BROWN
Alpert Medical School

PENNSTATE
College of Engineering

Volumetric Brain Analysis in Neurosurgery

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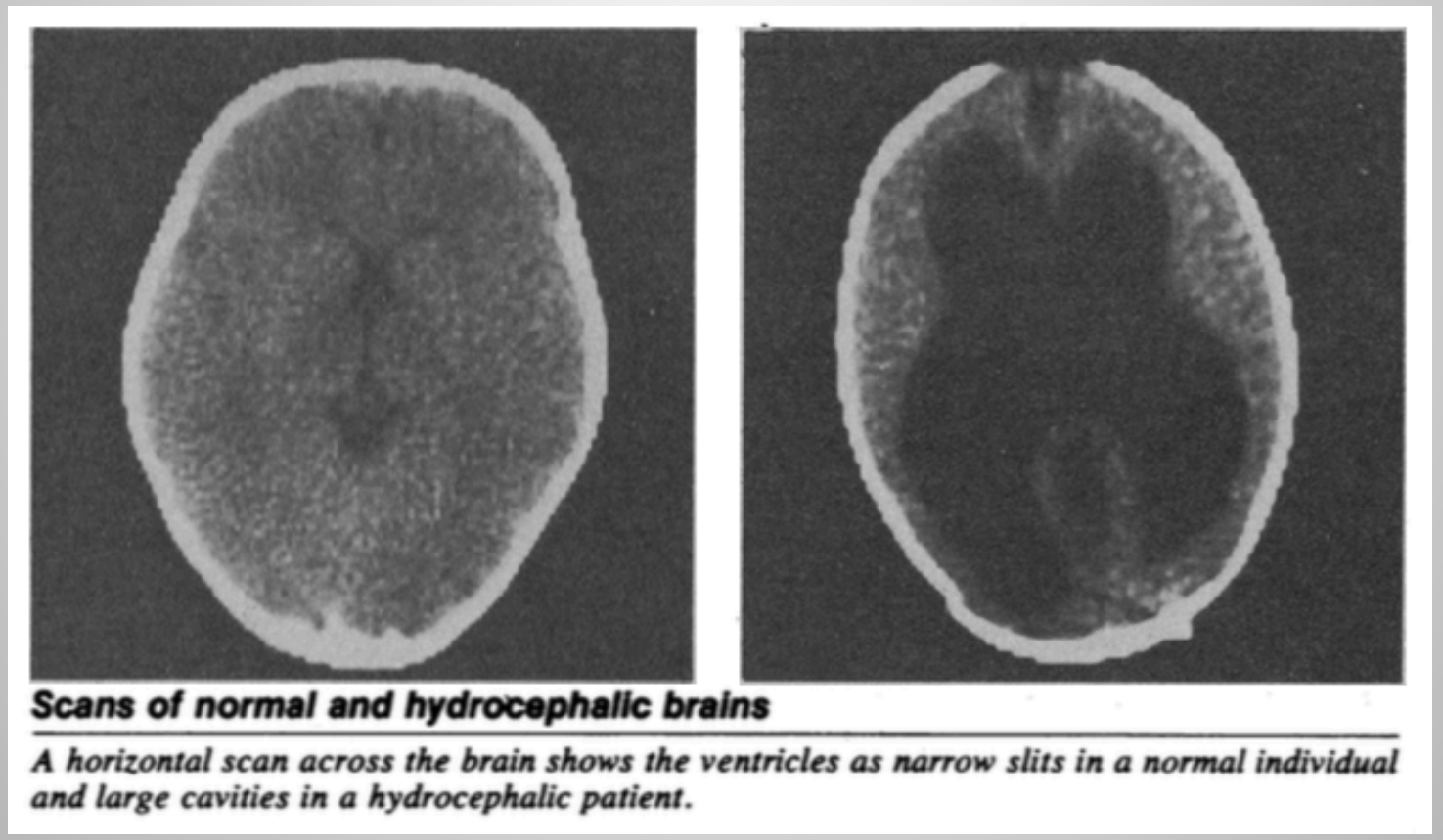
Banff, Canada, September 18, 2015

Is your brain really necessary?

