using FLASH(R=3) are offset by a lower SNR of ~17%: this may be partially responsible for the tendency of FLASH(R=2) ACS data to be rated higher than FLASH(R = 3) ACS data in terms of overall MIP quality. The lower SNR can easily be recovered with a modest increase in pixel size (Fig 2). There was no situation in this study in which ss-EPI outperformed FLASH.

Figure 2: Coronal and sagittal MIPs from the FLASH (R=3) ACS data protocol performed on a patient.

Conclusions: The findings from this study warrant further investigation; particularly in categorizing the differences between acceleration factors using separate reference scans. Our initial observations indicate a separate GRE reference scan provides a robust method for acquiring WBDWI MR images, and appears to provide a superior reconstruction to ss-EPI ACS data.

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