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Reliability and repeatability of apparent diffusion coefficient value of normal prostate

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1. Purpose

The IVIM model (1) predicts a fast exponential component in the diffusion weighted imaging (DWI) signal decay due to perfusion effects at low b-values. The perfusion fraction of IVIM has shown to be highly variable in prostate (2, 3). We aimed to investigate the reliability and repeatability of apparent diffusion coefficient (ADC) values calculated using low b-values (lower than 100 s/mm^2) compared with ADC values calculated excluding low b-values. Moreover, the reliability and repeatability of ADC values calculated using different number of b-values was examined.

2. Material and Methods

Ten healthy volunteers (mean age 53 ± 8) underwent in total four repeated 3T single-shot spin-echo epi based DWI examinations performed on two separate days using surface coils only. The following parameters were used: TR/TE 7000 ms/87 ms, FOV 260×260 mm, matrix size 128x128, slice thickness 5 mm, no intersection gaps, a bandwidth of 1628 Hz/pixel acquiring 6/8 (75%) of the k-space in the phase-encoding direction, 2 signal averages, GRAPPA with the acceleration factor of 2 and 24 reference lines for autocalibration. The following 16 equally distributed b-values from 0 to 2000 s/mm^2 were used: 0, 50, 100, 200, 350, 500, 650, 800, 950, 1100, 1250, 1400, 1550, 1700, 1850, 2000 s/mm^2. The acquisition time was 11 minutes and 6 seconds.

All possible b-value combinations containing at least one of the first 4 b-values (0, 50, 100, 200 s/mm^2) were used for ADC calculation. Apparent diffusion coefficient values were calculated using monoexponential fit:

adc_b.jpg

$$S(b) = S_0 e^{-bADC}$$

Fitting procedure was performed using the lsqnonlin MATLAB algorithm (Mathworks Inc., Natick, MA, USA). Multiple initialization values were used to limit possible effects of local minima in the fitting. The initialization values for ADC ranged from 0 to 0.01 with a step size of 0.0001. Eight regions of interest (ROIs) sized 6x6 mm (squares of 3x3 pixels) were placed in the peripheral zone (PZ) while 4 similarly sized and shaped ROIs were placed in the central zone (CZ) of each healthy volunteer.

Reliability and repeatability of ADC values, calculated using different b-value combinations, was analyzed using Shrout-Fleiss analysis. Shrout-Fleiss analysis is a reliability measurement based on intraclass correlation coefficients (4). Specifically, in the current study the intraclass correlation coefficients ICC(3,k) were calculated, which assumes that all subjects are exposed to the identical scan parameters throughout all scans in the study. The reliability calculation consisted of the mean of k ROIs using identical settings. In addition, no subject-scan interaction was assumed. In order to illustrate the variation between ADC values calculated using low b-values and excluding low b-values, Bland-Altman plots were constructed. The ROIs from CZ and PZ were pooled together in both of the analyses. Statistical analysis was performed with SAS System for Windows, version 9.3 (SAS Institute Inc., Cary, NC).

3. Results

In total 61436 b-value combinations were evaluated. Removal of 0 and 50 s/mm^2 b-values improved the reliability and repeatability of ADC values of normal prostate. The effect was mainly prominent when only 2 or 3 b-values were used for ADC calculation. In general, ADC values calculated using combinations without b-values of 0 and 50 s/mm^2 had better reliability and repeatability than ADC values calculated using b-value combinations without 0, 50 and 100 s/mm^2 b-values. The use of more than 5 b-values led to only minor further improvement in the reliability and repeatability of ADC values. Intraclass correlation coefficients, calculated using Shrout and Fleiss analysis for the subset of ADC values calculated using b-value combinations with the highest b-value of 650 s/mm^2 and 2 b-values used in the ADC calculation, are shown in Figure 1. In the same subset, 4.41% of observations were out of 2 standard deviations (SD) in Bland-Altman analysis when 4 b-values were used while only 1.77% when 7 b-values were used for the b-value combinations with and without the use of 0, 50 s/mm^2 (Figure 2). In the same subset, 4.54% and 2.84% of observations were out of 2 SD in Bland-Altman analysis when ADC values calculated using and excluding b-value of 0 s/mm^2 with the use of 3 and 4 b-values in total, respectively (Figure 3). Moreover, 2.91 % of observations were out of 2 SD for the b-value combinations with/without the use of 0, 50 s/mm^2 for 5 b-values used while 3.4% for the b-value combinations with/without the use of 0, 50 and 100 s/mm^2 for6 b-values used (Figure 4).

