Susceptibility-weighted imaging of acute ischemic stroke: quantification of hypoperfusion

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Target audience: Neuroradiologists and neurologist

Purpose: The signal intensity of the venous blood on susceptibility-weighted imaging (SWI) is blood-oxygen-level dependent (BOLD) and may reflect increased concentrations of deoxyhemoglobin in ischemic stroke patients with high oxygen extraction fraction[1]. The increased BOLD signal (IBS) in the affected hemisphere was referred to area of miserable perfusion[2]. The aim of our study was to quantitatively evaluate the correlation between the cerebral perfusion and IBS in patients with acute ischemic stroke by using arterial spin labeling (ASL) and SWI techniques, respectively.

Methods: Six patients with confirmed diagnosis of acute ischemic stroke underwent diffusion-weighted imaging (DWI), ASL, SWI in a 3.0-T MR scanner (Discovery MR 750, GE Healthcare, Milwaukee, WI, USA) using a body coil as transmission and an 8-channel head coil as signal reception. The DWI, SWI, and ASL scans of all patients were aligned to an MNI space using nonlinear registration. A pseudo-continuous ASL (pCASL)[3] with a 3D background suppressed fast spin echo stack-of-spiral readout module was employed for ASL perfusion and the scanning parameters were TR = 4632 ms, post-label delay = 1525 ms, TE = 10.5 ms, matrix size = 128 × 128, number of average = 3, slice thickness = 4 mm. Cerebral blood flow (CBF) maps were calculated from the scanner console with FuncTool 3D-pCASL (GE Healthcare). A perfusion deficit was defined as an area with visually significant decreased CBF signal when compared with the surrounding brain tissue and contralateral hemisphere. SWI was performed by 3D T2*-based multi-echo acquisition. We quantitatively evaluated SWI signal for the area percentage of venous drainage, as linear IBS, in the regions of interest (ROIs) of restricted diffusion and perfusion defect. The ROIs were mirrored to the contralateral normal-appearing hemisphere for unaffected controls. The difference of area percentage of IBS on SWI was calculated as the value of ROI on the side of the lesion minus that of the homologous control.

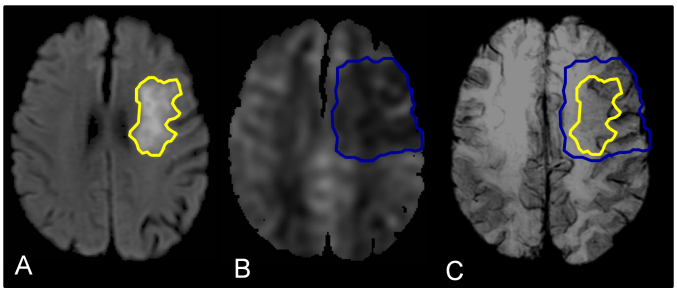

Figure 1. After registration of the DWI, ASL, and SWI images to MNI space, the ROIs of restricted diffusion (A, DWI) and perfusion defect (B, ASL) were manually selected and applied to the SWI image (C) for calculation of the area percentages of IBS.

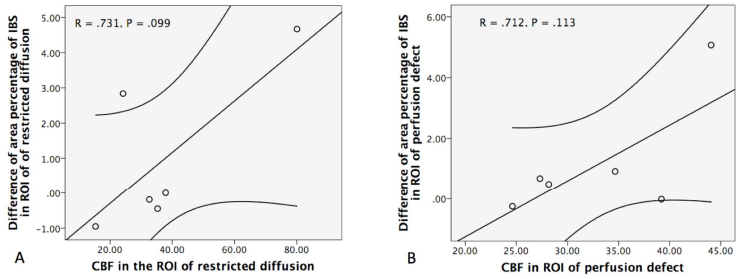

Figure 2. Scatter plots shows a positive correlation between the CBF and difference of area percentage of IBS in ROIs of restricted diffusion (A, R = .731, P = .099) and perfusion defect (B, R = .712, P = .113)

Results: For the six patients, the mean age was 68.2 (SD = 17.9) years, with a median baseline National Institutes of Health Stroke Scale score of 10. Median time from last known normal to MR imaging was 6.3 hours. Mean CBF values were significantly lower in the ROIs of perfusion defects 33.0 mL/100 g per minute (7.6) versus the controls 55.5 (10.6). Differences in CBF measured in the ROIs of restricted diffusion and perfusion defect were not significant. The mean area percentages of IBS were higher in the ROIs of restricted diffusion 2.9% (3.7) versus the controls 1.9% (1.9), so as higher percentages in the ROIs of perfusion defect 4.1% (2.3) versus the controls 2.9% (1.9). The differences of area percentages of IBS and CBF were marginally correlated (R = .731 and .712, P = .099 and .113 in the ROIs of restricted diffusion and perfusion defect, respectively).

Discussion: SWI uses phase shifts to magnify susceptibility contrast between deoxygenated blood and oxygenated blood in surrounding tissue. The IBS has been hypothesized to reflect relative elevations in concentration of deoxyhemoglobin in the draining veins due to poor CBF and the resulting high oxygen extraction fraction[4]. However, the correlations between CBF and IBS could change over time[5]. In our study, the IBS on SWI showed a positive correlation with CBF in either infarct core or penumbra, implying a mismatch between metabolic rate of oxygen consumption and CBF.

Conclusion: Our results showed that venous drainage identified as IBS on SWI may increase with CBF, a finding contradicting the concept of miserable perfusion implied by IBS.

References:

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