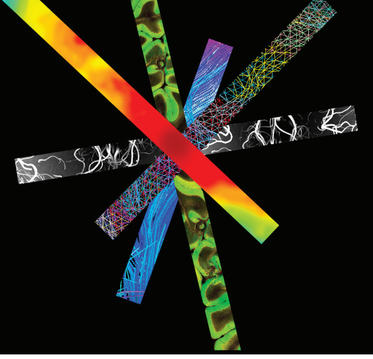
Automated Segmentation of the Choroid Plexus

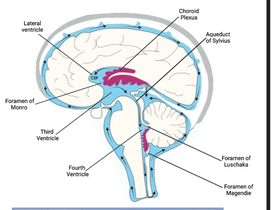
Thomas M. Morin[1,2], Filippo Bargagna[1,3], Ya-Chin Chen[1], Christopher J. McDougle[4], Jacob M. Hooker[1,4], Nicole R. Zürcher[1,4]

1 Martinos Center for Biomedical Imaging, Department of Radiology, Massachusetts General Hospital
2 Department of Neuroscience, Brandeis University
3 Department of Information Engineering, University of Pisa
4 Lurie Center for Autism, Massachusetts General Hospital



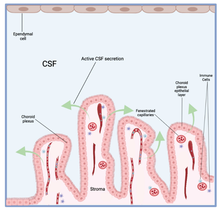
Background

- The choroid plexus forms the brain's blood-cerebrospinal fluid (CSF) barrier, produces CSF, and is involved in neuroimmune signaling.



- Group differences in choroid plexus volume and morphology have been identified across several conditions. Our group is interested in choroid plexus morphology in the context of autism spectrum disorder (ASD).

- While manual tracing of choroid plexus remains the gold standard, several automated methods are available.



(Bitanihirwe et al. 2022)

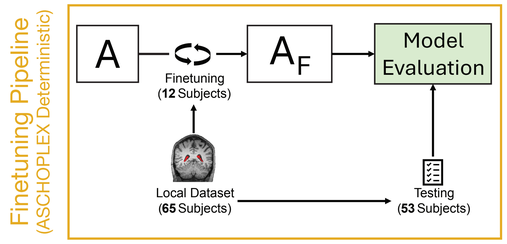
- One method, Automated Segmentation of CHoroid PLEXus (ASCHOPLEX) can be finetuned on new datasets to improve performance.

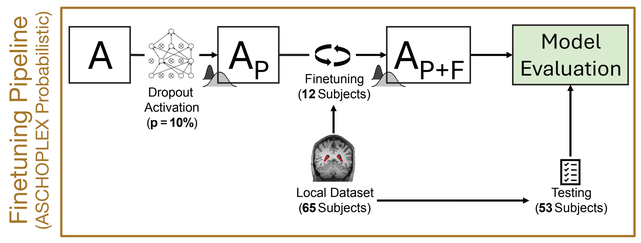
Research Questions:

- How do the available automated segmentation methods compare to manual tracing?
- Can we finetune ASCHOPLEX to segment the choroid plexus in a cohort that includes ASD participants?
- How well does ASCHOPLEX generalize to a larger dataset?

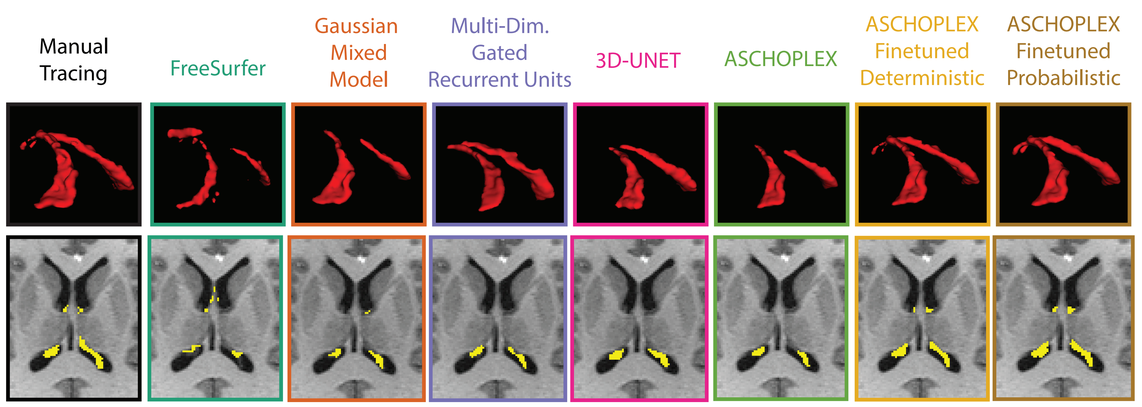
Publicly Available Segmentation Methods

1. **Manual Tracing**
   We traced on T1w MEMPRAGE images; when available, FLAIR and/or scans acquired with gadolinium contrast are preferred
2. **FreeSurfer** (Fischl et al. 2012)
3. **Gaussian Mixed Model** (Tadayon et al. 2020)
   Unsupervised clustering algorithm; constrained to ventricles
4. **Multi-Dimensional Gated Recurrent Units** (Müller et al. 2022)
   Supervised; deep learning; Trained on dataset of patients with multiple sclerosis, migraine, and neuromyelitis optica spectrum disorder
5. **3D-UNET** (Eisma et al. 2024)
   Supervised; deep learning; Trained on dataset of older and younger adults; patients with MCI and Alzheimer's disease
6. **ASCHOPLEX** (Visani et al. 2024)
   Ensemble of five supervised deep learning models; Trained on dataset of patients with multiple sclerosis
   - **6a. ASCHOPLEX - Finetuned on Local Data**
     We finetuned the ASCHOPLEX algorithm using 12 of our ASD and CON participants, manually traced
   - **6b. ASCHOPLEX - Finetuned on Local Data, Probabilistic**
     We implemented a probabilistic version of the algorithm by enabling edge dropout in the neural nets during finetuning.