-John Lorber (1980)

University student with in IQ of 126

"His cranium is filled mainly with cerebrospinal fluid."



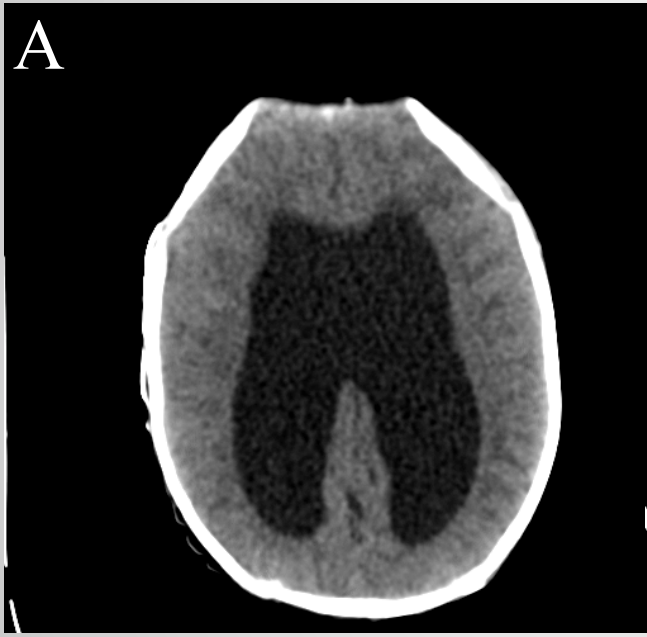
Scans of normal and hydrocephalic brains

A horizontal scan across the brain shows the ventricles as narrow slits in a normal individual and large cavities in a hydrocephalic patient.

Lewin, *Science* 1980

Which one is doing better after ventriculostomy?

Male 9 months

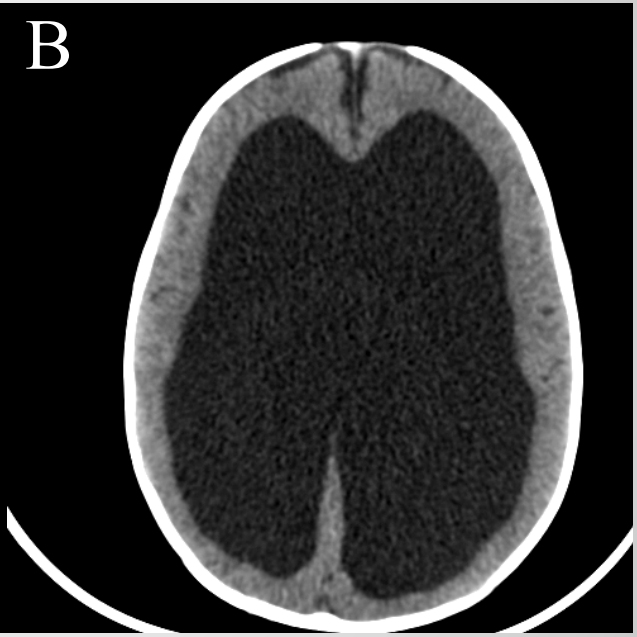


Normalized Fluid Vol = 6.5

Normalized Brain Vol = 0.67

Bailey Average = 2.7

Female 6 months



Normalized Fluid Vol = 44

Normalized Brain Vol = 0.86

Bailey Average = 8.3

Outline

- Methods of image analysis

  (particle filter segmentation)

- Measurements of hydrocephalus

- Neurocognitive outcomes

  (our brain is necessary)

