The Relative Sensitvity of Different White Matter Indices to Partial Volume Artefacts

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INTRODUCTION: This abstract focuses on a simple – but important - question for the neuroscientist / clinician wishing to characterize tissue microstructure using non-invasive MRI techniques. i.e, "*What is the relative sensitivity of different MRI microstructural metrics to partial volume artifacts*?" The question is important – since differential sensitivity may be interpreted as a more marked change microstructure - when none exists.

METHODS: Partial volume effects were simulated by first assuming a voxel contains a 'tissue' component (a diffusion tensor with fixed mean diffusivity 0.7 x 10^{-3} mm^2s^{-1}, and variable fractional anisotropy ($0.2 \leq FA \leq 0.9$)) and a 'CSF' component (an isotropic tensor with mean diffusivity of 3.0 x 10^{-3} mm^2s^{-1}). The 'tissue volume fraction', f, was varied so that $0.5 \leq f \leq 1$. Diffusion weighted data were then computed for a 30-direction gradient sampling scheme, for different b-values ($850\ s\ mm^{-2} \leq b \leq 1500\ s\ mm^{-2}$). A single tensor was subsequently fitted to the signals - and the mean diffusivity and fractional anisotropy derived.

RESULTS: The key results are presented below. **Figure 1** shows the percentage error in Trace (upper plots) and FA (lower plots) for 2 different anisotropies (FA = 0.2 and 0.9) and 7 different b-values ($900\ s\ mm^{-2} \leq b \leq 1500\ s\ mm^{-2}$). **Impact of FA**: Predictably, there is minimal impact of anisotropy on the error in the trace. However, there is a marked FA dependence of the percentage FA error. Specifically, the lower the anisotropy – the *greater* the error in the FA due to partial volume. **Impact of B-value**: The error in the quantitative metrics is most pronounced at b= $900\ s\ mm^{-2}$, and improves progressively as the b-value is increased. **Figure 2** shows how the percentage error varies as a function of FA (data for b = $1000\ s\ mm^{2}$). What is important to note here is that the change in anisotropy is *almost* proportional to change in volume (as shown by the plot being close to the line of identity). However, for low anisotropy (FA < 0.5) – the effect is more pronounced than changes in volume, (slope is steeper than identity), while for higher FA(>~ 0.5), the % change is *less* pronounced than the volumetric change. Thus – depending on the FA value, one reaches different conclusions about which is 'more sensitive' - FA or volume change. These dependencies are strongly dependent on the bvalue – and so the conclusion about which is more sensitive marker, depends on the b-value. **Figure 3** shows that % error in Trace rapidly diverges from the line of identity - i.e., trace is *much* more susceptible to partial volume effects. Elsewhere (ISMRM 2011 submitted abstract) we show the trivial result that changes to measure that express a *fraction* (e.g. myelin water fraction, qMT macromolecular volume fraction, restricted diffusion fraction) – will change in exact proportion to the partial volume effect.

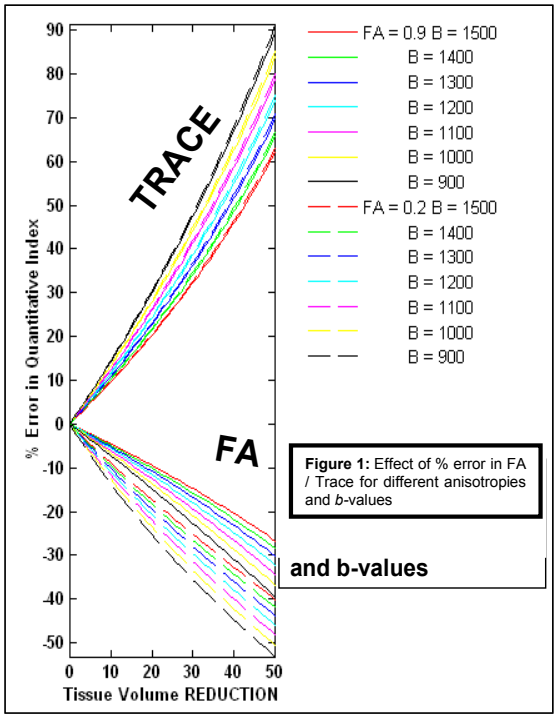

Figure 1: Effect of % error in FA / Trace for different anisotropies and *b*-values

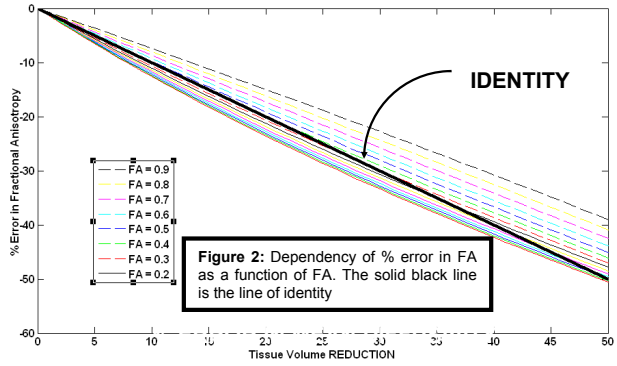

Figure 2: Dependency of % error in FA as a function of FA. The solid black line is the line of identity

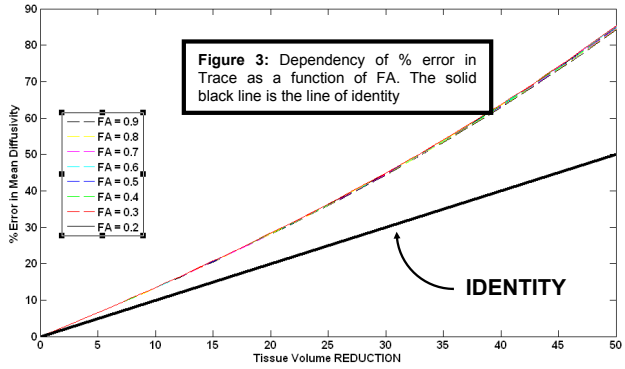

Figure 3: Dependency of % error in Trace as a function of FA. The solid black line is the line of identity

DISCUSSION / CONCLUSION: This is a simple question, i.e. "*What is the relative sensitivity of different metrics (FA, Trace, MWF etc.) to partial volume effects?*" Nevertheless, it does not appear to have been addressed in the literaturre. We can conclude that all voxel-based metrics are sensitive to partial volume – but the sensitivity is variable. Measures like myelin water fraction change in direct proportion to the change in tissue volume in the voxel. Further, mean diffusivity sensitivity is independent of anisotropy - butt far more pronounced than changes in volume (Fig 3) – and there is also a b-value dependences (with lower b-values producing a more marked effect). FA measures vary *almost* equally with tissue volume (but whether it is more or less pronounced, depends on the anisotropy and b-value). The effects are far more pronounced at low FA-values – and also at low b-values. These results have important implications for studies of development, ageing, and pathology – where volumetric differences in tissue due to development / atrophy are expected. Without due care and attention, one might conclude that, for example, 'Mean diffusivity is a far more sensitive marker of tissue microstructural change than FA or volumetry measurements' – when the changes in MD and FA are purely artefactual. Moreover, this study stresses the importance of matching b-value in multi-centre studies. As a final cautionary note, we highlight that clinical studies tend to use lower b-values (e.g. $900\ s\ mm^2$) – and pathological changes frequently occur in regions of low anisotropy, which means that any genuine effects of microstructural change – that occur alongside atrophy – will be doubly exaggerated.