Very high-resolution single shot diffusion weighted imaging using parallel imaging and fast receivers

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Introduction:

Diffusion weighted imaging is of increasing clinical importance, particularly in the evaluation of acute cerebral ischemia, but also in neoplasms and other CNS indications. Typical imaging protocols use an echo planar imaging approach with concomitant poor spatial resolution of the order of 2.5mm in plane. Furthermore, these images suffer from considerable blur due to the extended acquisition window required to collect the typical 128 echoes using typical 62kHz receiver bandwidth. Echo times up to 100ms lead to undesirable distortions and signal voiding due to the extreme sensitivity to magnetic susceptibility differences. Furthermore, the long TE leads to the undesirable contribution of T2-weighting to the raw diffusion weighted image (T2-shine through). Consequently, although of considerable potential utility, diffusion weighted images are commonly viewed as "blurry", "distorted" and "low resolution". The purpose of this study is to use parallel imaging with sensitivity encoding to reduce the echo train length (ETL) as well as fast receiver technology to shorten each echo acquisition period and thus in combination to acquire over a shorter period (with less k-space blurring) and with an overall shorter echo time, TE, reducing the magnetic susceptibility difference sensitivity and impact of T2-shine through.

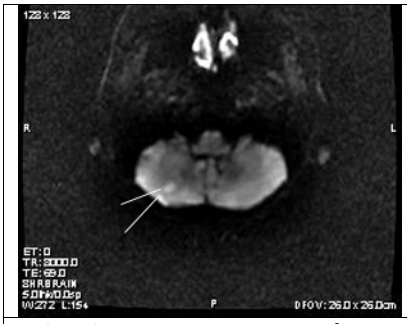
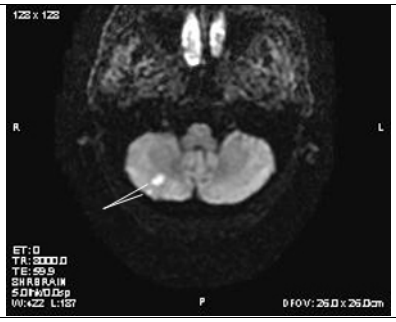
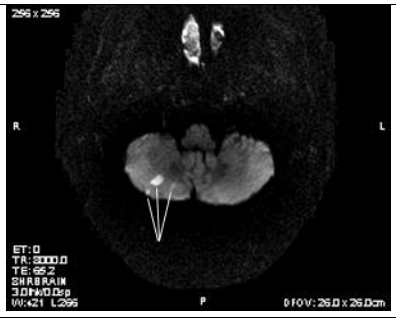
Methods:

Using parallel imaging (ASSETx2) and high receiver bandwidth (250kHz, "Excite") we are able to acquire 256x256 matrix single shot T2-weighted and diffusion weighted echo-planar images with high spatial resolution (<1mm in-plane) without excessive k-space blurring or TE prolongation (TE=65ms). These are compared against typical lower resolution echo-planar diffusion weighted images in 10 healthy volunteers and 14 neurological patients with a variety of lesions, including micro-embolic strokes. Images were acquired on a 1.5T TwinExcite platform (GE Medical Systems, Milwaukee, WI) using an 8-element head-coil (MRI Devices Corp) and the following sequences (26cm FOV):

1) Single-shot DW-EPI 128x128matrix, BW=250kHz, b=1000s/mm^2 (TE=69ms)
2) Single-shot DW-EPI 128x128 matrix, BW=250kHz, b=1000s/mm^2, ASSETx2, (TE=59.9ms)
3) Single-shot DW-EPI 256x256 matrix, BW=250kHz, b=1000s/mm^2, ASSETx2, (TE=65.2ms)

Results:

The use of 250kHz receivers improves the "regular" 128x128 matrix (non-parallel acquisition) compared with prior experience (largely attributable to reduced TE of 69ms). Nevertheless, in all cases, using parallel imaging (ASSETx2) improved image quality (reduced blur) on a 128x128 matrix, particularly in regions of magnetic susceptibility difference. However, lesion and small structure visualization was considered yet superior on hi-resolution 256x256 matrix scans (which by virtue of parallel imaging still has an echo train length, ETL, of only 128). The slight additional TE burden (65ms vs 59.9ms) was not deemed to over-ride the benefits of superior in-plane resolution, and was still superior to the non-parallel scan. The three image types are shown below, in a patient with multiple embolic lesions (this slice at the level of the cerebellum).

		
128x128 matrix DW-EPI, using fast receiver (250kHz) with TE=69ms in a patient with multiple embolic lesions (hyperintensity). Even with this rather short TE, lesions are poorly delineated.	128x128 matrix DW-EPI using parallel imaging (ASSETx2) to reduce the ETL to 64 and the TE to 59.9ms. Lesion conspicuity is improved, but spatial resolution remains ~2mm.	Invoking the acquisition speed of 250kHz receivers, this image was acquired using a 256x256 matrix. Parallel imaging (ASSETx2) reduced the ETL to 128, and resultant TE is 65ms (notably still less than the non-parallel 128x128 matrix exam). In-plane resolution is now ~1mm and conspicuity of multiple lesions is markedly improved.

Discussion

A protocol capitalizing on parallel imaging (to reduce ETL) and fast receiver technology (to reduce TE) is presented. T2-weighted and diffusion-weighted images are acquired with a single shot EPI approach yielding sharp anatomic definition (1mm in-plane resolution). Improved lesion conspicuity was found in neurological patients. Similar high resolution protocols can form the basis of screening T2 examinations in the uncooperative patient or diffusion tensor imaging approaches for white matter fiber tracking.