Combination of SWI, DWI and 3D ΔR2-based micro-MRA for predicting stroke evolution in rat with middle cerebral artery occlusion

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Introduction

Acute ischemic stroke (AIS) is one of the critical diseases about brain injury, which results primarily from a severe reduction in blood supply for brain tissue and could lead to abnormal oxygen metabolism and cell death ultimately [1]. It has been shown that an increase in oxygen extraction fraction (OEF) and reduced cerebral blood flow (CBF) are associated with increased risk of stroke [2]. Due to the ability of enhancing deoxygenated vessels based on hemodynamic changes, susceptibility-weighted imaging (SWI) has been demonstrated to be beneficial in detecting the prominent hypointense vessels resulting from the increased oxygen extraction of penumbra area [3]. Although Kao et al. emphasize that SWI/DWI mismatch could provide comparable information with PWI/DWI mismatch [4], the value of SWI is still controversial. Furthermore, 3D ΔR2-based microscopy of MRA was demonstrated to provide high resolution 3D information on the cerebral anatomy, microvascular architecture, and hemodynamic response [5]. As a result, the purpose of this study is using SWI, DWI and 3D ΔR2-based micro-MRA to assess the relationship between these imaging methodologies and stroke evolution in rats with middle cerebral artery occlusion (MCAO) during progression of stroke.

Methods

Six Sprague Dawley rats (aged 8-week-old, weighed around 300g) were enrolled in this study. Before MR imaging, model for inducing focal cerebral ischemia was performed using middle cerebral artery occlusion (MCAO) suture. After that, all the rats were anesthetized with 5% isoflurane at an oxygenation rate of 1L/min and then imaged in a supine position in a 4.7T MR system (Bruker, Ettlingen, Germany). DWI and SWI images were acquired with a quadrature surface coil using EPI and a multi-slice gradient echo sequence, respectively, at 1, 2, 4, 24 hours after MCAO suture. Parameters of SWI were used with TR = 50 ms, TE = 10.1 ms, slice thickness = 250 μm, matrix size = 256 x 256, in-plane resolution = 100 x 100 μm^2, NEX =1, acquisition time = 13m39s. To determine ΔR2, T2-weighted imaging (T2WI) was performed before and after injecting superparamagnetic iron-oxide nanoparticles (Resovist, Schering AG, Berlin, Germany) at a dose of 30 mg Fe/kg. T2WI was performed using a 3D FSE sequence with a repetition time (TR) of 1500 ms, an effective echo time (TEeff) of 82 ms, a sampling bandwidth of 50 kHz, an echo-train length (ETL) of 32, 4 averages, a field of view (FOV) of 2.8×2.8×1.4 cm, an acquisition matrix of 256×256×96 (zero-padded to 512×512×192), and a total acquisition time of 76 min. The in-plane resolution and slice thickness were 54.68 and 72.91 μm, respectively.

Results

Results of the acquired DWI and SWI images from rat brains with progressive stroke (infarct growth) and at a stable stage (non-infarct growth) are shown in Fig. 1 and Fig. 2, respectively. DWI images demonstrate the sequential changes of the suspected infarct area. Although ischemic stroke brains were established in both cases, asymmetric prominent vessels on SWI images are shown only in the ipsilateral hemisphere of the rat brain with progressive stroke. In addition, one of the transverse sections of the reconstructed 3D ΔR2-based micro-MRA images closed to the infarct area is displayed in Fig. 3. A small abnormality on the subcortical region of the ipsilateral hemisphere is shown compared with the contralateral side in the rat with progressive stoke. Conversely, a majority of disruption of vascular architecture is obtained on the rat brain with severe stroke, however, no significant increase of the infarct area was found on the cortical and subcortical regions.

Discussion

The present study indicates the feasibility of demonstrating asymmetric prominent vessels on the ipsilateral cerebral hemisphere of SWI images in ischemic rat brain after MCAO suture to facilitate predicting the following stroke evolution. Compare with the rat brain at a stable stage after stroke onset, an increase in deoxyhemoglobin concentration results in susceptibility changes due to high oxygen demand of the brain tissue in rat brain with progressive stroke, which is consistent with our clinical findings. Moreover, results of 3D ΔR2-based micro-MRA assess the in vivo information of the vascular architecture, which helps to determine the stroke condition. In conclusion, our preliminary finding demonstrates that the combination of SWI, DWI and 3D ΔR2-based micro-MRA provides additional information for evaluation of rat brain with acute ischemic stroke, and may have a potential to contribute to determining the penumbra and predicting of the stroke prognosis, as well as further quantitative measurements.

Reference

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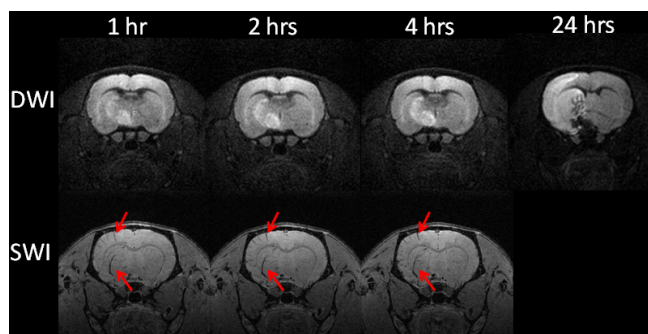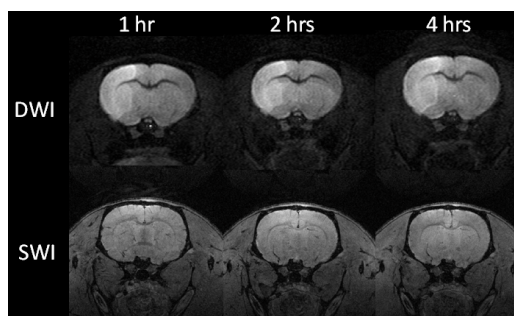5. Lin CY, et al. MeuroImage. 2009; 45: 824-31.

Figure 2 Illustration of the sequential DWI and SWI images from a ischemic rat brain at a stable stage.

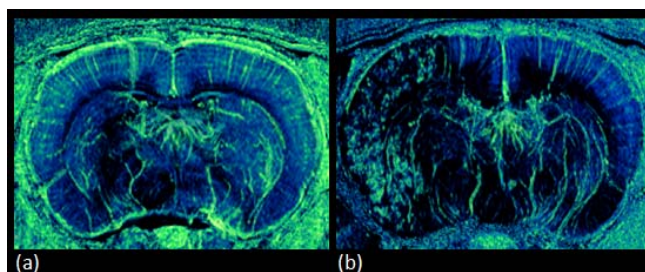Figure 1 Illustration of the sequential DWI and SWI images from a ischemic rat brain with progressive stroke.

Figure3 3D ΔR2-based micro-MRA acquired from rat brains with progressive stroke (a) and at a stable stage (b).