

ParaChiCSVO2

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Abstract

Background: Quantitative susceptibility mapping (QSM) is a magnetic resonance imaging (MRI) modality proposed to be a viable method of measuring cerebral oxygenation in neonates given its sensitivity to deoxyhemoglobin, a paramagnetic molecule. During QSM, however, paramagnetic sources can be obscured by opposing diamagnetic sources such as water and myelin. We sought to evaluate whether QSM images alone, or an algorithm that attempts to isolate their paramagnetic components, are more accurate in measuring oxygenation of the major cerebral veins in a cohort of neonates born preterm. Additionally, we aimed to determine whether a difference in oxygenation existed between the major cerebral veins.

Methods: 19 neonates born preterm were scanned on a 3T research MRI at term equivalent age. The protocol included a multi-echo susceptibility-weighted imaging sequence. The acquired imaging data were processed as QSM images to obtain the susceptibility values of the superior sagittal sinus (SSS) and central cerebral veins (CCV). These values were used to calculate the oxygen saturation (SvO2) of the SSS and CCV. QSM images were subsequently processed to isolate

their paramagnetic components. SvO2 values of the SSS and CCV were calculated again from the paramagnetic components.

Results: The mean SvO2 values of the SSS and CCV calculated from QSM images were found to be 72.4% (SD, 3.4%) and 68.7% (SD, 3.5%), respectively. The mean SvO2 values calculated from paramagnetic components were found to be 58.1% (SD, 7.3%) for the SSS and 57.7% (SD, 7.0%) for the CCV.

Conclusion: SSS SvO2 values derived from paramagnetic components agreed well with the existing literature and were closer than the values derived from QSM, however, they displayed greater variability. Although the CCV SvO2 data from QSM aligns more closely with existing literature, it is important to note that the current literature on this topic remains relatively limited in the CCV. Thus, decomposing QSM images into paramagnetic components shows great promise as a method for more accurately measuring cerebral oxygenation in neonates but may require more research to improve precision. Notably, no significant difference in oxygenation was observed between the CCV and the SSS, contrasting with previous studies.

Keywords: Quantitative Susceptibility Mapping, Preterm, Newborn, Cerebral Venous Oxygen Saturation

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1 Introduction

2 Methods

The study was approved by the Clinical Research Ethics Board at the University of British Columbia and Children's & Women's Hospital (H21-00655) and written informed consent was obtained from the parent/guardian for each infant.

2.1 Study population

Participant data comes from a previous study (Zhu et al. UNDER REVIEW May 2024). Participants consisted of preterm neonates born between 25- and 31-weeks gestational age (GA) who were admitted to the level III NICU at BC Women's Hospital. Recruitment took place over a span of one year, from February 2021 to January 2022, facilitated by a dedicated research nurse. Parents of eligible infants were approached by the research nurse prior to discharge from the NICU to explain the study objectives and seek their consent for participation. Infants meeting the criteria for inclusion were scanned for the study if they had already been discharged from the NICU, were in stable condition, and had reached a term equivalent age of 37 to 44 weeks GA. However, certain exclusion criteria were applied to ensure the homogeneity and integrity

of the study sample. Infants were excluded if there was clinical evidence of a congenital malformation or syndrome, a TORCH infection, or ultrasound evidence of large parenchymal hemorrhagic infarction (>2 cm, Grade 4 intraventricular hemorrhage).

2.2 Image acquisition

MR imaging was performed on a 3.0 Tesla General Electric Discovery MR750 scanner (scanner software version DV26.0_R03) equipped with a SREE Medical Systems single-channel neonatal head coil (Table 1). The scans were conducted at the BC Children’s MRI Research Facility. Prior to the scanning procedure, subjects were carefully prepared by a research nurse. Swaddling and feeding were used to ensure the comfort and cooperation of the subjects during the scan. Importantly, no sedatives or invasive markers were utilized throughout the procedure. Subjects were placed within a specially designed SREE Medical Systems MRI compatible incubator, which facilitated both safety and motion minimization. Molded foam was strategically positioned around the head and body within the incubator to further restrict subject movement. To protect against potential hearing damage, ear plugs were employed during the scanning process. Additionally, a pulse oximeter was affixed to the subject’s foot to monitor arterial oxygen saturation and heart rate throughout the scan.

