Investigation of DTI Bootstrap Reproducibility in the Human Brain

R. S. Vorburger[1], C. Reischauer[1], K. Dikaiou[1], P. Staempfli[1], and P. Boesiger[1]

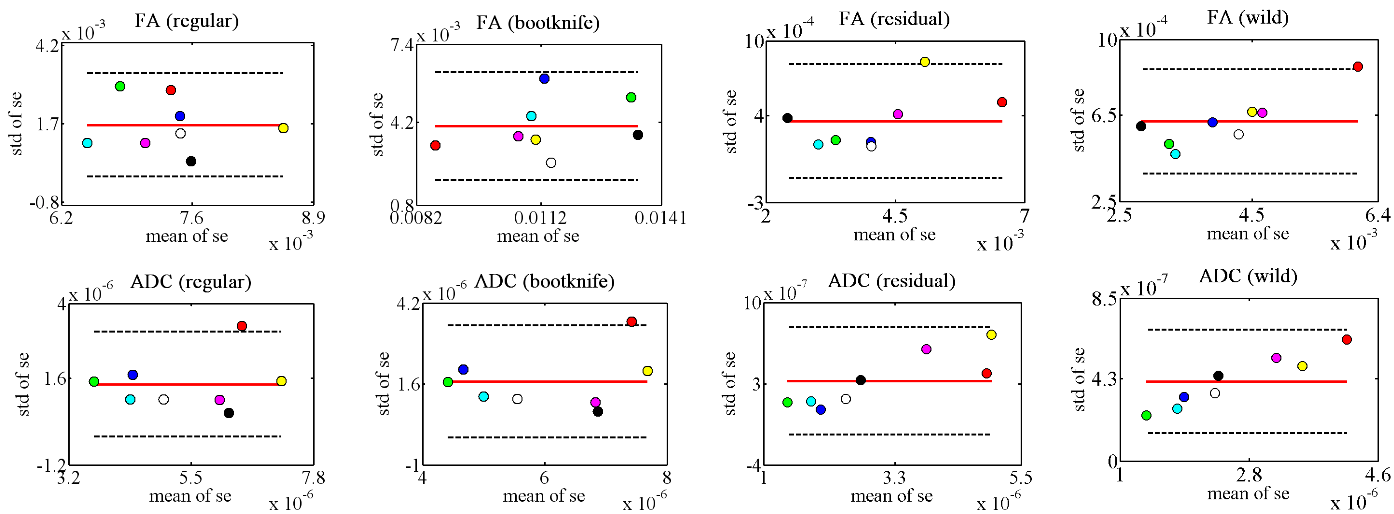
[1]Institute for Biomedical Engineering, University and ETH Zurich, Zurich, Switzerland

Introduction

Bootstrap methods have been recently introduced for the quantification of the uncertainty of parameters derived with diffusion tensor imaging (DTI) such as the fractional anisotropy (FA) value or the apparent diffusion coefficient (ADC). The performance of these methods has been investigated in several studies [1-5]. So far, the reproducibility of these techniques has been demonstrated solely in a restricted Monte Carlo framework [3]. In this study, four different bootstrap algorithms are investigated with respect to their reproducibility in in-vivo measurements. The non-model-based regular bootstrap approach [1,2] and the bootknife method [4] as well as the model-based residual and wild bootstrap techniques [4,5] are applied to selected regions of interest (ROIs) in the human brain.

Methods

Data was acquired on the 3T system Philips Achieva (Philips Healthcare, Best, the Netherlands) using a diffusion-weighted single-shot spin-echo EPI sequence with the following scan parameters: FOV = 210x210 mm^2, matrix = 104x102, reconstructed to = 112x112, 50 contiguous slices, slice thickness = 2 mm, SENSE factor = 2.1, TE = 43 ms. Cardiac gating was applied in all measurements. Diffusion weighted scans were performed along 30 directions with a maximum b-factor of 1000 s/mm^2, complemented by one scan with b = 0 s/mm^2. Eddy current induced image warping was corrected in each data set using a correlation-based affine registration algorithm. The scan was repeated 7 times for calculations with the regular bootstrap algorithm and the bootknife method. The residual and the wild bootstrap techniques were performed on the first scan of the series. 1000 bootstrap iterations were carried out in all four cases. The described scan session was repeated 8 times on 8 different days with the same volunteer. Subsequently, bootstrap analysis was performed in 8 ROIs in the brain. The mean FA values and ADCs were calculated in each ROI for all bootstrap samples. The standard error (se) of these mean values was then derived for each scan session. The relation between the standard deviation of these standard errors and their mean over the 8 scan sessions was used as the criterion of reproducibility [6].



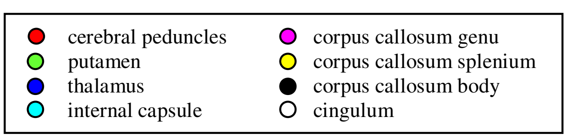


Fig. 1: Bland-Altman plots for the four bootstrap approaches. The value of interest is the standard error (se) of the mean FA and ADC in each ROI (see methods section). The standard deviation (std) of these values over the 8 repeated measurements is plotted against their mean.

Results

The quantification of the standard error of the ADCs and the FA values using bootstrap analysis is reproducible since more than 95% of the standard errors are in the range of two standard deviations which is depicted in the Bland-Altman plots (Fig.1). Thereby, all investigated techniques show similar reproducibility. The only exception occurs in the cerebral peduncles (red) where the results marginally exceed the limits of the confidence interval in three cases.

Discussion and Conclusion

The reproducibility of four different bootstrap approaches was demonstrated in a clinical measurement setup. A difference in reproducibility of the model-based and the non-model-based techniques was not observed. Therefore, the residual and the wild bootstrap provide powerful techniques to quantify the uncertainty of DTI parameters without the need of additional measurements which facilitates the application for clinical studies and in scientific research.

References

[1] Pajevic, S. et al., [2003], JMR, 161: 1-14. [2] Jones, D.K. et al., [2003], MRM, 49: 7-12. [3] O'Gorman, R. L. et al., [2006], MRM, 56: 884-890. [4] Chung, S. W. et al., [2006], NeuroImage, 33: 531-541. [5] Whitcher, B. et al., [2008] HBM, 29: 346-362. [6] Bland, J. et al., [1986], Lancet, 1:307-310.