Image Segmentation

1) Classification
2) Edge Tracing
3) Segmentation

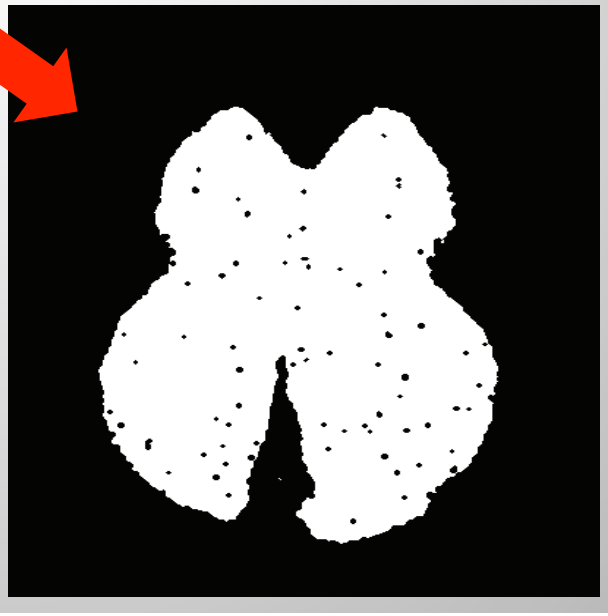


Image Segmentation: Classification

- What is the likelihood that a voxel contains brain or fluid?
- Based on 2D neighborhood around voxel