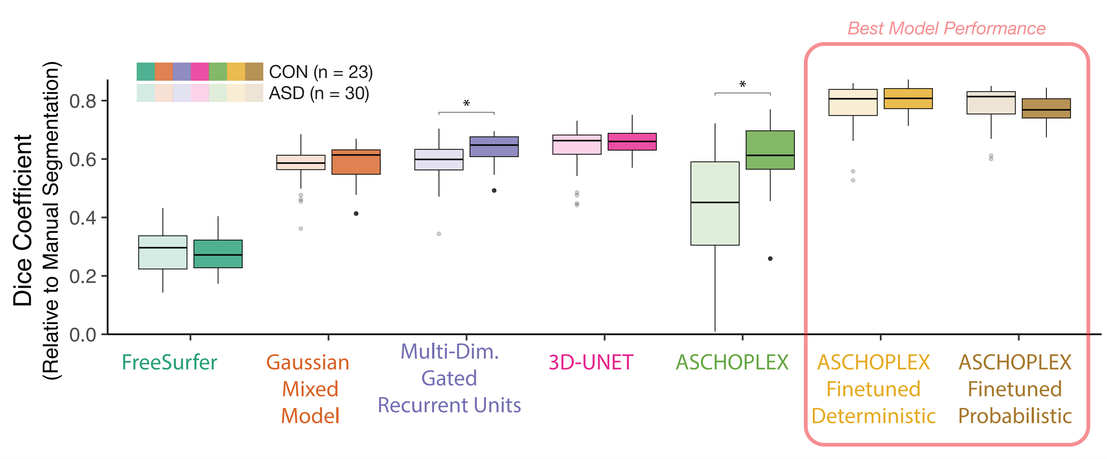




Choroid Plexus Segmentation for a Single Participant

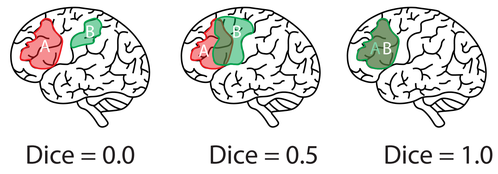


Choroid Plexus Segmentation Performance Across Our Cohort



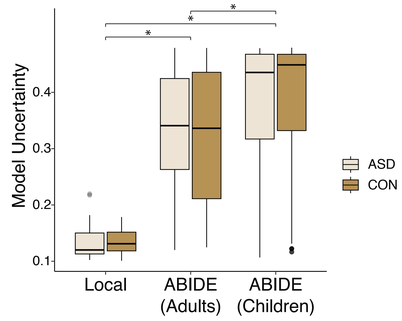
Calculating Dice Coefficient

$$Dice = \frac{2\sum_0^n a_i m_i}{\sum_0^n a_i + \sum_0^n m_i} = \frac{2 * A \cap B}{A + B}$$



Generalization of Finetuned ASCHOPLEX to the ABIDE Dataset

ABIDE
Autism Brain Imaging Data Exchange



- The Autism Brain Imaging Data Exchange (ABIDE) has released two datasets (ABIDE I and ABIDE II) that contain 2,000+ MRI scans from ASD and CON participants ages 5 - 65 (DiMartino et al., 2014; 2017).
- Using the finetuned probabilistic ASCHOPLEX model, we quantified uncertainty as the standard deviation across model iterations, averaged across all choroid plexus voxels.
- ASCHOPLEX shows minimal uncertainty in the local dataset, demonstrating effective finetuning.
- There is increased uncertainty in the ABIDE dataset overall, particularly in children.
- In both the local and ABIDE datasets, ASCHOPLEX does not show bias based on diagnosis.

Conclusions & Future Directions

- Finetuned versions of ASCHOPLEX showed the best performance in segmenting choroid plexus on our dataset.
- Finetuning eliminated ASCHOPLEX's original bias so that it now performs equally across both ASD and CON participants.
- Additional finetuning is needed to generalize to ABIDE data.
- We are in the process of hand tracing ~80 T1w images from the ABIDE dataset (using an iPad).
- This will allow us to use new datasets to investigate choroid plexus development throughout childhood, adolescence, and adulthood, in ASD and CON participants.

References

Bitanihirwe et al. 2022 (Molecular Psychiatry)
DiMartino et al. 2014 (Molecular Psychiatry)
DiMartino et al. 2017 (Scientific Data)
Eisma et al. 2024 (Fluids & Barriers of the CNS)
Fischl et al. 2012 (Neuroimage)
Müller et al. 2022 (Neurology: Neuroimm. & Neuroinf.)
Tadayon et al. 2020 (J. Alzheimer's Disease)
Visani et al. 2025 (Computers in Bio. & Med.)

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Thomas Morin, Ph.D.
tmorin2@mgh.harvard.edu
tommorin@brandeis.edu
www.tmmorin.com