Assessment of Image Quality in a Prospective Clinical Trial of Conventional vs. SENSE DWI at 1.5T

S. K. Nagle[1], D. B. Clayton[1], M. G. Lansberg[2], G. W. Albers[2], R. Bammer[1]

[1]Radiology, Stanford University, Stanford, CA, United States, [2]Neurology, Stanford University, Stanford, CA, United States

Introduction: Parallel imaging methods have been applied to an increasingly broad set of MRI pulse sequences over the past few years (1). Most of these applications have capitalized on the speed improvement obtained by having to make only a fraction of the k-space measurements needed in conventional methods. In the setting of diffusion-weighted imaging (DWI) of the brain in the diagnosis of acute infarction, several other benefits present themselves. Since most DWI scans are accomplished using single-shot echo planar (EPI) methods, the scans are quite sensitive to off-resonance effects due to the relatively long read-out time. These artifacts can obscure stroke in areas of the brain near the skull base, adjacent to the sinuses, or surrounding hemorrhage. In addition, T2*-related image blurring often occurs as the periphery of k-space is obtained late in the echo. This loss of resolution can impair the conspicuity of small infarcts. Since DWI scans are relatively short, the option of increasing image resolution rather than decreasing scan time offers the possibility to increase the sensitivity for detecting very small infarctions. This can be clinically significant when it leads to detection of an otherwise undiagnosed small single infarct or when it reveals otherwise undiagnosed infarctions in multiple vascular territories. The purpose of this study was to assess whether or not parallel imaging improves the quality of DWI in the diagnosis of stroke.

Methods: A consecutive series of 50 patients presenting with suspected acute stroke were enrolled in an NIH funded prospective study to perform a comparative evaluation of image quality between SENSE DWI and conventional diffusion-weighted single-shot EPI. Informed consent was obtained from all patients before enrollment in the study. Patients were scanned on a 1.5T clinical unit (GE Signa LX, 11.0; 40mT/m max. gradient strength) using either an 8-channel head coil or an 8-channel neurovascular array. Both conventional DWI and SENSE DWI sequences (128^2 acquisition matrix [128x96 with 0.75 phase FOV for SENSE DWI], 256^2 reconstruction matrix, FOV 24cm, 5mm/1mm slice thickness/gap, number of slice=20, TE/TR=60ms/4000ms, NEX=1). Diffusion-encoding gradients were played along the principal axes sequentially with a b-value of 1000 s/mm^2. For both SENSE DWI and conventional DWI, isotropic diffusion-weighted images were computed by averaging the DWIs obtained along the principle axes and were used for image quality comparisons. Image quality was assessed by two readers and quality scores were assigned by concensus to both exams on a 5-point scale. Features which contributed to the image quality score were: 1) global quality and overall appearance; 2) resolution enhancement; 3) level geometric distortion; 4) conspicuity of infarctions (if present); 5) subjective assessment of noise; and 6) amount of reconstruction artifacts. A score of 1 meant technically inadequate while a score of 5 meant outstanding.

Results: Susceptibility artifacts in the SENSE DWI images were markedly reduced compared with conventional DWI images in all 55 cases (Fig. 1). No additional infarctions were revealed on the SENSE DWI scans, although conspicuity of the lesions were somewhat improved. This improvement can most likely be attributed to decreased image blurring (Fig. 2) and reduced susceptibility artifacts. In four cases of parenchymal hemorrhage with a surrounding hyperintense rim, this signal "pile-up" artifact due to susceptibility changes caused by iron products could be reduced but not eliminated. A clear benefit was seen in the reduction of distortion due to the presence of any metallic foreign bodies, such as aneurism clips or surgical hardware (Fig. 1). To some extent the image quality of SENSE DWI was confounded by FOV/2 ghosts that were aliased back onto the patient's brain and were most apparent in the frontal and occipital areas (Fig. 1, arrow). These ghosts are normally found outside of the brain but due to the restricted FOV in R/L direction in this study, the replicas overlapped over the object. This could likely be reduced if the EPI-reference scan were improved to remove high frequency ghosts. On our system, these ghostings could be significantly reduced by switching the phase encoded direction from L/R to A/P (thus using a different gradient coil) at the price of smaller acceleration (or similar acceleration with increased geometric noise enhancement). Overall assessment of image quality moderately favored SENSE DWI over conventional DWI (Fig. 3). The average score for conventional DWI was 3.5 (+/- 0.7) and for SENSE DWI was 3.8 (+/- 1.0). When motion and residual aliasing artifacts did not impair image quality the SENSE images were clearly better. On a winner-take-all basis the SENSE DWI outperformed the conventional scan in 54%, performed equivalently in 16%, and underperformed in 30% of the cases.

