Quantifying Volumetric Differences in Infants with Hydrocephalus

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Introduction

Hydrocephalus is the increased intracranial pressure and clinical symptoms as a result of the abnormal accumulation of cerebrospinal fluid which is often associated with the dilation of the cerebral ventricles.[1]

Hydrocephalus occurs in ~1 in 1136 live births and more often in premature infants.[2,3]

There are many etiologies and classifications.[1]

Symptoms include irritability, lethargy, vomiting, a bulging of fontanelle, and above percentile head circumference. If left untreated, hydrocephalus can potentially lead to death.[4]

Pediatric hydrocephalus diagnosis is more dependent on the interpretation of anatomical changes because, unlike adult patients, pediatric patients are unable to fully participate in clinical exams.[5]

Research Question: How does hydrocephalus affect cortical and subcortical volume metrics in infants with hydrocephalus compared to typically developing infants?

Hypothesis: We expect there to be differences in cortical and subcortical volume metrics between typically developing infants and hydrocephalus infants.

Structure	Function
Lateral Ventricle	Subcortical area responsible for production and circulation of cerebrospinal fluid (CSF)
Inferior Lateral Ventricle	Inferior subdivision of lateral ventricle subcortical area that helps to facilitate the circulation of CSF
Cerebral White Matter	Cortical region that utilizes fiber pathways of axons linking cerebral cortical areas and subcortical structures to facilitate neural circuits for sensorimotor function, intellect, and emotion
Cerebral Cortex	Cortical region that aids in perception and higher motor function with sensory information processing and motor functions integration
Thalamus	Subcortical structure that processes sensory information going to the cerebral cortex and motor information going to the brainstem and spinal cord
Caudate Nucleus	Subcortical structure that plays a role in planning the execution of movement, learning, memory, reward, motivation, and emotion
Hippocampus	Subcortical structure that is primarily involved with memory formation, spatial navigation,and memory consolidation
Amygdala	Subcortical structure that processes the emotional information gathered from the autonomic system and the hypothalamus and is involved in hormone secretion

Table 2. Functions of cortical and subcortical structures/regions of interest.[6]

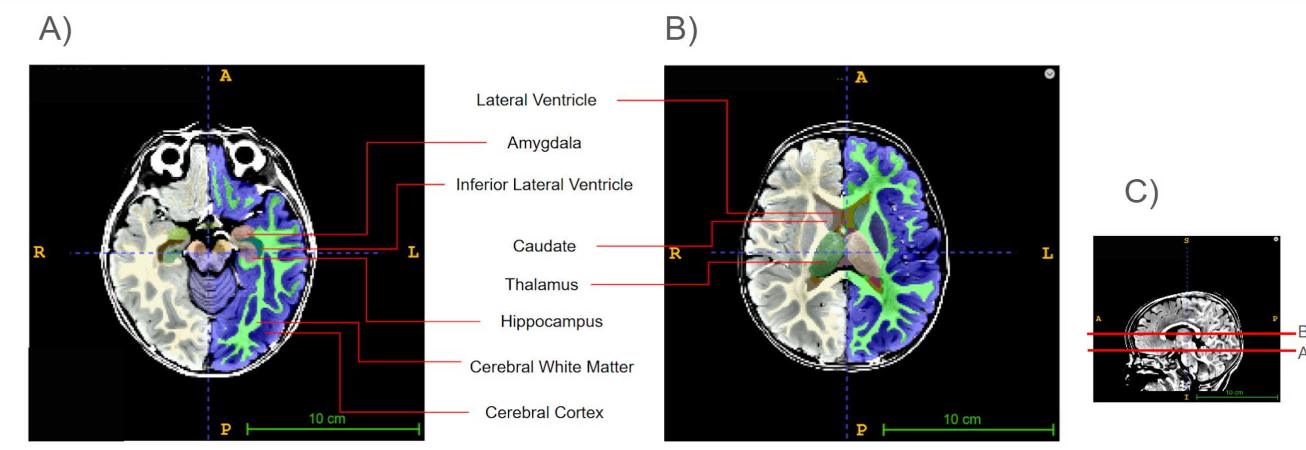


Figure 2. (A) and (B) Axial view of T1 weighted images of a BCP healthy control (8.3 months) with cortical and subcortical labels. (C) Sagittal view with locations of corresponding slices.