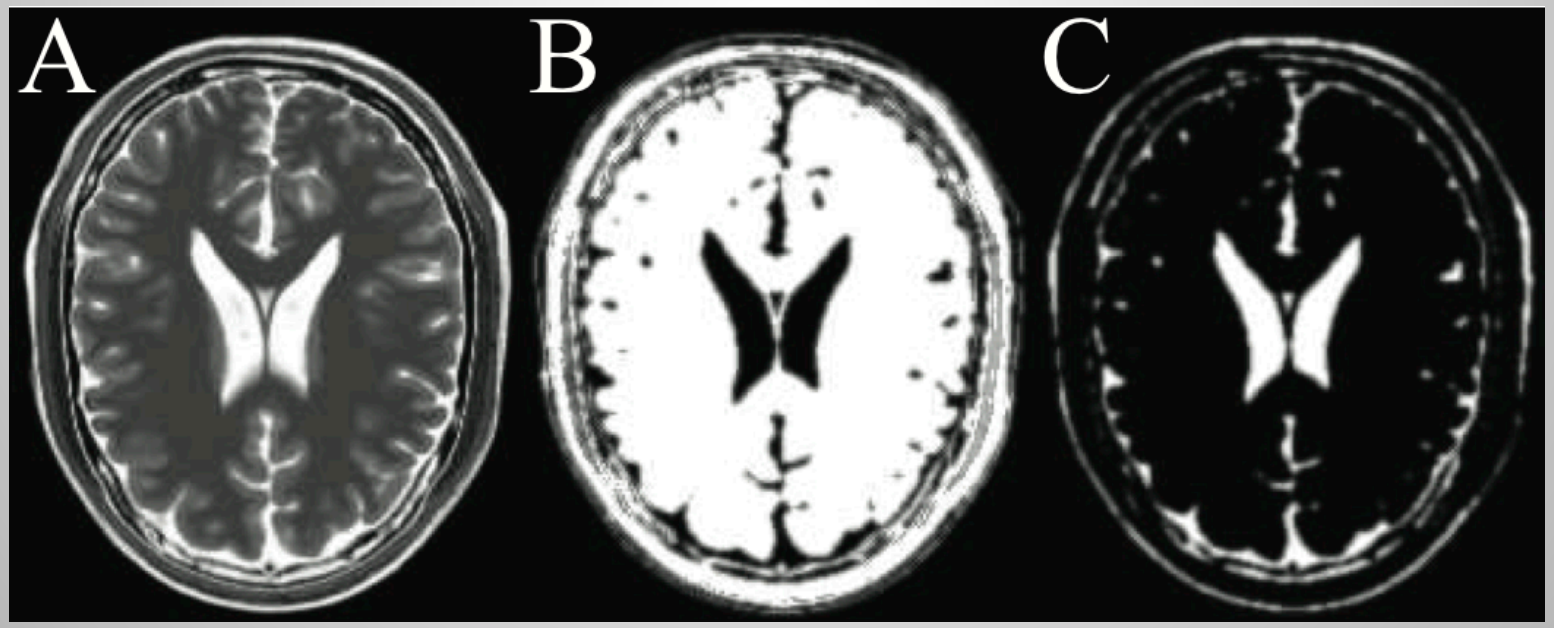


Image Segmentation: Edge Tracing

- The particle filter

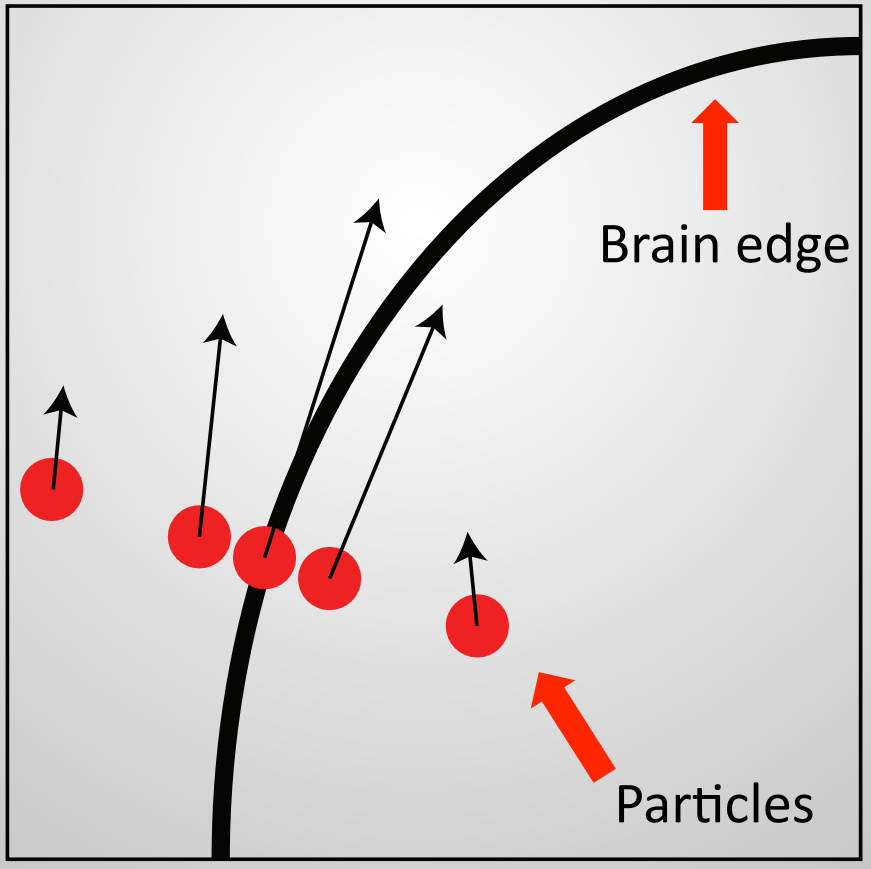