Figure 1

Intraclass correlation coefficients calculated using Shrout and Fleiss analysis for ADC values, calculated using b-values combinations with 2 b-values in total and the upper limit of 650 s/mm^2. Intraclass correlation coefficients with 95% confidence are shown.

figure_1_a_b.jpg

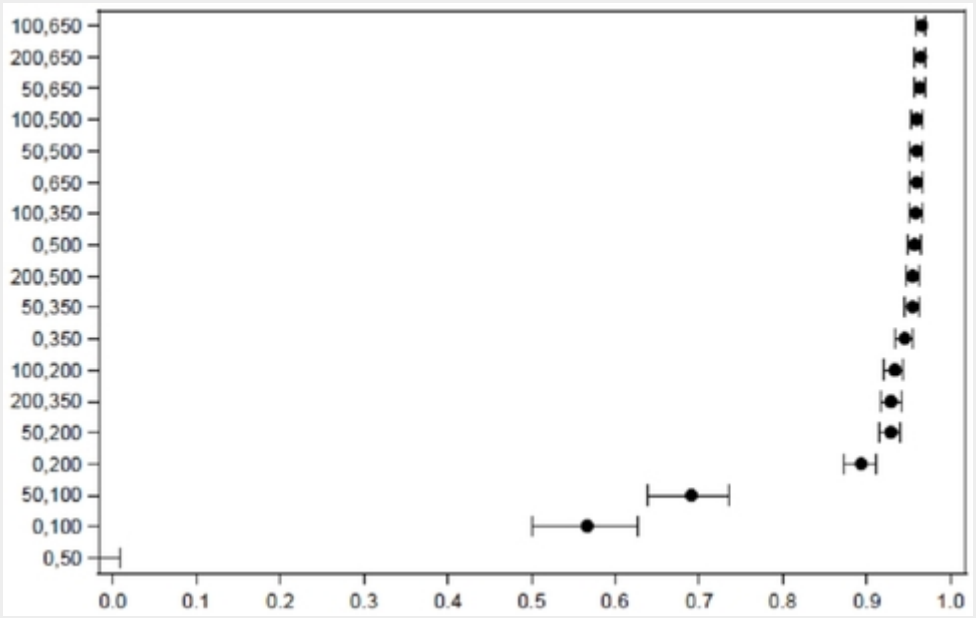


Figure 2

Bland-Altman plot for pairs of ADC values calculated using and excluding b-values of 0 and 50 s/mm^2. The upper limit for the b-values was 650 s/mm^2.

