Noise correction for diffusion kurtosis imaging

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GOAL

We hypothesize that after noise bias correction, the variability of the mean kurtosis (MK) across experiments will be reduced for a given brain area, independently of the SNR variability.

INTRODUCTION

Diffusion kurtosis (DK) is a recent model for diffusion imaging, which takes into account non-Gaussian diffusion, giving the opportunity to infer about microstructural changes in white matter but also in grey matter. Compared to the traditional diffusion tensor model, DK imaging requires higher diffusion weightings (b-values).

When acquiring diffusion data, low signal-to-noise ratio (SNR) becomes critical, especially at high diffusion weightings. Complex images resulting from the combination of multichannel data are generally rendered as magnitude images, introducing a strong bias in the actual signal estimate at low SNR.

Correction methods are essential to take into account this noise-induced bias in diffusion model estimation.

Two correction methods are presented here:

1. Power image correction (BE) [2] adapted for multichannel data
2. Look-up table correction (ETA) based on the analytical expression of the central chi distribution of the noise [3,4].

METHODS

Acquisition protocol - DKI data were acquired on a 3T scanner (Allegra, Siemens Medical Solutions, Erlangen Germany) with 8-channel head coil and the following parameters: 2.4mm isotropic spatial resolution, 60 directions, b=0/1000/2500 s.mm^{-2}.

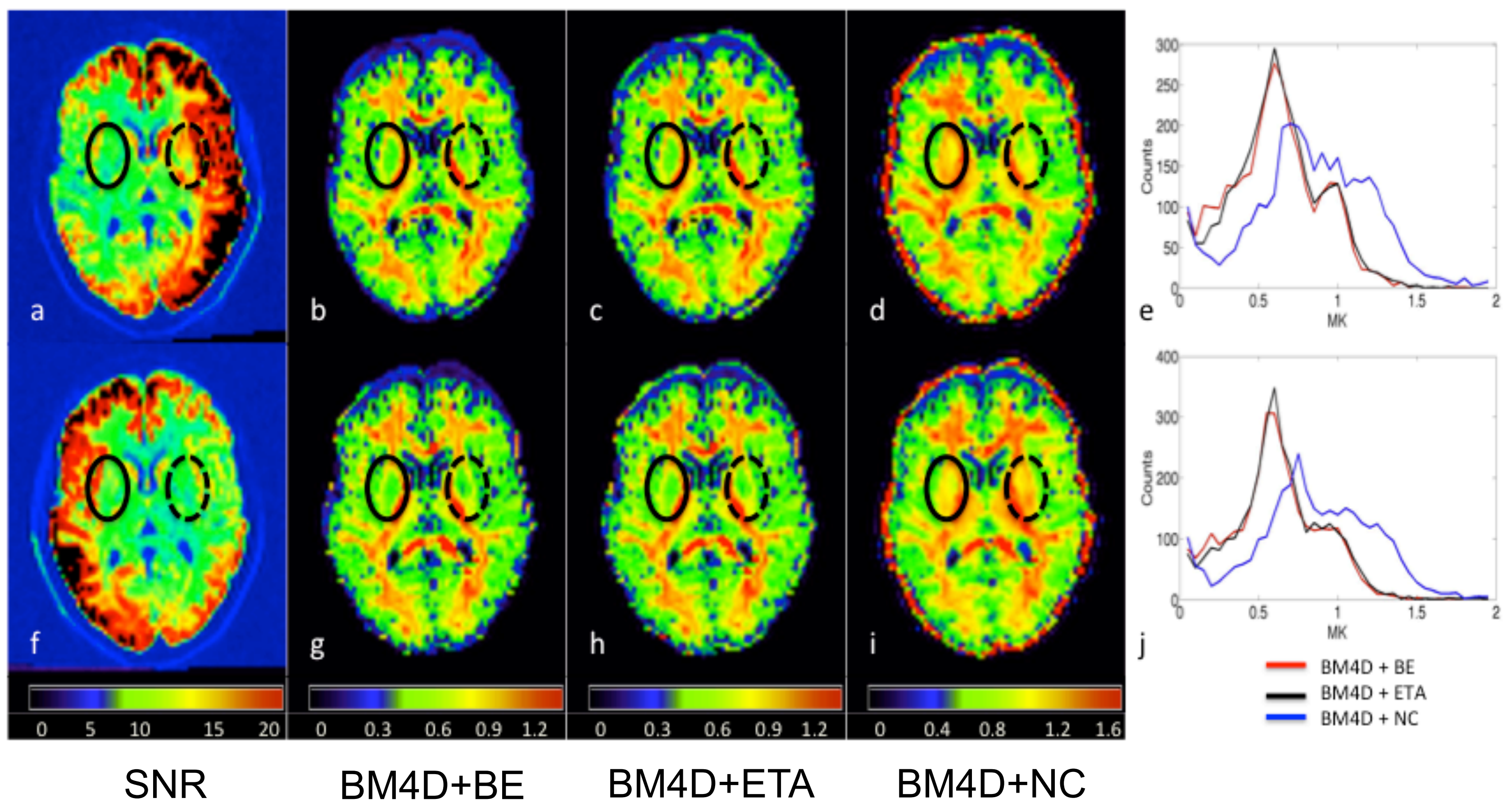
Spatial distribution - In order to compare data with different SNR levels, the same experiment was repeated 5 times on the same volunteer while varying the head position (centre of the coil, slight shift to the left, right, up and down) and therefore varying the spatial distribution of SNR.