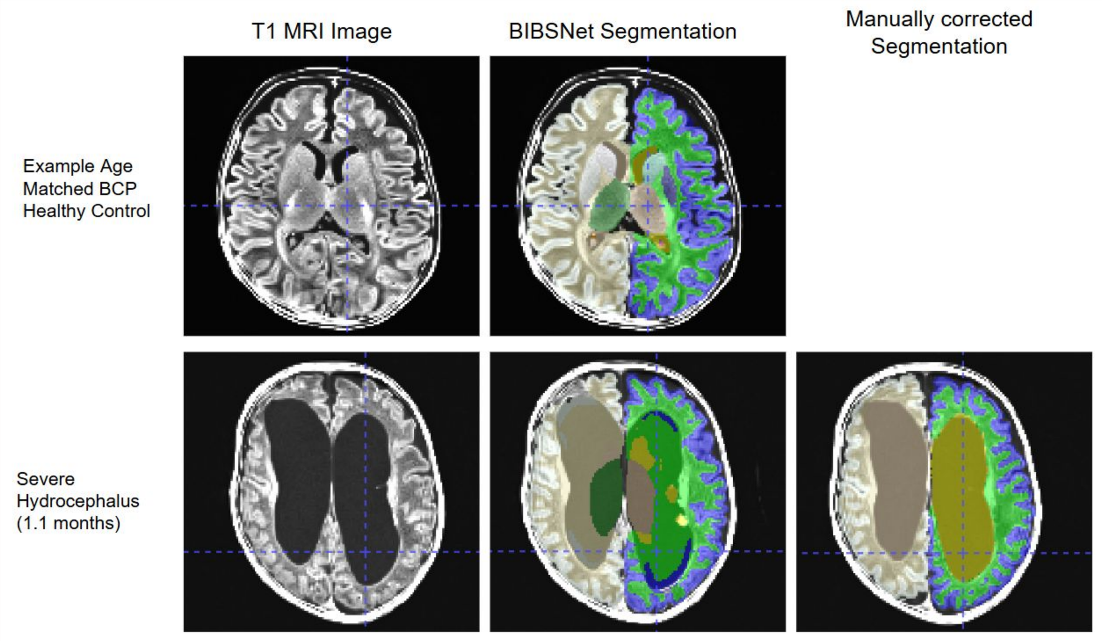


Figure 3. Axial view of T1 MRI image and corresponding segmentations of the clinical participant with Severe Hydrocephalus (1.1 months) compared with an example of an age matched BCP healthy control.

Methods

High resolution structural MRIs were conducted on a 3T Siemens Prisma MRI Scanner at the University of Minnesota.

BIBSNet, an open-source community model that utilizes data augmentation and large sample size of manually segmented images, was used to create general brain segmentations.

ITK-SNAP was utilized to manually correct segmentations of the T1 and T2 MRI images as needed for the clinical participants.

Cortical volumes were estimated for 154 participants (0 to 16.7 months old) for cortical and subcortical structures/regions of interest.

Clinical Participant Diagnosis	Gestational Age	Age at Scan (months)	Corrected Age (months)	Age Matched BCP Healthy Control Ranges (months)
Incidental Unilateral Ventriculomegaly	~40 weeks (Full-term)	16	NA	15.25-16.75
Ventriculomegaly	~27 weeks	9.8	6.8	7.55-6.05
Moderate Hydrocephalus	~23 weeks	12.2	8.3	7.55-9.05
Severe Hydrocephalus	~25 weeks	4.5	1.1	0.35-1.85

Table 1. Clinical participant information.