figure_2_a_b.jpg

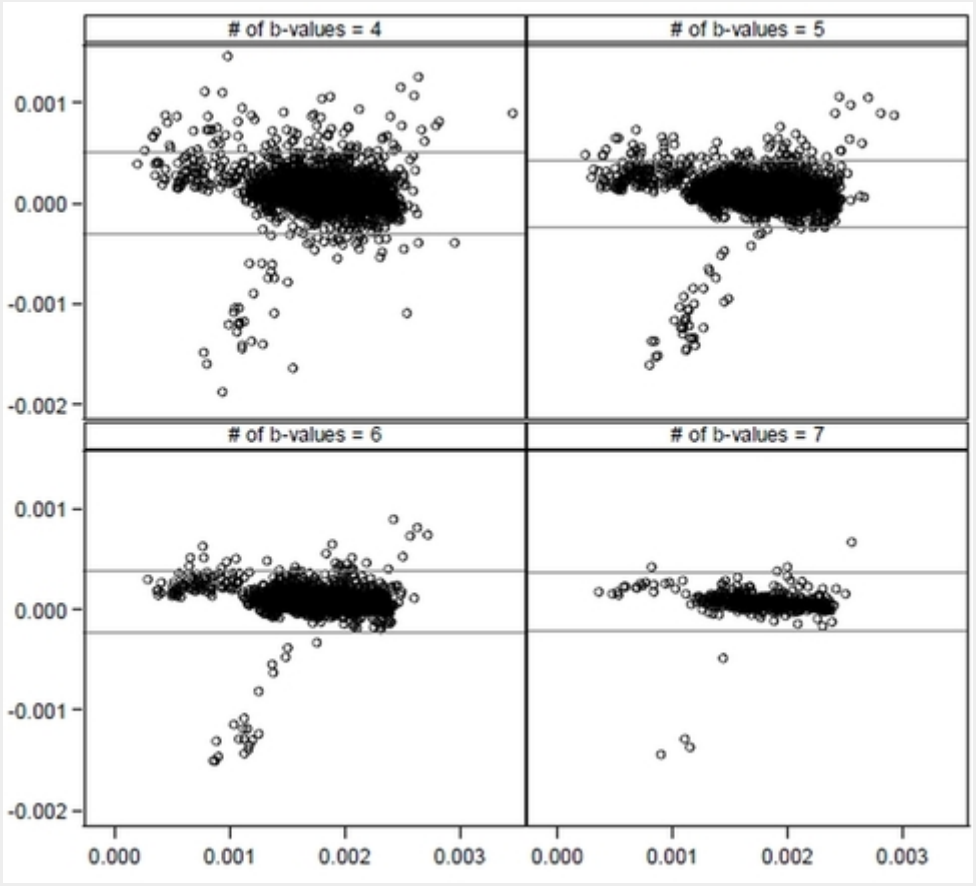


Figure 3

Bland-Altman plot for pairs of ADC values calculated using and excluding b-value of 0 s/mm^2. The upper limit for the b-values was 650 s/mm^2.

figure_3_a_b.jpg

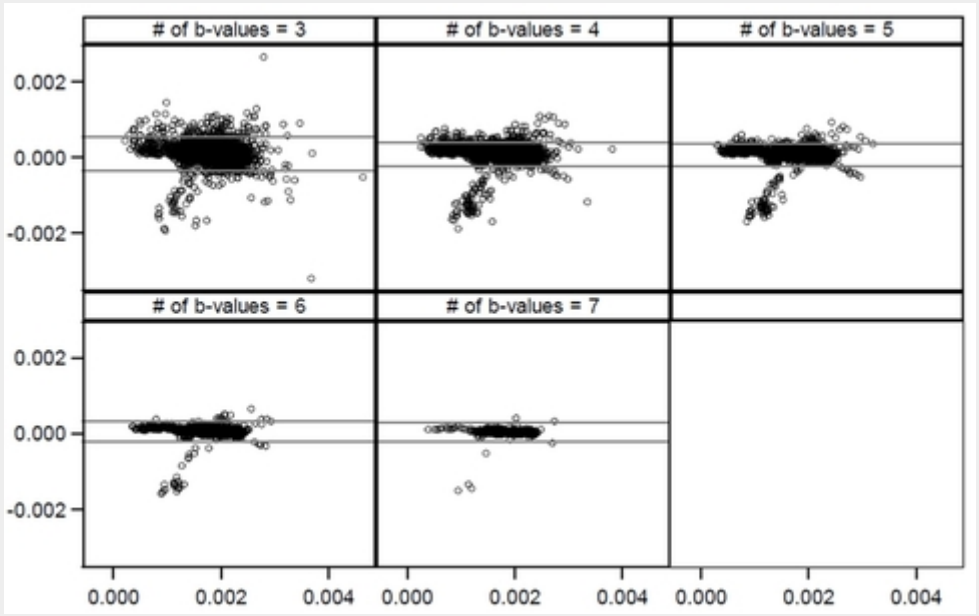
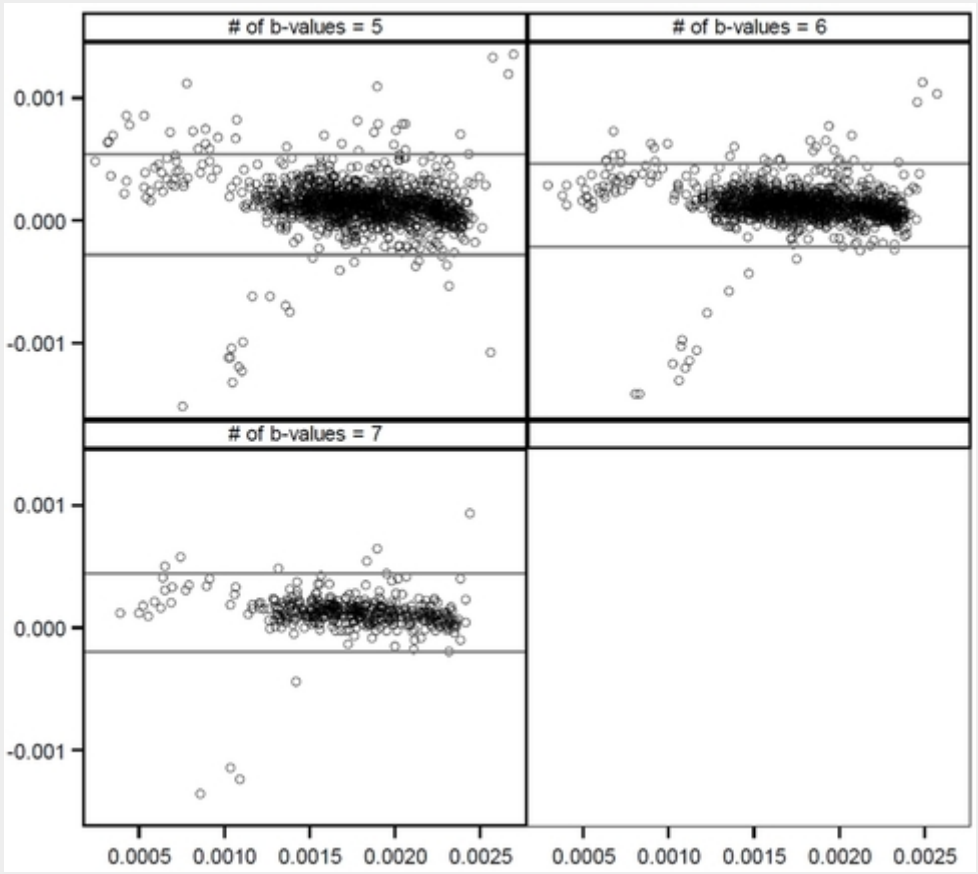