Image Segmentation: Edge Tracing

- The particle filter

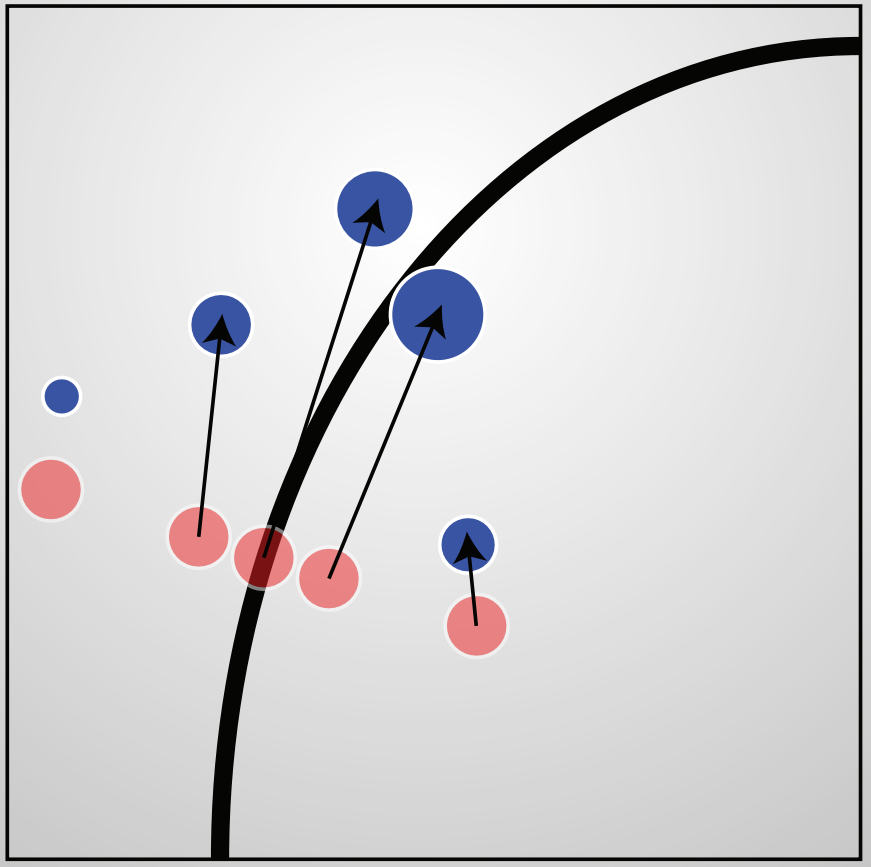


