Can Diffusion Kurtosis Imaging Provide Better Ischemic Lesion Delineation?

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Introduction

During ischemic brain injury, a potentially salvageable region with moderately reduced CBF surrounds a core with greatly compromised CBF[1]. Conventionally, lesion volume is defined as the region with reduced apparent diffusion coefficient (ADC)[2,3]. However there are times when ADC fails to identify ischemic tissues[3]. It has been reported that diffusion-weighted images (DWI) acquired with high b-value allowed better delineation of ischemic lesion[4,5]. In other words, advanced diffusion techniques that make use of DWI with high b-value might potentially provides more reliable ischemic tissue staging. One of which is diffusion kurtosis imaging (DKI) model which measures non-Gaussianity of water diffusion[6]. However, DKI application to stroke lesion volume identification remains limited and only a few human studies have been reported[7-9]. DKI was thus performed in ischemic stroke in an established transient middle cerebral artery occlusion (MCAO) rat model during the hyperacute, acute and subacute phases. Comparisons were made with perfusion, conventional diffusion techniques.

Methods

Three Male Sprague Dawley rats (250-300g) were subject to 45 min MCAO[10]. MRI experiments were subsequently performed using a 7T/30cm magnet at 30-34min after occlusion (denoted as 0hr), and 0.9, 1.3, 1.7, 24, 48hr, and 7day after reperfusion. A surface coil (2.3cm ID) with active decoupling was used for brain imaging and a neck coil for perfusion labeling. Cerebral blood flow (CBF) map was obtained using continuous arterial spin labeling. Diffusion-weighted images (DWIs) with 2 non-zero b-values (1.2 and 2.5 ms/μm^2) along 30 diffusion encoding directions were acquired using single-shot SE-EPI with NEX=4 (except before reperfusion with NEX=2). The entire imaging block took ~20min (~13min for pre-reperfusion). Mean diffusivity (MD), fractional anisotropy (FA) and mean kurtosis (MK) maps were estimated by fitting DWIs to the DKI model[6]. Region-of-interests (ROIs) of cortex and striatum of the contra-lesional hemisphere were defined using MD and FA maps at 0hr. Lesion volume for MD, MK and CBF were then defined when the value is 3 times the standard deviation of the ROI measurement in the contra-lesional hemisphere smaller, larger, and smaller, respectively, than that of the mean.

Results

Fig.1 shows lesion volume (red overlays) computed from MD, MK and CBF maps of a representative rat obtained at 34min after occlusion (0hr), 24, 48hr and 7day after reperfusion. **Fig.2** shows the lesion volume for MD, MK, and CBF plotted on logarithmic scale in time after reperfusion (hours). The solid lines indicate the lesion volume before reperfusion (black overlaps with blue). Notice that only lesion volume computed from CBF before reperfusion was shown.

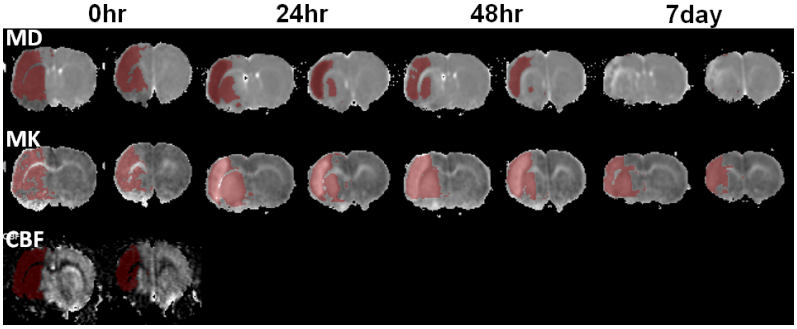

Fig.1 Lesion volume (red overlays) computed from MD, MK and CBF maps of a representative rat obtained at 34min after occlusion (0hr), 24, 48hr and 7day after reperfusion.

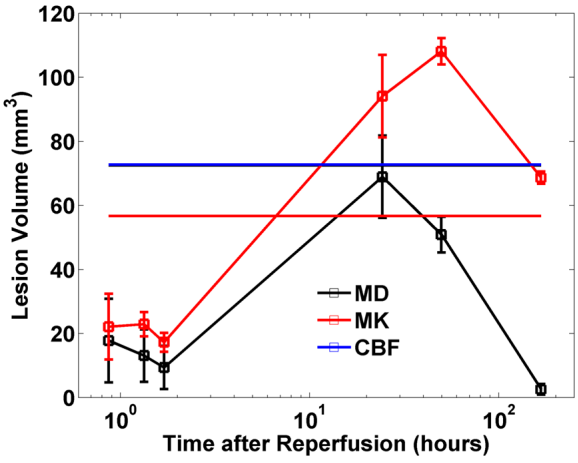

Fig.2 Lesion volume for MD, MK, and CBF plotted on logarithmic scale in time after reperfusion (hours). The solid lines indicate the lesion volume before reperfusion (black overlaps with blue). Notice that only lesion volume computed from CBF before reperfusion was shown.

Discussions and Conclusions

One of the interesting findings is that the lesion volume from MK is smaller than that of MD by ~28%. Another noteworthy point is that the "true" lesion (obtained from CBF) can still be delineated by MK even during late acute (<48hr) and subacute phases. The difference in depicting ischemic tissue between MD and MK might be due to the fact that MK is more sensitive towards tissue complexity changes that are associated with ischemic injury[6]. Histology will be performed in future studies to validate whether MK or MD provides a better delineation of the penumbra.

It is important to note that estimation of MK has higher variance as compared to MD, which might subsequently affect the lesion volume computation used in the current study. More sophisticated technique (such as ISODATA[11]) to identify the lesion core will be used in future studies.

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