Figure 4

Bland-Altman plot for pairs of ADC values calculated using and excluding b-values of 0, 50 and 100 s/mm^2. The upper limit for the b-values was 650 s/mm^2.

figure_4_a_b.jpg



4. Conclusion

Apparent diffusion coefficient values calculated without the use of 0 and 50 s/mm^2 b-values had better reliability and repeatability than ADC values calculated using low b-values. The effect was mainly prominent when 2-3 b-values were used in the ADC calculation. Additional removal of 100 s/mm^2 b-value had just a minor effect and seems to be unnecessary. Our findings support the use of non-0 b-values for ADC calculation of normal prostate.

References:

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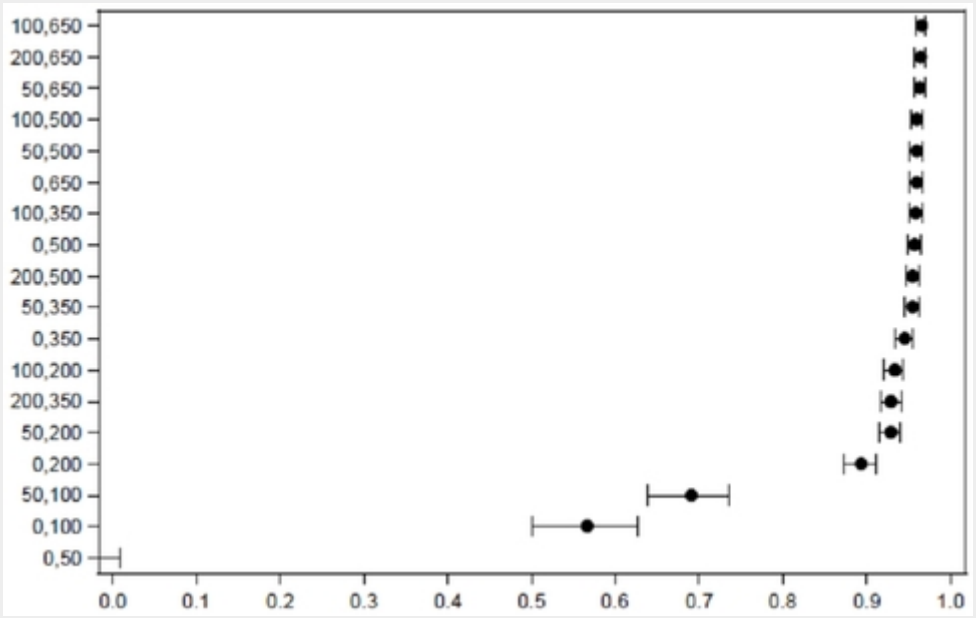
5. Mediafiles