Processing steps:
1- Intra-subject motion correction
2- Denoising (edge-preserving non-local mean filtering, BM4D [5])
3- Noise bias correction
3- Model fitting for each direction
4- Estimation of the kurtosis tensor and calculation of MK maps.
5- Registration of the five acquisitions onto the first one

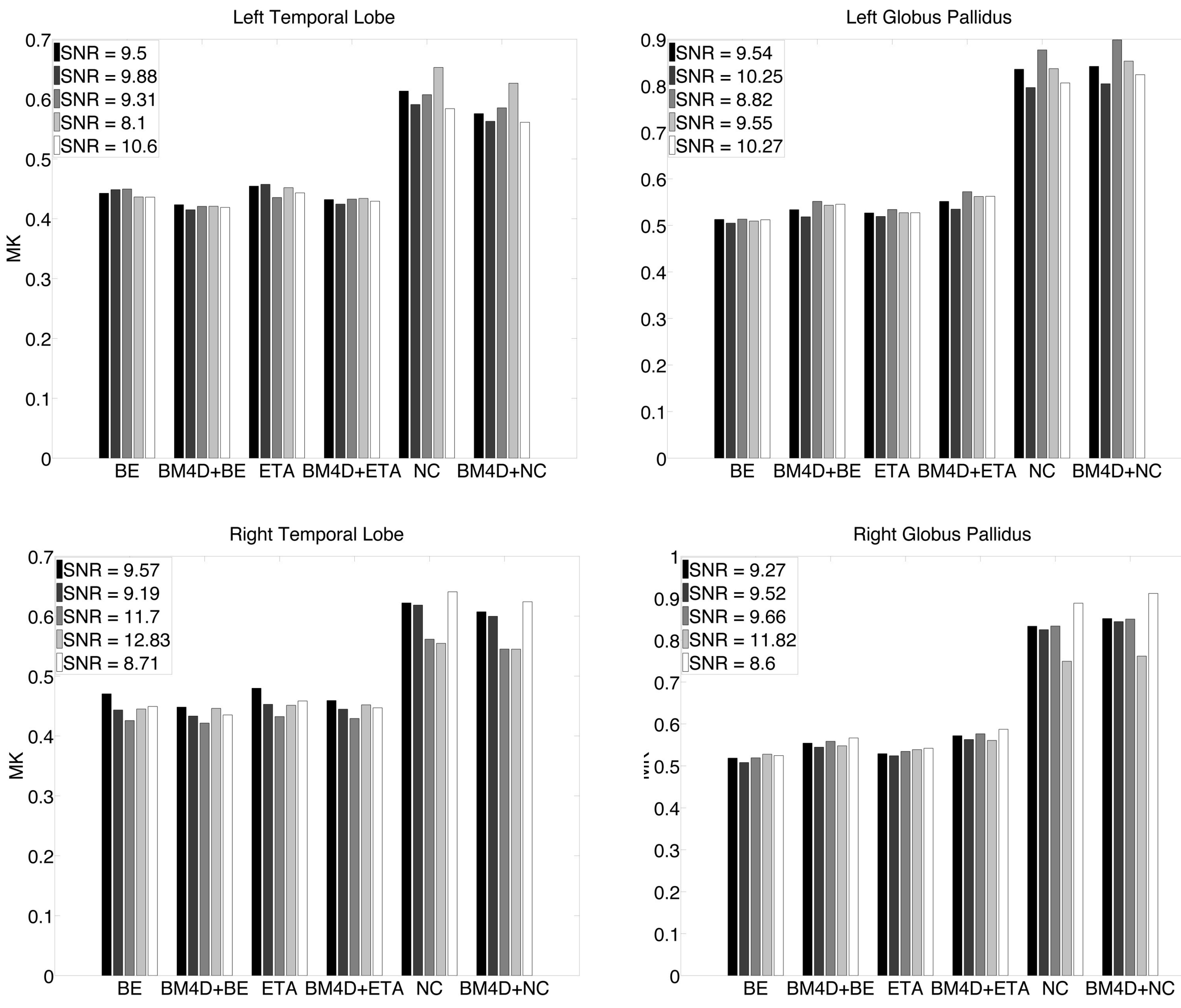
Region of Interest analysis (ROI)
8 ROIs were delineated in different white matter and grey matter areas using the Harvard-Oxford subcortical structural atlas and the JHU white-matter tractography atlas available in FSL.
MK was extracted from these ROI for comparisons.

RESULTS

MK maps (b-d, g-i) and corresponding histograms (e,j) for two different SNR distributions (a,e), showing the impact of noise correction on the MK estimate.
MK maps are similar for both correction schemes, independent of the SNR, as emphasized by their practically coinciding histograms (e, j). Without noise correction, MK maps (d, i) exhibit systematically higher values, especially when SNR is lower, as delineated by the dashed circle and demonstrated by the histograms.



MK comparison for 4 ROIs. For each ROI, the barplot shows the MK estimate for each measurement (5 bars with different grey shading and SNR level) and each processing scheme. The lower the SNR, the higher the bias in estimating MK. Noise correction leads to lower MK values which are consistent through the measurements and SNR-independent.



MK values are independent of SNR after noise correction. Without any noise bias correction, MK is globally higher and highly depends on SNR.

Conclusion

We showed that noise bias correction has an impact on kurtosis estimation and must be applied prior to kurtosis estimation to provide reliable and reproducible results independently on SNR and hence on head position.

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