Rapid automated QA for diffusion MRI

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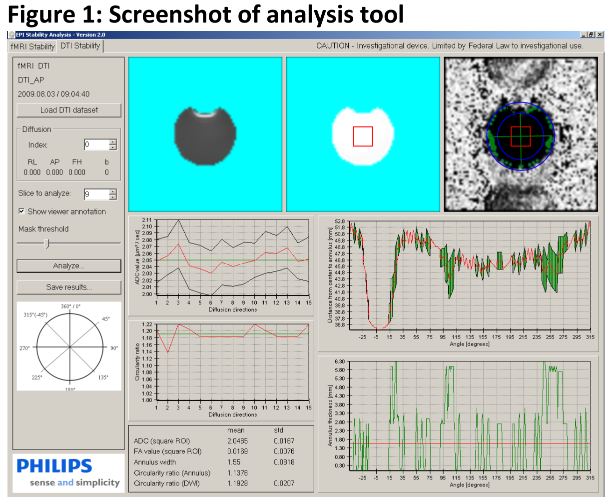
Background Diffusion-weighted MRI is widely used in clinical radiology, and diffusion tensor imaging (DTI) is increasingly important in research studies and pre-surgical evaluation. Since it uses very large gradients to achieve diffusion weighting, and fast gradients during the typical EPI readout, DTI is particularly sensitive to system defects in the gradient chain. Previous authors have suggested methods for routine QA in DWI [1-4] however none of the proposed methods has demonstrated sensitivity to system defects e.g. miscalibration of eddy current compensation (ECC). We have developed a new QA method using a rapid acquisition (less than 3 minutes) with fully automatic processing. Our results show that two measures related to geometric deformation are highly sensitive to gradient sub-system defects.

Method A 10cm-diameter spherical water-based phantom was used, located centrally in the 8-channel head coil. Three DTI scans were acquired with the following parameters: TR 2060ms, TE 85ms, 15 diffusion directions, b-factor 1000, 3x3x3mm voxels, 80x80 matrix, 19 slices, scan time 40secs. The three scans were oriented so that phase-encoding was along each gradient axis. Data were acquired on five 3.0T Achieva systems located in a development environment. Eddy current compensation was disabled on each of the gradient axes in turn, and then all three axes together. Test data were also acquired from 10 hospital systems.

Figure 1: Screenshot of analysis tool



Analysis was performed fully automatically with specially-written software (in C#). A 10x10-pixel ROI was located in the middle of the phantom image on the central slice and used to calculate ADC for each diffusion direction, and fractional anisotropy (FA). The largest circularity ratio (defined as longest axis divided by shortest axis for perpendicular axes) of the phantom image was determined for each diffusion direction. A mask was created by first finding pixels with above-threshold values in all the diffusion images (the 'AND' mask) and then finding those which were above-threshold in at least one DW image (the 'OR' mask). The DEF (deformation) image is created by subtraction ('OR' minus 'AND'), and this should be approximately a circular annulus. The annulus width was measured as a function of angle using the center of mass of the annulus mask. The ADC, annulus width, and DWI circularity, were averaged over the diffusion directions. As well as numerical output, the software provides graphs for visual inspection of the results (fig 1).

Results Table 1 summarizes the results from the QA method for three conditions; data from systems with no defects; data with ECC problems orthogonal to the PE direction; and data with ECC problems on the same axis as the PE direction. **Bold** typeface indicates data which are significantly different from the known 'good' data ($p < 0.001$). Note that the DWI Circularity Ratio is high due to a variable-sized bubble in the top of the phantom. In a well-filled (or gel) phantom, this measure would be close to 1.0 and may also be sensitive to ECC problems.

	ADC mean $\times10^{-6}mm^2/s$	ADC s.d. $\times10^{-6}mm^2/s$	FA mean	FA s.d.	DEF Annulus width mean [mm]	DEF Annulus width s.d. [mm]	DWI Circularity Ratio mean	DWI Circularity Ratio s.d.
No ECC defect	2.1169	0.0195	0.0176	0.0063	1.3156	0.0603	1.1384	0.0159
ECC defect on PE axis	2.1580	0.0128	**0.0687**	**0.0088**	**6.8291**	0.0816	1.1611	**0.0768**
ECC defect on non-PE axis	2.1008	0.0184	0.0162	0.0059	2.8313	0.0650	1.1381	0.0140

Conclusion Our new QA method is very sensitive for miscalibration of ECC's. By implication it should also be sensitive to other gradient chain failures, such as gradual loss of amplifier performance. We continue to collect data with our collaborators to test the value of this method in the real world.

References

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