Quantitative Measurement of Deep Medullary Venous in Susceptibility Weighted Imaging:Comparison of Hypoxic-ischemic and Normal Neonates

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Target audience

MR physicians and pediatric neurologists.

Purpose

Hypoxic-ischemic encephalopathy (HIE) represents a major pattern of neonatal brain injury and increase level of deoxygenated blood. The susceptibility-weighted imaging (SWI) is particularly sensitive in detecting intravascular deoxygenated blood alterations [1]. Minimal intensity projection (mIP) based on the magnitude images of SWI is helpful to reveal small veins in neonatal brain. In some previous SWI studies, the dilated veins in the brain were often found in HIE neonates [2], Moreover, the HIE neonates with prominence of deep medullary veins were believe to associated with poor outcomes at later stage [3]. However, whether the volume of cerebral small veins differs between the HIE and normal neonates is still unknown. Therefore, this study aimed to evaluate the prominence of deep medullary veins in neonatal brain by a quantitative method for predicting degree of injury after HIE.

Methods

This study was approved by the local institutional review board. The neonates were all sedated (oral chloral hydrate, 50 mg/kg) before MRI scanning. 7 normal neonates as control were with mean postmenstrual ages (PMA) of 40±4weeks (range of 35-44weeks) and 20 HIE neonates with mean PMA of 39±2weeks (range of 35-43 weeks). There were no significant differences in body temperature between two groups during the MRI examination. All images were obtained by using a 3.0T MR system (Signa HDxt, General Electric Medical System, Milwaukee, WI, USA) with 8-channel head coil. A 3D gradient-echo sequence (Enhanced T2* weighted angiography - ESWAN) was performed with TR=51 ms, number of echoes=8, TE =6~60ms, FA=20°, slice/gap=2mm/0mm, NEX=0.69，FOV= 18×18cm^2 and matrix=384×256. The phases were low-pass filtered to remove background inhomogeneity. During post-processing by SPIN software (Signal Processing in Nmri, version 2131), the neonatal mIP images are typically reconstructed with a low effective mIP thickness of 8mm. For each subject, two axial slices were selected: (i) a slice #1 tangential to the roof of the lateral ventricles; (ii) a slice #2 through the lateral ventricles parallel to the first slice, in which the deep medullary veins could be shown more clearly. For the quantification of the deep medullary veins, we developed bilateral region of interest (ROI)-based analysis in the centrum semiovale in slice #1 [3] (see Fig. 1 A), deep white matter (WM) of frontal lobe(ROI-2,see Fig. 1 B) and temporal-occipital junction in slice #2 [4] (ROI-3,see Fig. 1 B). Threshold segmentation of veins in the ROIs based on signal intensity was performed using MATLAB (Mathworks, Natick, MA, USA). Pixels with signal intensity that deviated from the ROI maximum by a predefined threshold were considered as vein area. Here, the threshold was expressed as a percentage of the maximum [5]. The appropriate threshold was applied to image segmentation analysis, in which various values were within a range of 0–30% (see Fig. 2) . Vein-ROI ratio (VRR) in ROIs was defined as: VRR=vein area/ROI area. The differences in VRR between the normal and HI groups were tested by One-Way ANOVA analysis. Statistical differences with P<0.05 were considered significant.

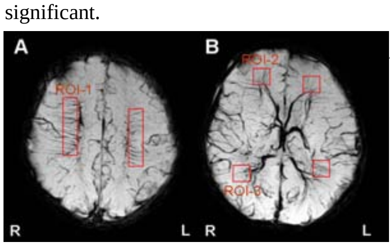

Fig. 1 ROIs depicted on mIP.
Two axial slices: A. a slice #1 tangential to the roof of the lateral ventricles; B. a slice #2 through the lateral ventricles parallel to the first slice. The location of bilateral ROIs were shown in A. (ROI-1:width 0.7cm, length 3.0cm) and B.(ROI-2,3:width 1.0cm, length 1.0cm).

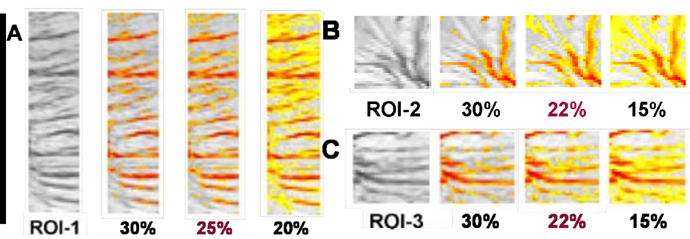

Fig. 2 The segmentation of deep medullary veins with different thresholds in different ROIs.
The ROIs were shown in A. ROI-1:left centrum semiovale B.ROI-2: deep WM of right frontal lobe; and C. ROI-3:deep WM of left temporal-occipital junction. The differences in venous prominence were segmented with using thresholds of 25% for A and 22% for B and C, which were highlighted in red color.

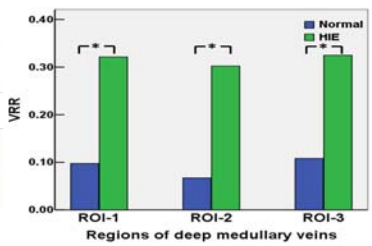

Fig. 3 Comparisons of VRR between HIE and normal group in three ROIs.
ROI-1:centrum semiovale; ROI-2: deep WM of frontal lobe; ROI-3: deep WM of temporal-occipital junction. In all of regions, the VRR values were higher in HIE group when compared to the normal group (*p<0.001).

Results

To accurately extract deep medullary veins in mIP images exactly, different thresholds were evaluated (Fig. 2 A–C). Appropriate thresholds were determined according to the effects of veins segmentation. In this study, the optimal thresholds for deep medullary veins in centrum semiovale and periventricle regions were set to 25% and 22%, respectively. In all neonatal brain, the deep medullary veins in defined regions showed no significant difference between the two hemispheres by the paired-sample t-Test (P>0.05). However, the VRR values (mean$\pm$SD) in the centrum semiovale, deep WM of frontal lobe and temporal-occipital junction were 0.097$\pm$0.087, 0.067$\pm$0.048 and 0.108$\pm$0.093 in normal group , and 0.321$\pm$0.128, 0.302$\pm$0.123 and 0.325$\pm$0.125 in HIE group, respectively. The statistical testing showed increased VRR values for deep medullary veins in HIE versus normal group (p<0.001, Fig. 3).

Discussion and Conclusion

The mIP images of deep medullary veins in SWI, which is highly sensitive to deoxygenated venous blood, highlights the cerebral small vessels as very subtle hypointense branches lying in the WM. In this study, we quantitatively measured the deep medullary venous prominence in ROIs by a threshold segmentation method. In different brain regions, we found increased prominence of deep medullary veins in HIE when compared to normal group as indicated by VRR. The increased VRR values could be interpreted by the degree of increased area of veins in ROIs. The prominence of deep medullary venous is influenced by various factors that include the increased venous concentration of deoxyhaemoglobin, venous stasis/thrombosis, and venous dilation due to adenosine release[1,2,4]. The present study suggests that VRR can be a potential marker for assessing the degree of hypoxia in neonates with HIE. The proposed quantitative method may be valuable for clinically assessing the prominence of cerebral small venous for predicting degree of injury after HIE.

Acknowledgements The authors would like to thank Drs. He Wang, Hao Shen, and Guang Cao from Applied Science Lab, GE Healthcare for their technical assistance. This study was supported by a grant from National Natural Science Foundation of China (No.81171317).

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