Table 1: Technical parameters for MR imaging protocol.

	T1w	T2w	pcASL	SWI
Sequence	3D FSPGR	3D CUBE	Multi-shot 3D \\\ fast spin-echo	3D spoiled GRE flow-compensated Axial
Phase-encoding direction	Coronal	Sagittal	Axial	
TR (ms)	7.74	2,300	4,680	30.9
TE (ms)	2.97	66.29	10.55	5.24
Flip angle	12°	90°	111°	20°
FOV (cm)	20	20	24	25
Acquisition Matrix	512 x 512	256 x 256	128 x 128	256 x 256
In-plane resolution (mm)	0.39 x 0.39	0.78 x 0.78	1.875 x 1.875	0.977 x 0.977
Slice thickness (mm)	1	1	4	2, reconstructed to 1 mm with zero filling (ZIP2)
Number of slices	126	106	50	92

	T1w	T2w	pcASL	SWI
Additional parameters	n/a	n/a	1,450 ms label period; 2,025 ms pulse lable; 24 control-label pairs	n/a
Scan duration	4 min 39 s	5 min 1 s	5 min 26 s	5 min 29 s

The MRI scan protocol comprised several sequences, including a T1-weighted scan, a T2-weighted scan, a pseudo-continuous arterial spin labeling (ASL) scan, a multi-echo susceptibility-weighted imaging scan, and a diffusion-weighted imaging (DWI) spin-echo echo planar imaging (EPI) sequence.