Image Segmentation: Edge Tracing

- The particle filter

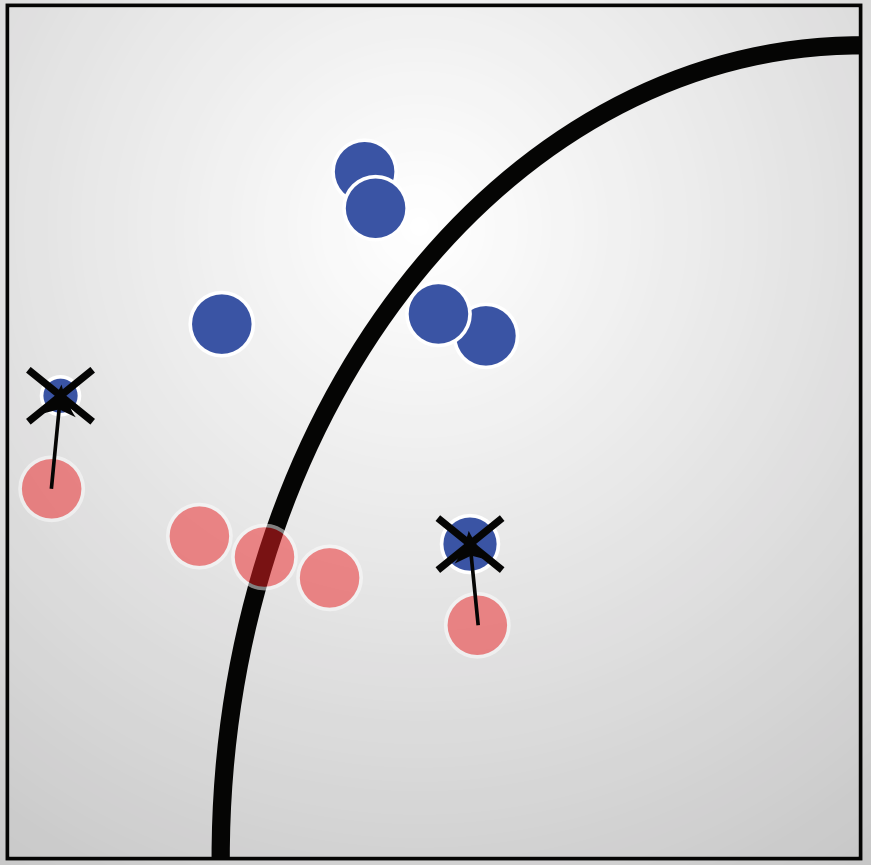


Image Segmentation: Edge Tracing