Discussion: The benefits of applying parallel imaging methods to DWI sequences were confirmed in this larger patient study. Current limiting factors for SENSE are of technical nature and with improved implementations of parallel imaging methods further improvements are expected. Although SENSE DWI will not be likely to change the diagnosis of stroke for large lesions, it will likely improve diagnostic confidence for smaller lesions that may escape notice due to artifact or blurring in conventional imaging. A study with a larger sample size is currently underway at our institution to prove this hypothesis.

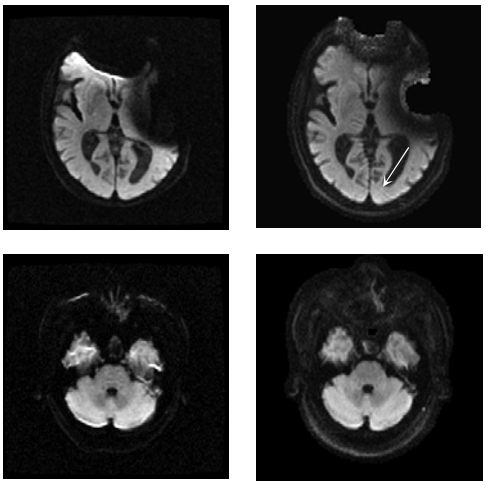

Fig. 1. Decreased susceptibility artifact due to metallic foreign bodies (top) and the mastoid air cells (bottom) in conventional (left) and SENSE (right) DWI images.

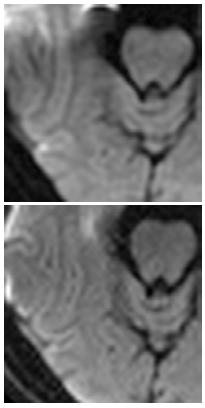

Fig. 2. Blurring in conventional DWI (top) caused by T2 decay during the EPI readout is less pronounced in SENSE DWI (bottom).*

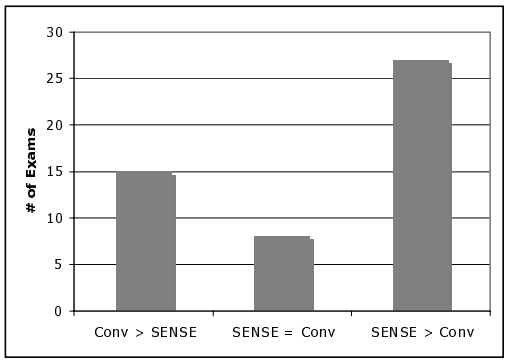

Fig. 3. On a winner-takes-all basis, conventional DWI imaging outperformed SENSE DWI in only 30% of the cases.

Acknowledgements: This work was supported in part by the NIH (1R01EB002771-S1), the Center of Advanced MR Technology at Stanford (P41RR09784), Lucas Foundation, and Oak Foundation.

References: 1. Bammer R, Schoenberg SO. Top Magn Reson Imaging 2004;15(3):129-158. **2**. Bammer R, Keeling SL, et al. Magn Reson Med 2001;46(3):548-554.