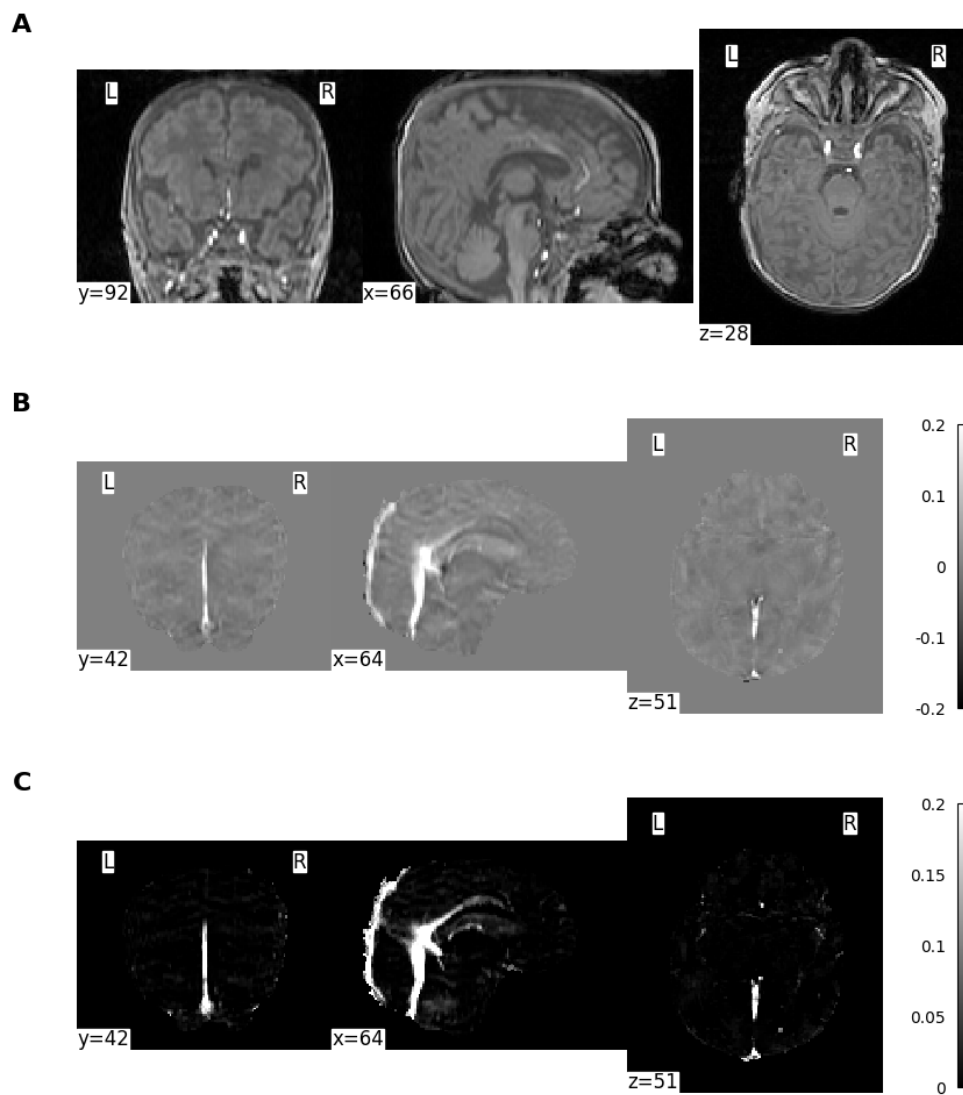


Figure 1: Sample images

Source: [Python Figures](#)

See [Figure 2](#)

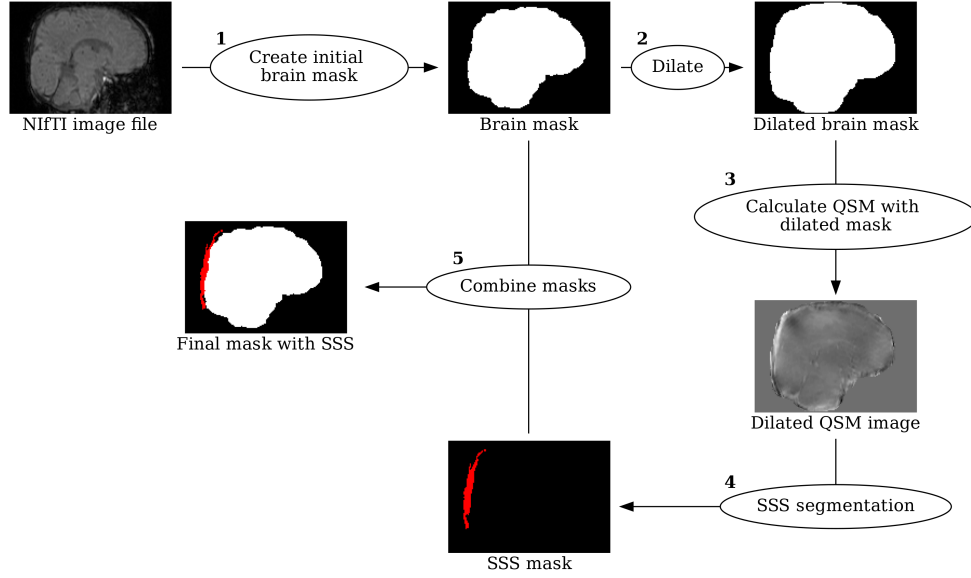


Figure 2: A graph of the methods to create a mask

Source: [Python Figures](#)

3 Results

(Ahmed et al. 2023)

4 Conclusion

References

- Ahmed, Maruf, Jingjia Chen, Arvin Arani, Matthew L. Senjem, Petrice M. Cogswell, Clifford R. Jack, and Chunlei Liu. 2023. "The Diamagnetic Component Map from Quantitative Susceptibility Mapping (QSM) Source Separation Reveals Pathological Alteration in Alzheimer's Disease-Driven Neurodegeneration." *NeuroImage* 280 (October): 120357. <https://doi.org/10.1016/j.neuroimage.2023.120357>.
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