Diffusion Imaging for Monitoring CSF Pressure and ICP Alteration in Hydrocephalus Treatment

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Introduction Hydrocephalus can be defined broadly as a disturbance of formation, flow, and cerebrospinal fluid that leads to an increase in volume occupied by this fluid in CNS. ICP rises if production of CSF exceeds absorption. This occurs if CSF is overproduced, CSF flow is obstructed, or venous sinus pressure is increased. Typical features of MR imaging include ventricular dilatation and periventricular white matter edema due to the transependymal resorption of spinal fluid[1-2]. Ventricular enlargement caused by an initial rise in CSF pressure.. Shunts eventually performed in the majority of patients to establish a communication between drainage cavity. Continuous CSF pressure monitoring can help in predicting a patient's response to CSF shunting. The enlarged ventricular area reflects increased force on the ventricular wall. We have postulated that the diffusion of water in ventricle should be affected by CSF pressure, resulting in decrease of water diffusion In addition we investigated the water diffusion in periventricular regions and some basal ganglia regions before and after treatment.

Diffusion Constant & Pressure Based on simple gas model of ventricular CSF, diffusion constant was related to pressure as follows

$$D = \frac{kT}{6\pi a^2 P}\sqrt{\frac{3kT}{m}} \quad [1]$$

, where m is molecular mass, P is pressure for ideal gas

For non-ideal gas, it became nonlinear when using coefficients of the Virial equation,

$$D = \sqrt{\frac{3}{m}}\,\frac{(kT)^{\frac{3}{2}}}{6\pi a^2 P}\left\{1 + B\left(\frac{P}{RT}\right) + C\left(\frac{P}{RT}\right)^2 + \ldots\right\} \quad [2]$$

For liquid, diffusion constant is related to viscosity according to Einstein relation, Since liquid viscosity increases linearly as pressure increases untill 1000 atm [3], water diffusion decreases as pressure increases approximately as shown in a simulated plot of water vapor model[Figure 1].

$$D = \frac{kT}{6\pi\eta R} \approx \frac{1}{P + Const.} \quad [3]$$

, where η is viscosity of fluid and R is radius of particle.

Method Twenty two patients with obstructive hydrocephalus and three normal control were examined with MR diffusion imaging using a 1.5T whole-body MR scanner (GE Signa) with quadrature head coil. We used slice thickness of 10mm, a 128×128 matrix, and a 22cm FOV. Diffusion weighted images were obtained with several different b values before and after shunting treatment. A calculated ADC map was produced from this series of DWIs by a linear least square fitting, on a pixel-by-pixel basis, of the natural logarithm of signal intensity vs. b value. The ADC value in each pixel was calculated from the slope of the best-fit line. Average ADC, D_{avg}, was assessed in a number of selected regions of ventricle, periventricular region(PV), and Basal ganglia(BG)as shown in Figure 2. Ventricular size before and after treatment were assessed by measuring the frontal and occipital horn ratio(FOR).[4]

Results and Discussions Average apparent diffusion constants of selected regions were summarized in Table 1. D_{avg} value for hydrocephalus CSF was decreased by 10% compared with normal CSF(3.30), and increased by an average of 10.5% after treatment. This was indicative of the resolution of CSF pressure caused by hydrocephalus. Periventricle region showed decrease by an average of 21.9% after treatment. Relatively little decrease by less than 0.1% was also observed inTemporal lobe region. Increased diffusion in the periventricular region from increased extracellular water has been documented in animal model[5] and clinical cases of hydrocephalus [6-67. Decreased CSF D_{avg} and increased D_{avg} of PV may be clinically useful sign of hydrocephalus, while their change after treatment may be valuable in assessing the treatment response because CSF pressure and ICP usually decreases toward normal levels with successful treatment. FOR value was decreased by 4.3 % after treatment. This indicates that the change in CSF D_{avg} may provide more sensitive response from treatment than ventricular size change. This suggest CSF D_{avg} may be important prognostic factor when assessing treatment outcome of various hydrocephalus

Table1. Regional D_{avg} (SD) value before and after shunt (unit x 10^{-5} cm^2/s)

Before shunt				After shunt			
CSF	PV	BG	FOR	CSF	PV	BG	FOR
3.03(0.06)	1.14(0.05)	0.94(0.07)	0.46(0.06)	3.35(0.07)	0.89(0.07)	0.87(0.08)	0.44(0.05)

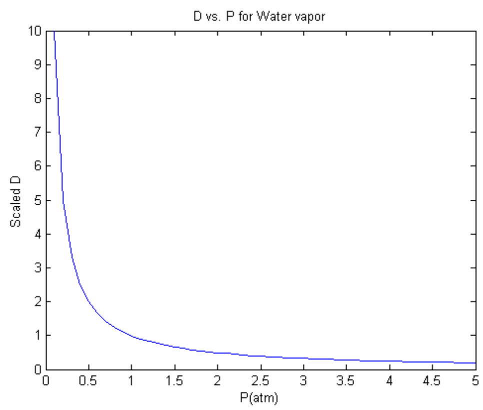

Figure 1. D vs P for water vapor

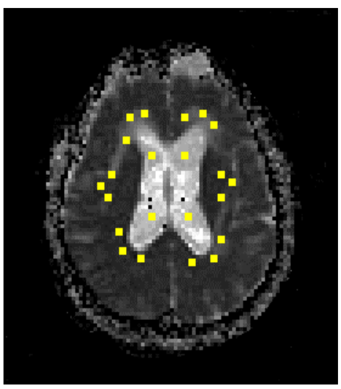

Figure 2. ADC map and selected region for measuring D_{avg}

References

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