The Stability of Diffusion Measurements with Simultaneous Multi-Slice Imaging: A Multi-Scanner, Multi-Site, Test-Retest Study using the NIST/QIBA CalibreMRI Diffusion Phantom

Ryckie Wade *
NIHR Academic Clinical Lecturer, University of Leeds, Leeds, England

Matthew Marzetti
NIHR Academic Clinical Lecturer, University of Leeds, Leeds, England

Abstract

Introduction: Multi-band, also referred to as Simultaneous Multi-Slice (SMS) imaging, has become an essential tool for accelerating diffusion-weighted imaging (DWI). By acquiring multiple slices simultaneously, SMS reduces acquisition time, improves patient comfort, and limits motion artefacts. However, there are concerns about the accuracy of quantitative parameters, including apparent diffusion coefficients (ADC). This prospective multi-centre, multi-scanner, test re-test study evaluates the effect of SMS acceleration on ADC measurements across different MRI systems using a traceable diffusion phantom.

Methods: A CaliberMRI diffusion phantom with 13 traceable insets (with known diffusivity values) and MR-readable thermometers, from the National Institute of Standards and Technology (NIST) was scanned on four Siemens, GE and Philips systems at 1.5 and 3.0 Tesla. Scans were performed using a head coil per the manufacturer specifications; all parameters were constant except the SMS factors which were off, 2, 3, and 4. ADC values were extracted using the manufacturer's qCal software and compared to the published reference values for the phantom at the recorded temperature. We assess the relationship between the observed and reference ADC values across the phantom's range. Mean absolute percentage differences were calculated to quantify deviations. Repeat scans were acquired to assess reproducibility.

Results: The phantom was scanned on 15 separate days, spanning a period of 1 year, 7 months and 10 days. Data from 4,962,505 voxels, spaced over 9178 vials (2118 containing water and 7060 containing PVP gels) were captured. Overall, scanners measured diffusivity 4% higher (CI 3·59, 4·46) than the NIST reference values. Without SMS acceleration, scanners measured diffusivity a mean 2·80% higher than the NIST reference value (CI 2·40, 3·26) and using SMS 2 did not introduce additional bias. However, SMS 3 and SMS 4 both introduced significant additional biases in estimates of diffusivity across all media (mean bias 4.62% and 9.22%, respectively). The scanner brand appeared to explain some bias in diffusivity caused by SMS3; GE systems were worst (mean bias 8·04% [CI 3·67, 17·6]), followed by Siemens (mean bias 4·10% [CI 3·68, 4·58]). Philips system generated no statistically significant bias (1·45% [CI 0·81, 2·58]). Estimates were stable within sessions (same day) and over time (month-to-month). Shortening the TR from 8 to 2 seconds had no demonstrable impact on ADC estimation.

Conclusions: Higher SMS factors can bias ADC measurements and reduce SNR. We advocate caution with high SMS factors in both clinical and research imaging where absolute ADC quantification is required. However, ADC measurements appear temporally consistent (even at high SMS factors) suggesting potential utility in longitudinal monitoring of relative ADC changes. Low SMS factors do not significantly degrade image quality or bias ADC values across scanner manufacturers, and therefore may be clinically acceptable to reduce scan times.