Optimisation of diffusion trace measurements using diffusion-weighted single-shot STEAM

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Purpose:

Diffusion-weighted single-shot STEAM sequences (TSTEAM) provide an alternative solution to echo-planar imaging (EPI) for diffusion tensor imaging that is insensitive to susceptibility artefacts and geometric distortions [1,2]. A primary diffusion-weighted spin-echo replaces the first pulse of a single-shot STEAM sequence, where multiple differently phase-encoded stimulated echoes are read out by low flip angle pulses. Here, the optimisation of isotropic diffusion weighted images (DWiso) and maps of the apparent diffusion coefficient (ADC) were investigated using TSTEAM in combination with 5/8 partial Fourier encoding and POCS image reconstruction.

Method:

Studies were performed at 2.9 T using a Siemens whole-body MRI system (Trio, Erlangen, Germany) with 40 mT/m gradients and a maximal slew rate of 200mT/m/s. Images were obtained with use of a 8-channel phased-array headcoil. Written informed consent was obtained in all cases before the examination. The spatial resolution was 2x2mm^2 (160x256mm^2 FOV) with 4mm section thickness. Phase encoding was performed using centric reordering for the central 20 lines, using the POCS algorithm for image reconstruction[3]. Trace weighting was obtained by three independent measurements of the gradient directions (1,1,-1/2),(1,-1/2,1),(-1/2,1,1) (three-scan-trace) as well as with one averaged diffusion weighting (one-scan-trace). For one-scan-trace measurements, gradients of nearly equal strength (≈30mT/m) with the following durations [in µs] for b=750s/mm^2 were applied: G_{phase}=6940, 21040, 21040, 6940 (+- - +); G_{read}=13850, 14130, 13850, 14130 (+-+-); G_{slice} =13350,14630,14630,13350 (+-+-), forming a symmetric/antisymmetric pair around the 180° pulse with minimal crossterms (2.3s/mm^2, 1.4s/mm^2, -3.3s/mm^2).

Results and Discussion:

Figure 1 shows a comparison between three-scan-trace images of different measuring time and different ratios of non-DW images to DW images. The best ratio for the determination of the ADC was found to be 1:6 in accordance with [5] ($SNR_{ADC(1:6)}$:$SNR_{ADC(1:3)}$≈10.6 : 9.5). This ratio also allows for switching each gradient direction twice in plus/minus direction for eddy current cancellation. For b=750s/mm^2 one-scan-trace images seem also a possible solution despite of the signal loss due to the long TE (Figure 2).

Taking the assumption of cylindrical symmetric diffusion ellipsoids, the number of unknown variables reduces to 4 (the eigenvalues λ_1,λ_2 and only two Euler angles Φ and Θ), so that an approximate map of ADC and anisotropy can already be determined by 4 gradient directions $g=[\sin\theta\cos\phi, \sin\theta\sin\phi, \cos\theta]^T$ by solving four independent equations $g^TDg = \lambda_1[\sin\theta\sin\Theta\cos(\phi-\Phi) + \cos\theta\cos\Theta]^2 + \lambda_2[\sin^2\theta\sin(\phi-\Phi) + (\cos\theta\sin\Theta - \sin\theta\cos\Theta\cos(\phi-\Phi))^2]$.

Conclusion:

The best compromise appears to be three-scan-trace images with 2av at 1:6 ratio, yielding 1:50min for 18 sections (Figure 1, middle row).
More sections within the same measuring time are expected to be imaged while application of TSTEAM in combination with parallel imaging [6].

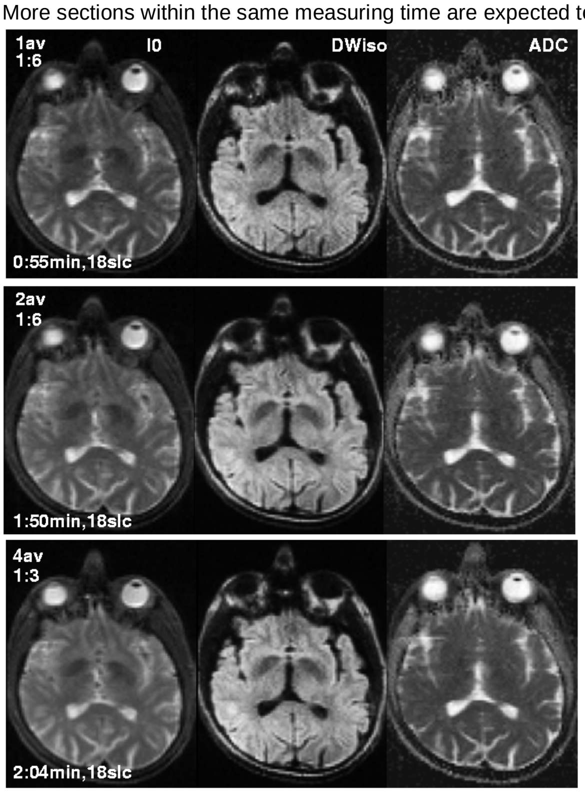

Figure 1: Non-DW image (I0), isotropic DW image and ADC map for (top) 55s, (middle) 1:50min, (bottom) 2:04min (18 sections each, b=1000s/mm^2). The ratio of non-DW images to DW images was either 1:6 or 1:3 as indicated.

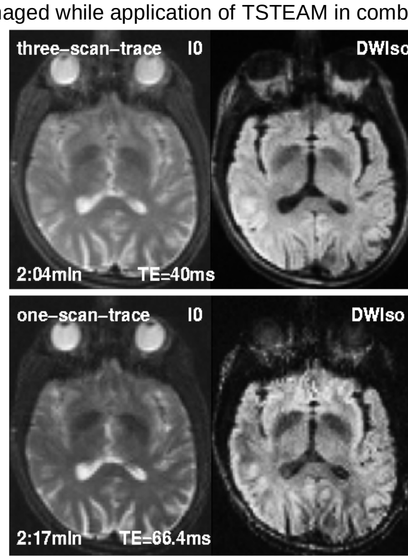

Figure 2: Non-DW image (I0) and isotropic DW image for (top) three-scan-trace and (bottom) one-scan-trace (18 sections each, b=750s/mm^2).

References:

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