Absolute and Relative Blood Volume Measurements by dual T1 and T2 MRI acquisitions with single contrast agent in Acute Phase of Ischemic Brain

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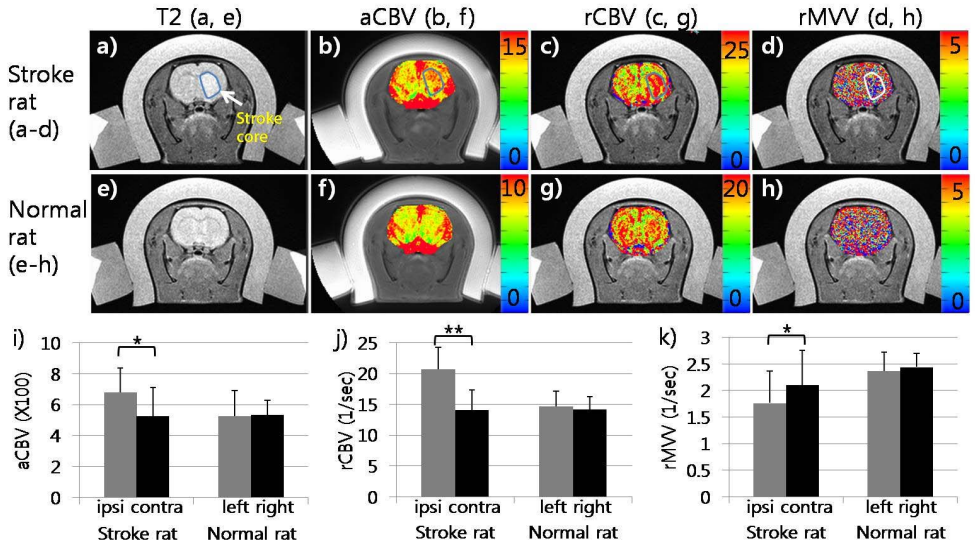
INTRODUCTION: Blood volume changes during the acute phase of brain ischemia are not well understood but presumably linked to other neuronal degenerations. In this study, using the routinely synthesizable superparamagnetic iron oxide (SPION) as a dual contrast agent, we aimed to quantify MRI-derived vascular blood volume parameters in rat ischemic brain models progressed 24hrs reperfusion following 1hr middle cerebral artery obstruction (MCAO), and compared these parameters with contralesional of the stroke and normal rat brain. We posit that simultaneous acquisitions of both positive and negative contrast-enhanced images offer complementary information, increasing the certainty and accuracy on the measurements of blood volumes.

MATERIALS & METHODS: MRI experiments were performed on 3T magnet system (Philips) using rat brains following 24 hrs after reperfusion submitted to middle cerebral artery occlusion for 60 min (n=7) and normal rat brains (n=5). A kind of 3D T1 MRI signal intensity, ultra-short TE (UTE) sequence was used to quantify absolute cerebral blood volume (aCBV) before and after intravenous administration of superparamagnetic iron oxide nanoparticles (SPION, 6.7mg/kg). aCBV was calculated using signal changes in brain tissue as compared to relative signal changes in vessel, after creation of subtraction images (i.e., $SI_{post\_SPION}-SI_{pre\_SPION}$) at 90 flip angle. Additionally, T2- and T2*-weighted images were acquired before and after SPION injection to obtain relative cerebral vascular blood volume (rCBV, $R2^*_{postSPION}$-$R2^*_{preSPION}$), relative microvascular volume (rMVV, $R2_{postSPION}$-$R2_{preSPION}$). Regions of interests (ROIs) for stroke lesions were drawn by manual contouring on every slice: the abnormal bright area on the T2 images.

RESULTS & DISCUSSION: Positive enhancement of signal change in UTE and negative diminution signal changes in T2(*) images were observed after SPION injections due to its concurrent T1-T2 effects. From the hemodynamic perspectives, acute phase of ischemic brain seems to be governed by both protective (via flow compensation) and vascular degenerative (disruption of microenvironment) mechanisms. aCBV (measured from UTE) and rCBV (measured from T2*) were increased whereas rMVV measured in the ipsilesional subcortex regions were significantly less than those in the contralesional stroke and normal subcortex areas. Coupled relationship between the ischemic tissue damage and increased CBV may suggest the autoregulatory vasodilation dedicated to the rapid normalization of blood oxygen and glucose levels. On the other hand, rMVV decrease in the ipsi-lesion may indicate the ischemia-induced defect for the effective perfusion reserve that may be used for accurately delineating the true perfusion and neurovascular status.



Representative T2, aCBV, rCBV, and rMVV maps (a-h) and their comparisons between ischemia and normal rat subcortical brains (i-k). Note the increased absolute and relative CBV and declined rMVV in the ipsilesional subcortical regions compared to the contralesional (stroke brain) and normal subcortical brains.