Cerebrospinal fluid as an internal quality control marker

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Introduction: Diffusion tensor imaging (DTI) is a quantitative magnetic resonance imaging technique that allows measurement of *in vivo* water diffusivity. Two often used parameters derived from DTI data are the apparent diffusion coefficient (ADC) and fractional anisotropy (FA), describe the average directional water diffusivity and a measure of tissue anisotropy, respectively. However, factors such as the signal-to-noise ratio (SNR) and field strength affect the calculation of both the ADC and FA. With many purposed applications of DTI in brain studies, such as predicting treatment outcomes and recurrence [1], assessing tumor response [2, 3], assisting in the grading of tumors [4], and differentiating between tumor types [5, 6], assessment of DTI metrics becomes necessary. Ideally, an internal marker should be used, especially in multi-institutional or longitudinal studies where data are acquired under different conditions. For cerebrospinal fluid (CSF), the FA and the ADC should be close to that of pure water: 0 and $3x10^{-9}$ m^2/s, respectively. We present a feasibility study of using CSF as such an internal QC marker for DTI studies of the brain.

Methods: 174 brain DTI studies, of which 111 were acquired at 1.5T and 63 at 3.0T using GE Excited HD scanners with an eight-channel head coil, on 20 patients were analyzed using a GE AW workstation (version 4.4, GE Medical Systems, Milwaukee, WI). The DTI acquisition protocol for 1.5T scanners is: Axial SE EPI scan of 5 mm slices with 1.5 mm gap, FOV=22cm, acquisition matrix=128x128, TR=10000ms, number of average=1, number of diffusion encoding direction=27, b=1200 s/mm^2, maximum number of slices=22 with total acquisition time=5minutes. For 3.0T scanners, an axial SE EPI scan of 3.5 mm slices with no gap, FOV=22cm, acquisition matrix=128x128, TR=8750ms, number of average=1, number of diffusion encoding direction=27, b=1200 s/mm^2, maximum number of slices=32 with total acquisition time=4minutes and 23 seconds. Regions of interest (ROI) were defined in the left and right ventricle and in CSF-filled areas of tumor resections where possible. ROIs were placed centrally inside of each ventricle or resection on a slice for which partial volume averaging appeared minimal. Mean ADC and FA values and corresponding standard deviations were then calculated from ROI pixels using Functool (version 4.5.3, GE Medical Systems, Milwaukee, WI). Means, standard deviations, and coefficients of variation were calculated for each patient and for all exams at 1.5T and 3.0T, separately.

Results & Discussion: The inter-patient coefficients of variation for ADC and FA measurements were 4.2% and 14.2% for all patient scans at 1.5T, respectively and 6.2% and 19.7% for all patient scans at 3.0T, respectively. Intra-patient coefficients of variation for ADC and FA fell in the range (2.0%, 9.1%) and (8.7%, 20.3%), respectively. ADC variations were small for patients that exhibited progressive disease and a complete response to treatment (Figure 1) over the time course of treatment, which indicates stability in the ADC despite physiological changes and differences (1.5T vs. 3.0T) in data acquisition. In addition, average measured ADC and FA values for all scans at 1.5T and 3.0T matched closely with those reported by Hunsche *et al* [7] as summarized in table 1. FA values for all patients exhibited a positive bias from the expected value of zero, consistent with previous theoretical work [8, 9].

Conclusions: This study shows that the variations of ADC measurements in CSF are small regardless of physiological changes and differences in acquisition, while FA measurements had larger variations. In addition, the percent differences between our measured ADC values and those reported previously were small, less than 1%. Hence, CSF is an excellent candidate for an internal quality control marker for brain studies as evidenced by the low variability in ADC and FA over time and under varying acquisition and physiological conditions.

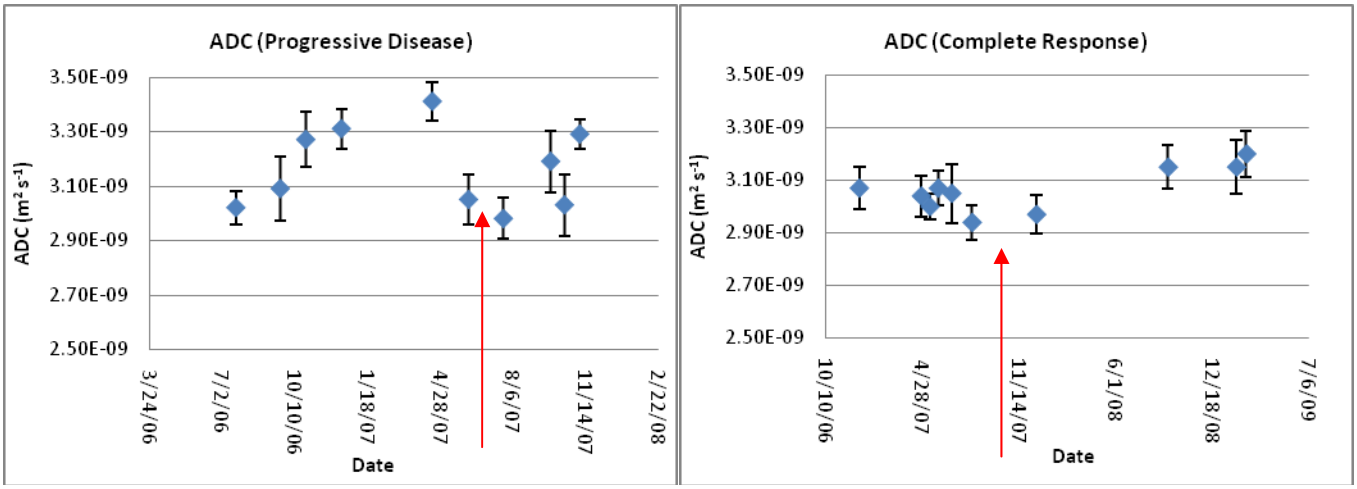

Figure 1: ADC in CSF as a function of time for a patient with progressive disease (*left*) and for a patient with complete response to treatment (*right*). The red arrow, on both plots, represents the administration of bevacizumab. The average ADC is $3.16x10^{-9}$ m^2/s and $3.09x10^{-9}$ m^2/s, respectively, with coefficients of variation of 4.81% and 3.86%, respectively. The patient exhibiting progressive disease was imaged at both 1.5T and 3.0T (*left*) while the patient exhibiting a complete response to bevacizumab (*right*) was imaged only at 1.5T.

References: [1] Price et al. *Eur Radiol*. 2007;17, [2]Hamstra et al. *JCO*. 2008;26, [3] Hamstra et al. *PNAS*. 2005;102, [4] Ferda et al. *Eur J Radiol*. 2009;[E-pub], [5] Wang et al. *Am J Neuroradiol*. 2009;30, [6] Wang et al. *NeuroImage*. 2009;44, [7] Hunsche et al. *Radiology*. 2001;221, [8] Basser et al. *J Mag Res B*. 1994;103, [9]Yanasak et al. *Mag Res Imaging*. 2008;26

	Measured		Hunsche *et al*	
	ADC (10^{-9} m^2/s)	FA	ADC (10^{-9} m^2/s)	FA
1.5T	3.147±0.131	0.139±0.0144	3.138±0.236	0.21±0.07
3.0T	3.184±0.199	0.143±0.0282	3.174±0.222	0.17±0.02

Table 1: Measured and reported ADC and FA values at 1.5T and 3.0T.