adc_b.jpg

$$S(b) = S_0 e^{-bADC}$$

figure_1_a_b.jpg



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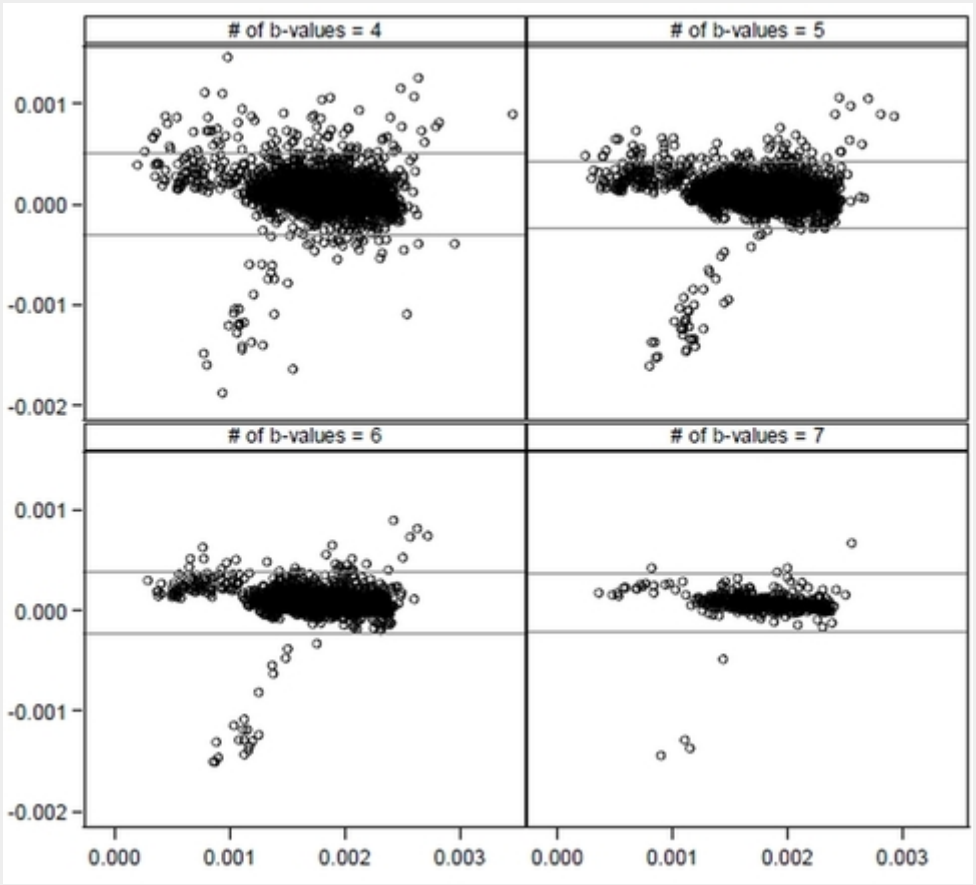

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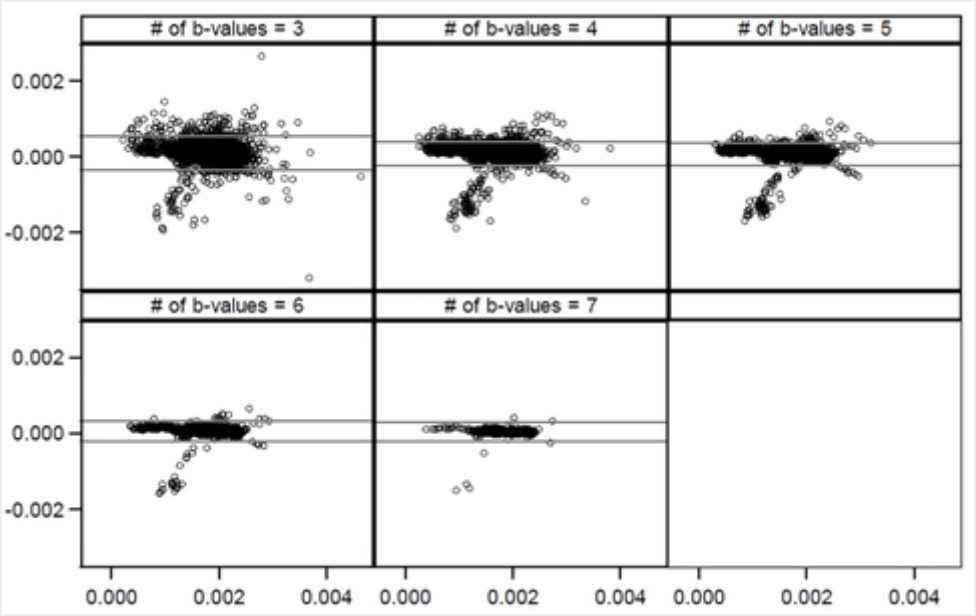

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