Effect of Number of Shots on the Calculated Apparent Diffusion Coefficient in Phantoms and in Human Liver in Diffusion Weighted Echo Planar Imaging

M. Shiehmorteza[1], C. Sirlin[1], T. Wolfson[2], A. Gamst[2], A. Soumekh[1], S. Heaton[1], C. Kohl[3], N. Pinto[1], and M. Bydder[1]

[1]Radiology, University of California San Diego, San Diego, CA, United States, [2]Family and Preventive Medicine, University of California San Diego, San Diego, CA, United States, [3]Radiology, University of Arizona

Introduction: Single-shot spin-echo echo planar imaging (SE EPI) is a common MRI technique used in diffusion imaging [1]. For a given *b*-value, the entire 2D k-space data is acquired by a single RF excitation pulse within a fraction of a second and the sequence is repeated for each b-value. Therefore, each imaging slice experiences a series of identical RF excitation pulses with different applied gradients, evenly spaced by the repetition time (TR). Owing to the finite repetition time, the longitudinal magnetization reaches steady state only after a sufficient number of prior excitations [2]. If the approach to steady state occurs during the acquisition of multiple *b*-values for ADC measurement, the calculated results will be confounded.

Materials and Methods: This HIPAA-complaint, IRB-approved prospective study was performed on 35 adult patients with a history of liver disease (21 men, 14 women; mean age, 46.0 years; range, 19-73 years) and 20 healthy volunteers (13 men, 7 women; mean age, 36.0 years; range, 25-56 years). Diffusion images were obtained on a 3T GE Twin Speed (Milwaukee, WI) scanner using a breath-held diffusion-weighted spin-echo echo planar imaging sequence. The following parameters were applied: field of view 320 - 420 mm; flip angle 90°; matrix 128 x 160 pixels; slice thickness 8 mm; intersection gap 0 mm; frequency-selective fat suppression; and parallel imaging factor two. The minimum TE was selected, as calculated by the scanner, but was constant for each protocol.

Three protocols were used: **(A)** eight consecutive shots at a fixed *b*-value of 0 s/mm^2; **(B)** seven consecutive shots at *b*-values 0, 1000, 750, 500, 250, 100, 0 s/mm^2(in that order); and **(C)** seven consecutive shot (as in protocol B) with TR 1000, 1750, 3500 and 7000 msec. Three co-localized oval regions of interest (400-600 mm^2) were placed in representative areas of each liver, while excluding intrahepatic vessels, focal liver lesions and artifacts. ADC was computed by non-linear least squares fitting of the 6 *b*-values signal intensity to a mono-exponential decay. Mixed effects linear regression version of a paired t-test which accounts for within-subject dependence, was used to compare data.

Results: For protocol **(A)**, signal intensity decreased significantly from the first to second shot (p<0.0001) and thereafter remained constant (Fig. 1). The observed difference between the initial shot and the subsequent shots was significantly lower at TR=3000 msec than TR=1000 (p<0.0001). For protocol **(B)**, the ADC depended on which b=0 s/mm^2 image was used. Using the first *b*=0 s/mm^2 (pre-steady state), the mean ADC was 15% higher than using the second *b*=0 s/mm^2 (steady state) (p<0.0001) (Fig. 2). For protocol **(C)**, the difference between ADC using the first *b*=0 s/mm^2 and the second *b*=0 s/mm^2 decreased as the TR increased (Fig. 3a,b).

Conclusion: Our results indicate that ADC value depends on whether the *b*=0 s/mm^2 image is acquired at pre-steady state or at steady state. These finding imply that images acquired before steady state is achieved do not provide a pure measure of ADC. Therefore, when measuring ADC in a SE EPI, at least one dummy pulse should be applied even when TR ≥ 3000 msec.

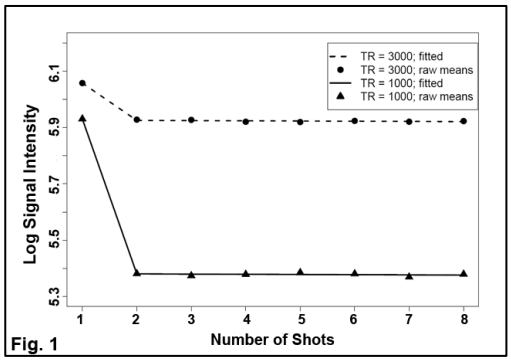

Fig. 1

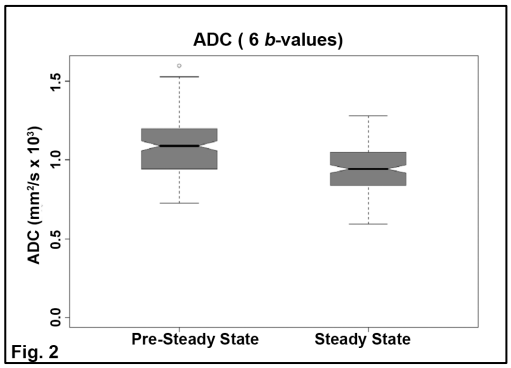

Fig. 2

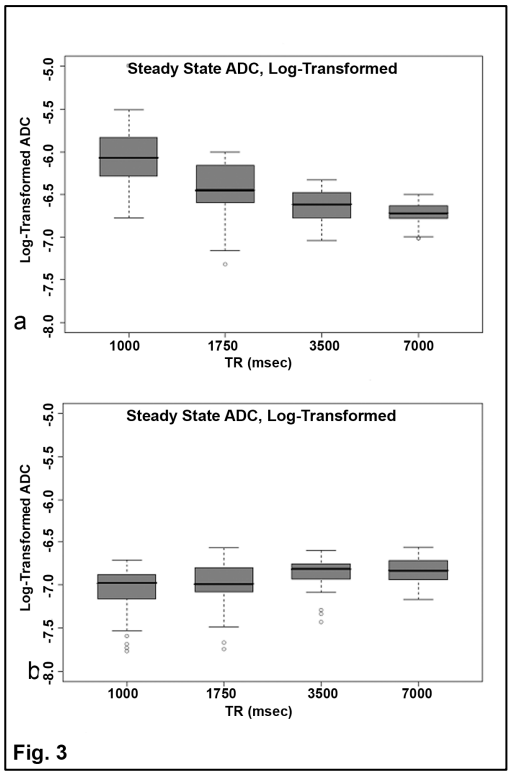

Fig. 3

References:

[1] Yamashita Y et al. Ultrafast MR imaging of the abdomen: echo planar imaging and diffusion-weighted imaging. J Magn Reson Imaging 1998;8(2):367-374.

[2] Bernstein MA et al. Basic Pulse Sequences. Handbook of MRI pulse sequences. 1st ed. Burlington: Elsevier Academic Press, 2004; 588

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