Diffusion Weighted Imaging Near the Base of the Brain: Reducing Magnetic Susceptibility Effects using Parallel Imaging EPI vs. PROPELLER FSE

T. Roberts[1], F. Liu[1], M. Sussman[1]

[1]Medical Imaging, University of Toronto, Toronto, ON, Canada

Introduction

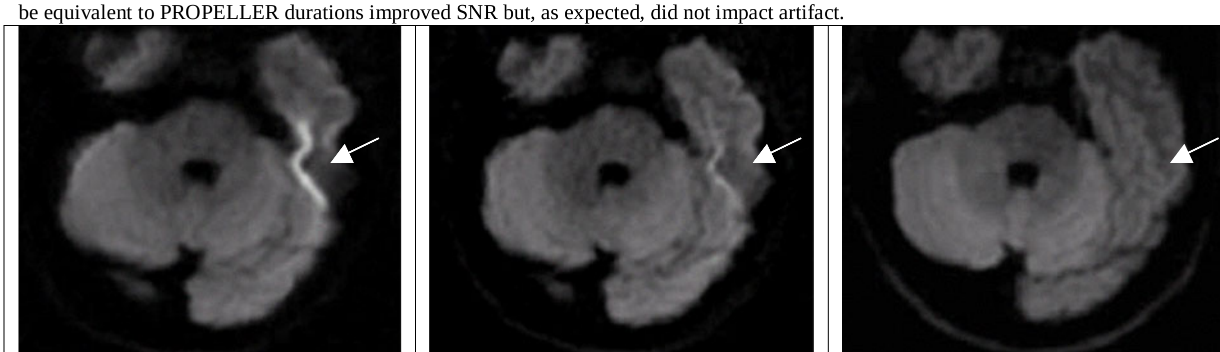
Diffusion weighted imaging is a powerful technique in clinical applications, particularly the detection and delineation of acute cerebral ischemia. However, in areas of high magnetic susceptibility differences, such as the base of the brain, typical echo-planar based imaging methods (with long echo times, TE) are hampered by geometric distortions and signal loss. To combat this parallel imaging with sensitivity encoding has been proposed as a means of reducing echo train length and TE. Using a motion corrected multishot fast spin echo approach (such as PROPELLER) offers a compelling alternative, with very little sensitivity to magnetic susceptibility differences. This study compared both approaches, quantitatively evaluating distortions and signal to noise ratios at 1.5T in 12 healthy volunteers and three neurological patients.

Materials and Methods

All scanning was performed on a 1.5T Twin Excite MRI (GEMS, Milwaukee, WI) equipped with an 8-element head RF coil (MRI Devices Corp) and 8 fast receiver channels. 12 healthy volunteers and three neurologic patients were evaluated with conventional DW-EPI (128x128), parallel DW-EPI (128x128, ETL=64, “ASSETx2”) and a diffusion-weighted multishot “PROPELLER” FSE sequence with over-sampling of the center of k-space. All sequences had equivalent b-values of 0, 1000s/mm^2. All sequences were repeated twice for signal to noise ratio (SNR) estimation. Given the spatial variation of noise in parallel imaging approaches and the noise behavior of the PROPELLER sequence, we chose a practical approach to SNR determination. By repeating each scan twice and performing an image-image subtraction, we were able to estimate “signal” from the mean of the two image acquisitions and “noise” from the difference. Such determination could be made at any or all pixels within the image.

Results

Using high receiver bandwidth (250kHz) and parallel imaging (ASSETx2) using an 8-element head coil allowed TE to be reduced from 69ms to 59ms, significantly improving image quality by reducing magnetic susceptibility mismapping and signal voiding artifact. PROPELLER imaging (TE=120ms) gave almost no evidence of anatomic distortion at the expense of longer scan times (see figure, all images b=1000s/mm^2). SNR decreased by up to a factor 2 from DW-EPI to parallel DW-EPI, but was nonetheless sufficient to appreciate the reduction in magnetic susceptibility artifact. Increasing parallel DW-EPI total scan durations (by increasing NEX) to be equivalent to PROPELLER durations improved SNR but, as expected, did not impact artifact.



a) DW-EPI 128x128 (TE=69ms). Note region of marked magnetic susceptibility artifact (mismapping and signal void) – (arrow)	b) Parallel DW-EPI (ASSETx2) 128x128 matrix is achieved with a n echo train length, ETL, of 64 reducing k-space blur and shortening TE to 59ms. Note improvement in signal quality in region of magnetic susceptibility difference (arrow) as well as increased tissue interface sharpness.	c) PROPELLER DW-EPI. 128x128 PROPELLER scan shows no evidence of signal artifact associated with magnetic susceptibility differences. Note also improved gray-matter / white matter contrast and sharpness.

While the parallel imaging echo planar approach did not increase scan times relative to conventional DW-EPI (single shot, therefore total acquisition time limited only by choice of number of b-values, diffusion-sensitizing directions and inter-image interval), the multishot PROPELLER sequence required approximately 1minute 20secs per image (therefore > 5 minutes for a b=0 and three directions at b=1000 s/mm^2). This long scan duration appears prohibitive in the case of uncooperative patients, whose images are confounded by motion-related artifact.

Discussion

Magnetic susceptibility differences leading to field inhomogeneity compromise the image quality of conventional DW-EPI. Exploiting parallel imaging using multiple coils/receivers enables a reduction in echo train length, with reduced k-space blurring and shortened TE, reducing sensitivity to field inhomogeneity. Nonetheless some sensitivity to field inhomogeneity persists, manifest as signal voiding and mismapping. Alternatively a PROPELLER fast spin echo approach shows almost no sensitivity to magnetic field inhomogeneity, but requires considerably longer scan times. For clinical application, either parallel imaging or PROPELLER should be considered - Parallel imaging is favored for the uncooperative patient, or to minimize T2-shine through effects, or for “ultra-fast” stroke protocols; PROPELLER is favored if high-resolution definition of anatomic structures near magnetic susceptibility mismatches is required.

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