

Multi-centre reproducibility of diffusion MRI parameters for clinical sequences in the brain

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Target Audience: Those interested in using diffusion for clinical evaluations.

Purpose: Diffusion imaging is widely used both in research and in the clinic. In areas where clinical data are sparse, such as in rare diseases, it may be necessary to include data from multiple centres in order to conduct experiments on a sufficiently large group of patients to reach meaningful conclusions. While the availability of multi-centre data may be beneficial in terms of increasing the amount of data available for a given study, it introduces the question of whether such data, obtained using clinical echo-planar imaging (EPI) based diffusion protocols and on different scanners with different field strengths, is comparable. We thus aim to assess the reproducibility of diffusion MRI, and in particular the apparent diffusion coefficient (ADC), intra-voxel incoherent motion (IVIM) parameters and diffusion tensor imaging (DTI) parameters, across multiple centres using clinical sequences.

Methods: An ice-water phantom¹ and between four and eight healthy volunteers were scanned across five centres on eight scanners – four 1.5T and four 3T machines. The mean ADC, IVIM parameters – diffusion coefficient (D) and perfusion fraction (f), and DTI parameters – mean diffusivity (MD) and fractional anisotropy (FA), were measured in grey and white matter and a mixed effect model generated in order to calculate the intra- and inter-scanner coefficient of variation (CV) for each parameter.

Results: In the ice-water phantom ADC, D and MD had very similar results with a mean value of $1.1 \times 10^{-3} \text{ mm}^2 \text{s}^{-1}$ for all three parameters, matching the expected value. Results for the reproducibility in the volunteers are shown in Table 1. ADC, D, MD and FA had a good intra- and inter-scanner reproducibility in both grey and white matter, ranging between 1 and 7.4%; mean 2.6%. The IVIM parameter f had a poorer intra-scanner CV of 8.4% and inter-scanner CV of 24.8%. The mean values of ADC, D and MD were 0.83, 0.75 and 0.85 in grey matter and 0.70, 0.65 and 0.70 in white matter respectively; f was 0.10 in grey matter and 0.08 in white matter. FA had a mean value of 0.42 in white matter and 0.17 in grey matter.

Discussion: ADC, D, MD and FA all showed a good reproducibility, with the intra-scanner CV having very similar values to the inter-scanner CV, suggesting that using data from multiple scanners does not have an adverse effect when compared to using data from the same scanner. On the other hand f was affected by the scan acquisition resolution, which would need to be taken into account when comparing data from different scans. In accordance with previous literature, ADC, D and MD all had a higher value in grey matter than in white matter; grey matter had an increased perfusion compared to white matter; and FA was higher in white matter where the presence of structured fibres contributes to the anisotropy of the diffusion of water molecules.

Conclusion: Diffusion MRI measures, and in particular ADC, D, MD and FA have a good reproducibility and research studies can benefit from incorporating multi-centre data without any loss of reproducibility compared to what would be achieved from a single scanner at a single site.

Funding: This work has been funded by Cancer Research UK, grant number C7809/A10342.

References: 1. Malyarenko D, Galbán CJ, Lundy FJ, et al. Multi-system repeatability and reproducibility of apparent diffusion coefficient measurement using an ice-water phantom. *JMRI*. 2013.

| | | Volunteers | Mean | Inter-scanner | Volunteer | Intra-scanner |
|------|-----|--|--------|---------------|--------------|---------------|
| DWI | ADC | GM $\times 10^{-3} \text{ mm}^2 \text{s}^{-1}$ | 0.8327 | ± 0.0203 | ± 0.0246 | ± 0.0242 |
| | | CV | | 2.4% | 3.0% | 2.9% |
| | WM | $\times 10^{-3} \text{ mm}^2 \text{s}^{-1}$ | 0.7010 | ± 0.0210 | ± 0.0156 | ± 0.0072 |
| | | CV | | 3.0% | 2.2% | 1.0% |
| IVIM | D | GM $\times 10^{-3} \text{ mm}^2 \text{s}^{-1}$ | 0.7495 | ± 0.0207 | ± 0.0186 | ± 0.0159 |
| | | CV | | 2.8% | 2.5% | 2.1% |
| | WM | $\times 10^{-3} \text{ mm}^2 \text{s}^{-1}$ | 0.6506 | ± 0.0249 | ± 0.0115 | ± 0.0108 |
| | | CV | | 3.8% | 1.8% | 1.7% |
| DTI | f | GM | 0.1005 | ± 0.0204 | ± 0.0026 | ± 0.0111 |
| | | CV | | 20.3% | 2.6% | 11.1% |
| | WM | | 0.0799 | ± 0.0234 | ± 0.0020 | ± 0.0047 |
| | | CV | | 29.2% | 2.6% | 5.8% |
| | MD | GM $\times 10^{-3} \text{ mm}^2 \text{s}^{-1}$ | 0.8490 | ± 0.0212 | ± 0.0080 | ± 0.0202 |
| | | CV | | 2.5% | 0.9% | 2.4% |
| | WM | $\times 10^{-3} \text{ mm}^2 \text{s}^{-1}$ | 0.6971 | ± 0.0111 | ± 0.0180 | ± 0.0094 |
| | | CV | | 1.6% | 2.6% | 1.3% |
| | FA | GM | 0.1726 | ± 0.0047 | ± 0.0097 | ± 0.0128 |
| | | CV | | 2.7% | 5.6% | 7.4% |
| | WM | | 0.4187 | ± 0.0083 | ± 0.0157 | ± 0.0088 |
| | | CV | | 2.0% | 3.8% | 2.1% |

Table 1: Reproducibility in Volunteers. The table shows the mean and standard deviation values for each of the measured parameters (ADC, D, f, MD and FA) together with the associated coefficient of variation (CV) in grey matter (GM) and white matter (WM). The first column gives the mean, the second shows the inter-scanner reproducibility, the third shows the changes expected if a different volunteer is scanned on the same scanner, while the fourth column shows the intra-scanner CV.