Phase analysis of neonatal cerebral venous system by susceptibility-weighted magnetic resonance imaging

T. Niwa[1], N. Aida[2], H. Kawaguchi[3], T. Obata[3], A. Shishikura[2], and T. Inoue[4]

[1]Kanagawa Children's Medical Center, Yokohama, Kanagawa, Japan, [2]Kanagawa Children's Medical Center, Japan, [3]National Institute of Radiological Science, Japan, [4]Yokohama City University, Graduate School of Medicine, Japan

Introduction: Susceptibility-weighted imaging (SWI) is a magnetic resonance (MR) imaging technique that is very sensitive for detecting intravascular venous deoxygenated blood, enables venography, and demonstrates oxygen saturation [1]. SWI is based on the common BOLD contrast, with additional weighting by magnetic susceptibility as provided by MR phase images. Magnetic susceptibility within a vein causes an average intravascular proton frequency shift that leads to a phase difference between venous blood and surrounding tissue [2]. Analysis of phase differences was reported to be a noninvasive method of blood oxygenation [3]. In neonates, active metabolism was reported in deep gray matter. We aimed to evaluate phase value differences of the venous system on SWI to assess oxygen consumption in neonates.

Materials and Methods: We retrospectively assessed SWI of 36 neonates (18 boys, 18 girls; 40 ± 2.5 weeks corrected age) without abnormal MR findings. SWI was performed on a 1.5-T MR scanner (Avanto, Siemens, Erlangen, Germany) with repetition time of 69 ms, echo time of 60 ms. Magnitude image and phase image were transferred to off-line PC. Veins were masked out of pixels more than 0.03 π radian (= 5.4 degrees) on the brain region in the phase image using custom software on an interactive mathematics program (Matlab 7.5; Mathworks, Natick, MA, USA). We assessed the phase values of cortical veins (veins in the rolandic area, frontal and parietal veins) and deep veins (internal cerebral veins, basal veins). Phase values of respective veins were compared by Wilcoxon rank sum test.

Results: The mean phase changes in basal veins, internal cerebral veins, veins in the rolandic area, and frontal and parietal veins were 19.2 ± 7.8, 29.5 ± 9.2, 10.5 ± 1.6, and 10.3 ± 1.5 degrees, respectively (Figure 1). Phase values of deep veins (average of basal and internal cerebral veins) were significantly larger than those of cortical veins (24.3 ± 7.3 vs. 10.4 ± 3.8 degrees, $p<0.0001$). In deep veins, the phase values of internal cerebral veins were significantly larger than those of basal veins ($p<0.0001$). In cortical veins, the phase values of the veins in the rolandic area and frontal and parietal veins were not significantly different ($p=0.81$).

Discussion and Conclusion: In this study, phase values were higher in deep veins. In neonates, active metabolism was noted in deep gray matter by MR spectroscopy and PET studies [4,5]. Venous blood from deep gray matter enters mainly to deep veins, which was correlated with the higher phase values in this study. We consider that the higher phase values in deep veins may correlate with the active metabolic and oxygen consumption area in neonates. The reason for phase differences between internal and basal veins may include different circulatory areas in deep gray matter of each vein and the influence of other venous returns such as the limbic system and insula to the basal veins. The information provided by phase value on SWI may help the understanding of the oxygen consumption pattern in neonates.

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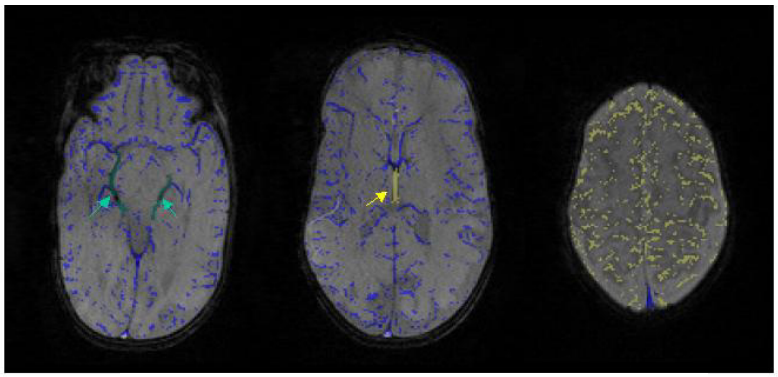

Figure 1. Magnitude image with vein mask of phase image information. The figure shows cortical and deep veins segmented by the software. Phase values in basal veins (Figure a, arrows), internal cerebral vein (Figure b, arrow), and cortical veins (Figure c) were analyzed.