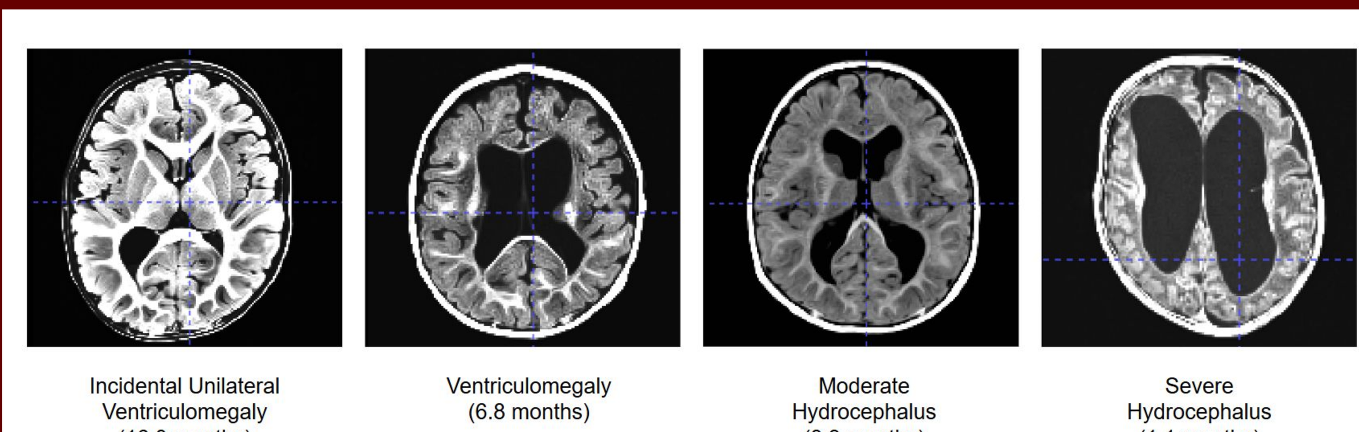
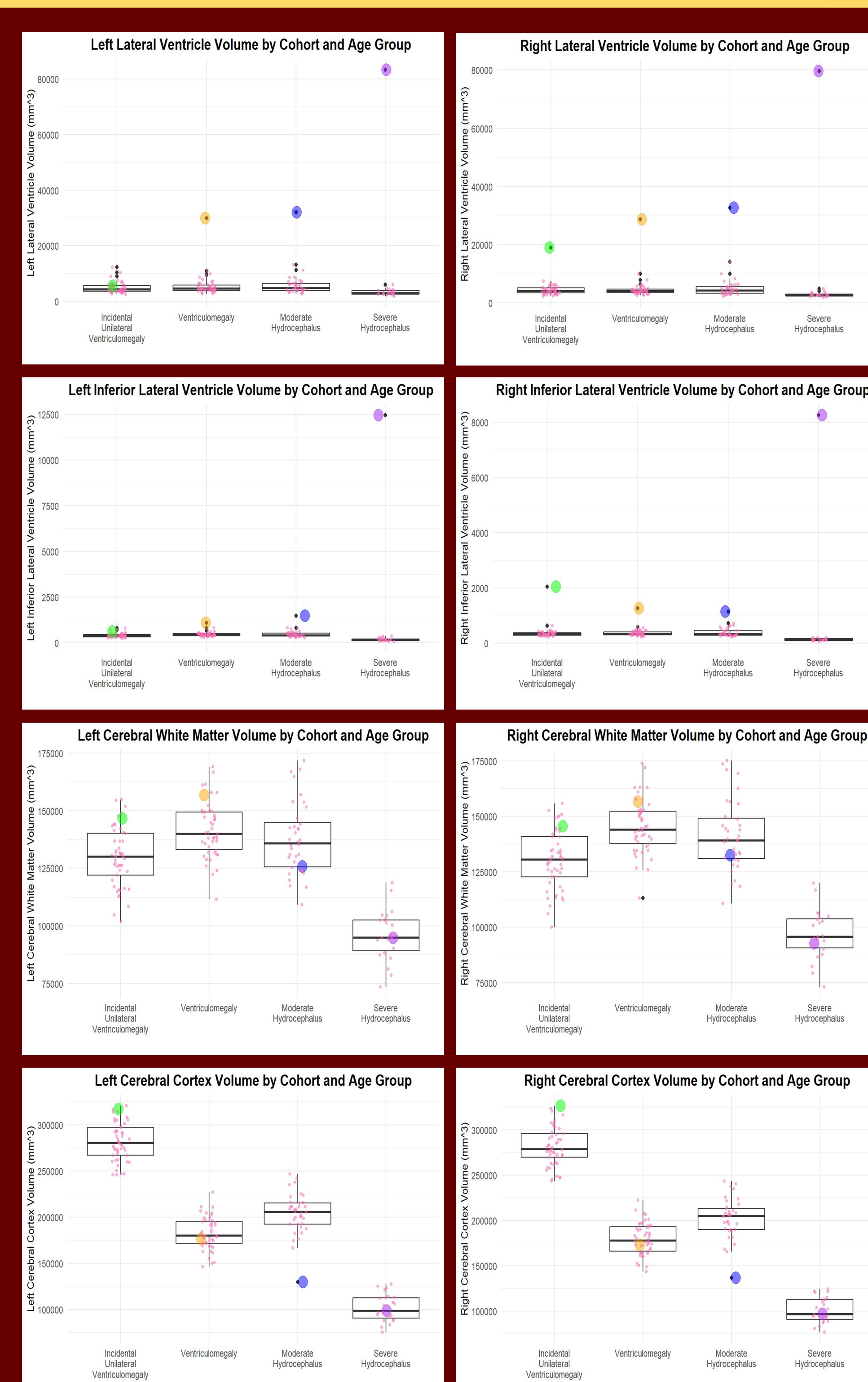


Figure 1. Structural T1 MRIs of the clinical participants to visualize anatomical differences in order of severity (right to left).