- The particle filter

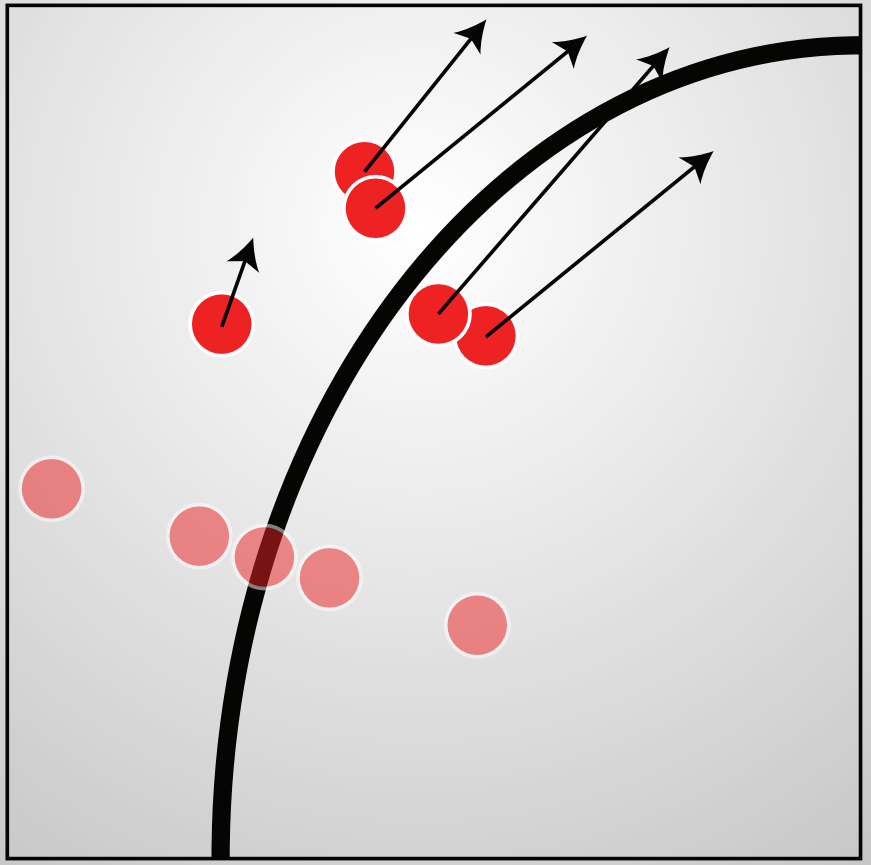
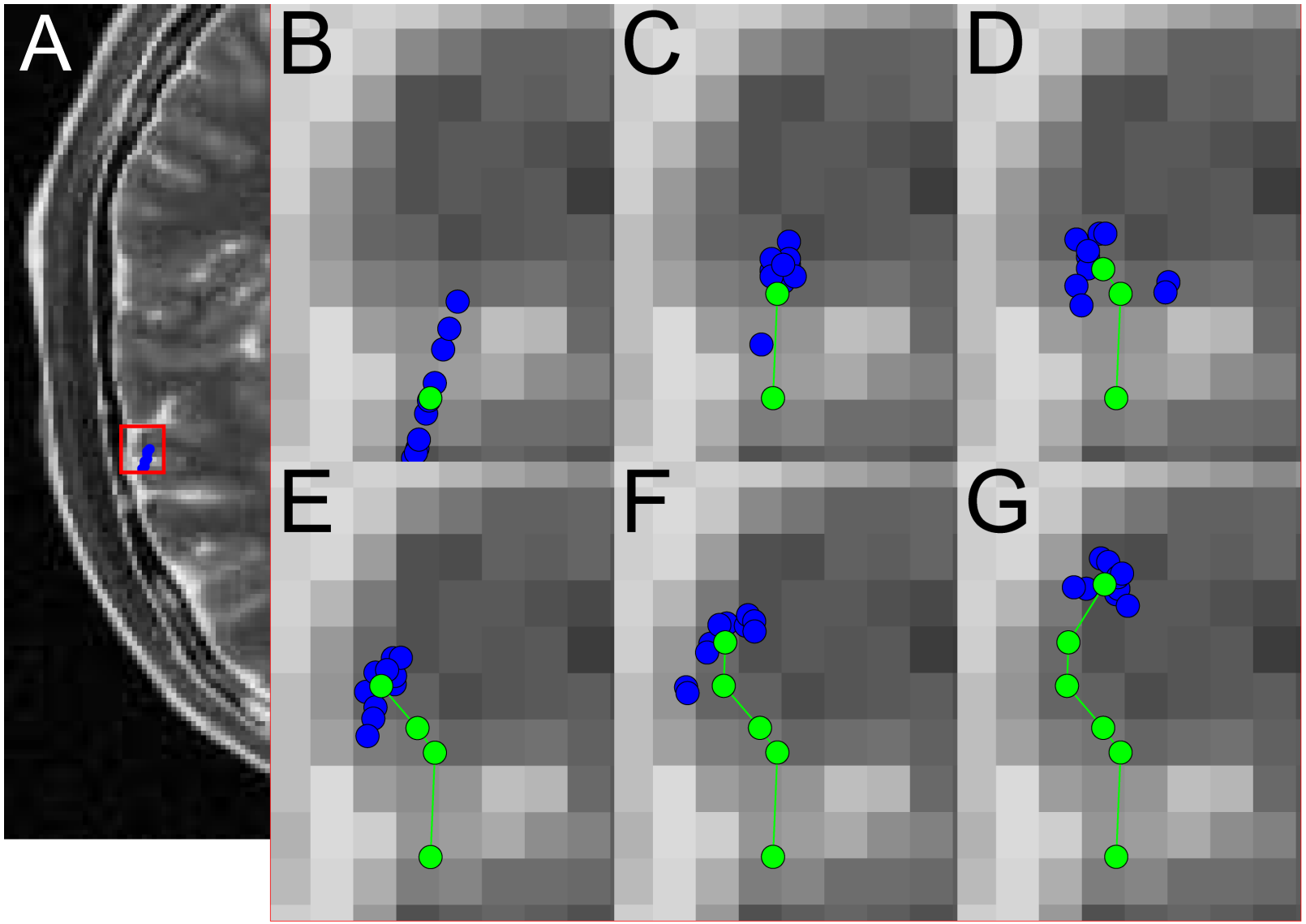


