Factors Affecting the Detection of Permeability Derangements in Perfusion Imaging of Stroke Patients

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Background: In acute ischemic stroke (AIS) patients, damage to the blood-brain barrier (BBB) can ultimately lead to the most feared complication of thrombolytic therapy, intracranial hemorrhage (ICH). MRI evidence of breakdown in the BBB has been linked to subsequent ICH in animals and in humans. Recent studies have demonstrated that leakage of contrast during PWI of AIS patients due to increased permeability may be a sensitive predictor of subsequent hemorrhagic transformation. (1;2) Currently, however, no technique using perfusion-based permeability imaging (PPI) in stroke patients has been able to quantify permeability. Furthermore published methods for PPI in AIS have been poorly described and not rigorously tested with basic MR principles.

Hypothesis: The signal change caused by contrast leakage through the BBB is dependent on the parameters of the acquisition which need be corrected for in order to quantify permeability.

Methods: PPI algorithm: Damage to the BBB results in contrast extravasation into the parenchyma during the course of a PWI acquisition. This affects the recorded signal by introducing a T₁ component to what is primarily a T₂* weighted signal. In the absence of BBB derangements, changes in tissue contrast agent concentration are measured as changes in relaxivity with the equation: (3)

\[ \Delta R_{2}^*(t) = \frac{1}{1-TE} \ln \left( \frac{S(t)}{S_0} \right) \]

Where TE is the time to echo, S(t) is the signal intensity in the voxel at time t, and S₀ is the baseline signal intensity prior to delivery of the contrast bolus. When taking into consideration the effects of extravasation, the measured signal is more accurately characterized by adding a term to equation (1) to account for T₁ effects: (3)

\[ \Delta R_{2}^*(t)_{\text{measured}} = \Delta R_{2}^*(t)_{\text{corrected}} = \Delta R_{2}^*(t) - \frac{TE}{T_{R}} \left( 1 - e^{-\frac{TE}{T_{R}}} \right) \frac{R_{1} C_{\text{tissue}}(t)}{2} \]

where TR is the time to repetition, R₁ is molar T₁ relativity of the contrast agent, and C_{tissue}(t) is the concentration of contrast in the tissue at time t. This T₁ affect can be modeled as a percent of the CBV over time as described by Boxerman et al. (4) referred to as K₂. Thus the K₂ values measured are relative to the T₁ properties of the sequence acquired.

Results: The uncorrected K₂ values had a mean of 8.2%±13.7 for the enhancing hemispheres and a mean of 0.8%±1.0 for the control hemispheres. Comparing the two hemispheres across the patient cohort with a paired t-test revealed a statistically significant difference (p=0.006). The correction factor was then divided into the K₂ values to make them comparable between scans.

Conclusions: While PPI offers a novel and potentially quantifiable method for measuring damage to the BBB, application of this method must account for basic MR principles. Choice of scan parameters may enhance or degrade our ability to detect BBB derangements from PWI.

Reference List