Super-Resolution Track Density Imaging: Anatomic Detail versus Quantification

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I have read with great interest the article by Hoch et al,[1] in this issue of the *American Journal of Neuroradiology* describing an MR imaging protocol to discriminate the internal anatomy of the human brain stem. Their study provides a very nice illustration of one of the key strengths of MR imaging, in which multiple MR imaging contrast mechanisms/parameters can complement each other and provide an enhanced visualization of brain structures. In this particular study, the synergy of a recently proposed echo modulation curve (EMC) method for T2 mapping[2] and the super-resolution track density imaging (TDI) method[3] is shown to visualize many of the tracts and nuclear groups within the brain stem, to a level not previously shown before with in vivo 3T MR imaging. Most important, this combined protocol was achieved with a total acquisition time that is feasible for clinical investigations (though it relies on postprocessing methods that may be, so far, available only at large specialized centers, a limitation likely to be overcome in the future, with the widespread use of these methodologies).

The results of the study by Hoch et al,[1] demonstrating the synergy of TDI with other MR imaging parameters to achieve enhanced anatomic delineation are consistent with the findings from previous studies, such as the combination of super-resolution TDI and ultra-high-field T1-weighted images to delineate the substructures of the thalamus at 7T MR imaging.[4]

A related issue, also briefly mentioned in the article by Hoch et al,[1] is that of quantification. While T2 is a well-studied parameter and one that has been used quantitatively for clinical applications in the past (eg, in epilepsy,[5] Friedreich ataxia,[6] and multiple sclerosis,[7] among others), quantification of TDI has been the subject of recent controversy, with some studies reporting successful clinical applications[8-10] and others emphasizing its potential limitations for quantitative studies.[11-14]

The super-resolution TDI method was initially developed primarily as a qualitative imaging method with high anatomic contrast.[3] Despite its potential role as a quantitative parameter for fiber-density mapping (given that TDI is a measure of the density of streamlines from fiber tracking), recent studies have highlighted its limitations as a fully quantitative parameter, including relatively low quantitative reproducibility[12] and sensitivity to detecting false-positives and false-negatives.[14]

Given these limitations, it could be argued that the power of super-resolution TDI is not as a quantitative tool but rather in the high anatomic contrast and detail it provides (as illustrated by the results from Hoch et al,[1] and other related studies[3,4,15,16]). Quantification is therefore better performed on the basis of, for example, other complementary track-based parameters, such as track-weighted apparent diffusion coefficient (TW-ADC), track-weighted fractional anisotropy (TW-FA), and track-weighted fiber-orientation distribution (TW-FOD),[12,17] or even on the basis of other properties of the streamlines themselves (such as their lengths in the average pathlength map [APM] method)[13] or on measures of the voxelwise fiber-orientation distribution (such as those related to the apparent fiber density [AFD] method).[14,18] While these maps have reduced anatomic contrast relative to that seen in TDI maps, they have more reliable quantitative properties[12,13] and are therefore more suitable for quantitative analysis in clinical applications.

In this context, one could envisage a scenario in which the protocol proposed by Hoch et al[1] is used to identify and delineate the structures of interest (eg, specific tracts and nuclear groups within the brain stem, as in Figs 2–8 in that study), but then these other complementary parameters are used for quantification within those specific structures. Thus, some maps (eg, EMC and super-resolution TDI) are used to define the structures of interest (on the basis of their high anatomic contrast and detail), while other maps (eg, TW-ADC, TW-FA, TW-FOD, APM, total AFD, and so forth) are used to provide more reliable quantitative measures. This approach, in turn, emphasizes once again the strength in the synergy of multiple MR imaging parameters or as Aristotle once said, "The whole is greater than the sum of its parts."

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