Results



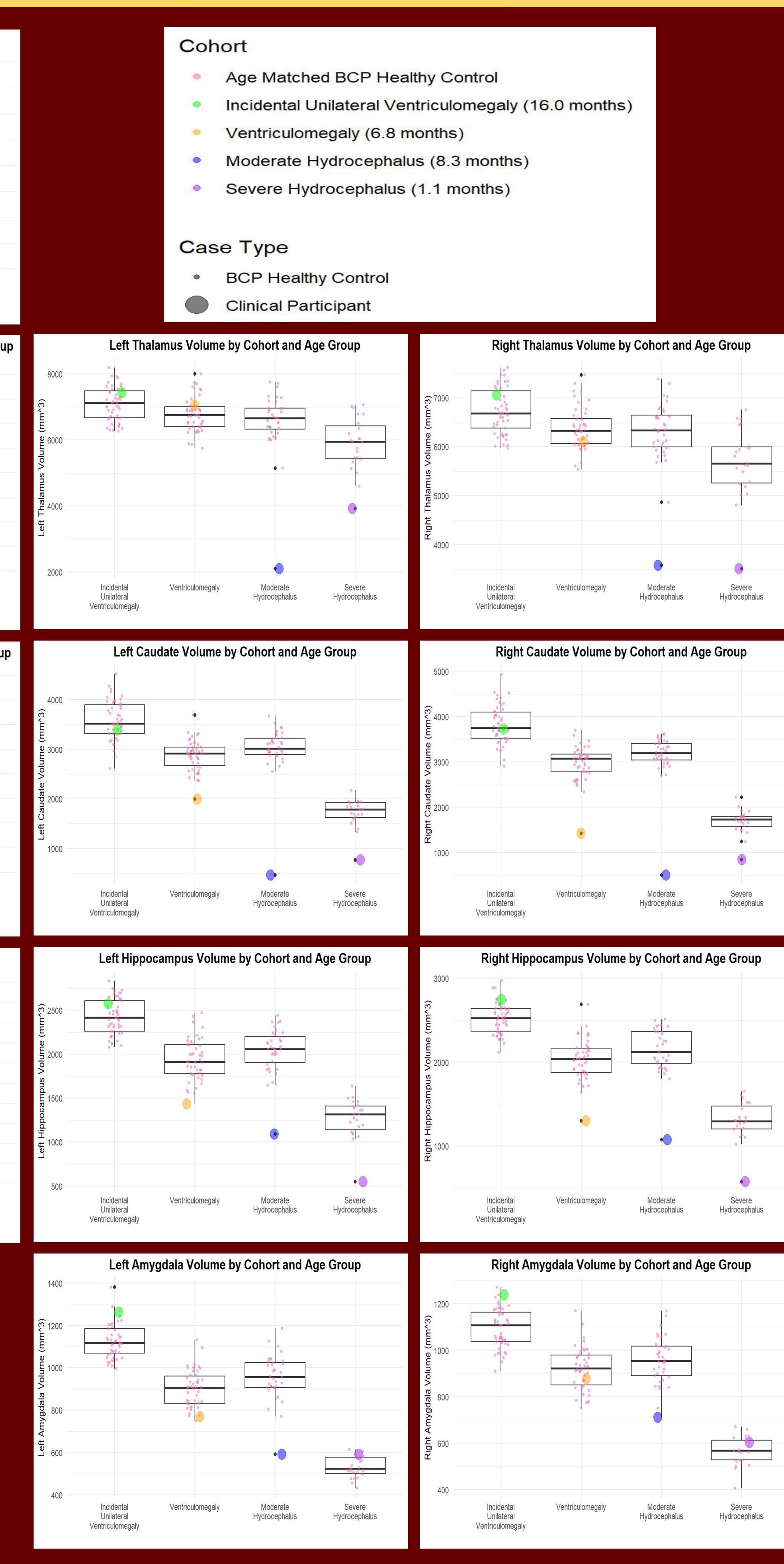


Figure 4. Comparison of volumes of cortical and subcortical structures/regions of interest of clinical participants to age matched healthy controls by hemisphere and structure/region. (Lateral Ventricle, Inferior Lateral Ventricle, Cerebral White Matter, Cerebral Cortex, Thalamus, Caudate Nucleus, Hippocampus, Amygdala)

Conclusion

There are differences in cortical and subcortical volume metrics between typically developing infants and hydrocephalus infants.

The level of differences seems to track with the severity of clinical diagnosis.

Impact: The more information that we have about the differences between these clinical infants and typically developing infants the better we can understand the full effects of hydrocephalus on brain development.

Future studies can aim to investigate volumetric differences longitudinally as well as consider the data from pre- and post- shunt insertion as a treatment.

Acknowledgements/References

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References:

[1]Wright et al., 2016; [2]Isaacs et al., 2018; [3]Koleva & De Jesus, 2023; [4]Kestle, 2003; [5]Peña Pino et al., 2024; [6]Ludwig et al., 2022