Image Segmentation: Edge Tracing



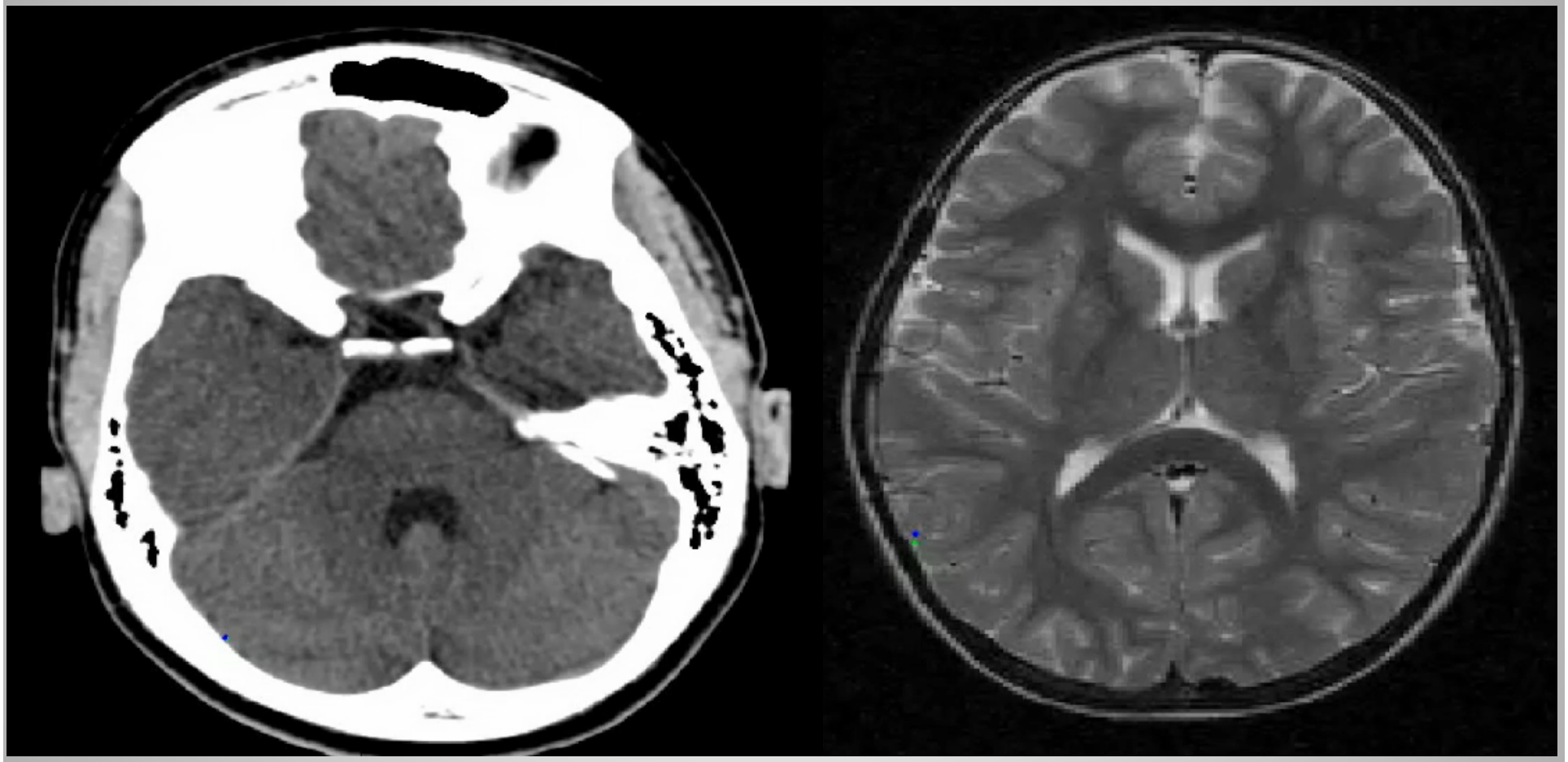
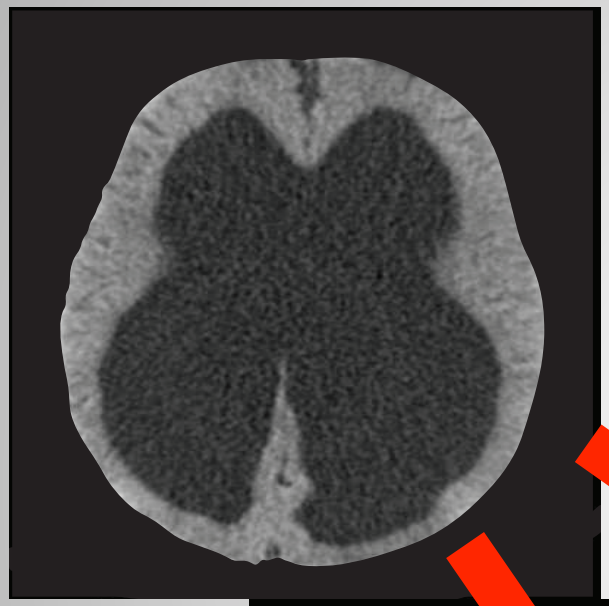
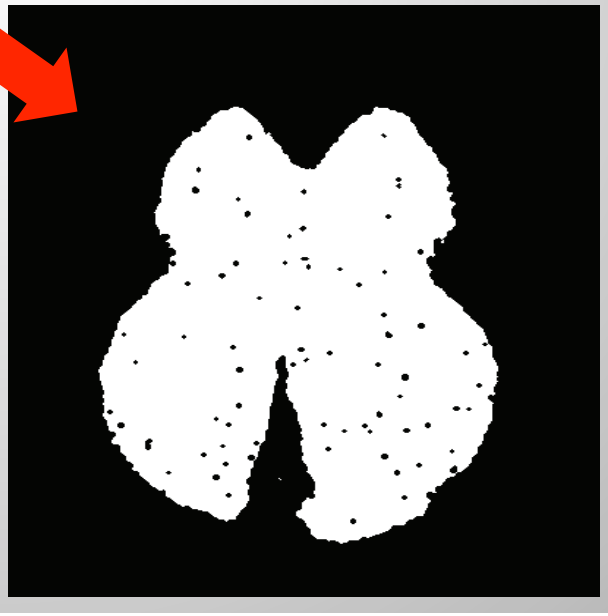


Image Segmentation: Final Step

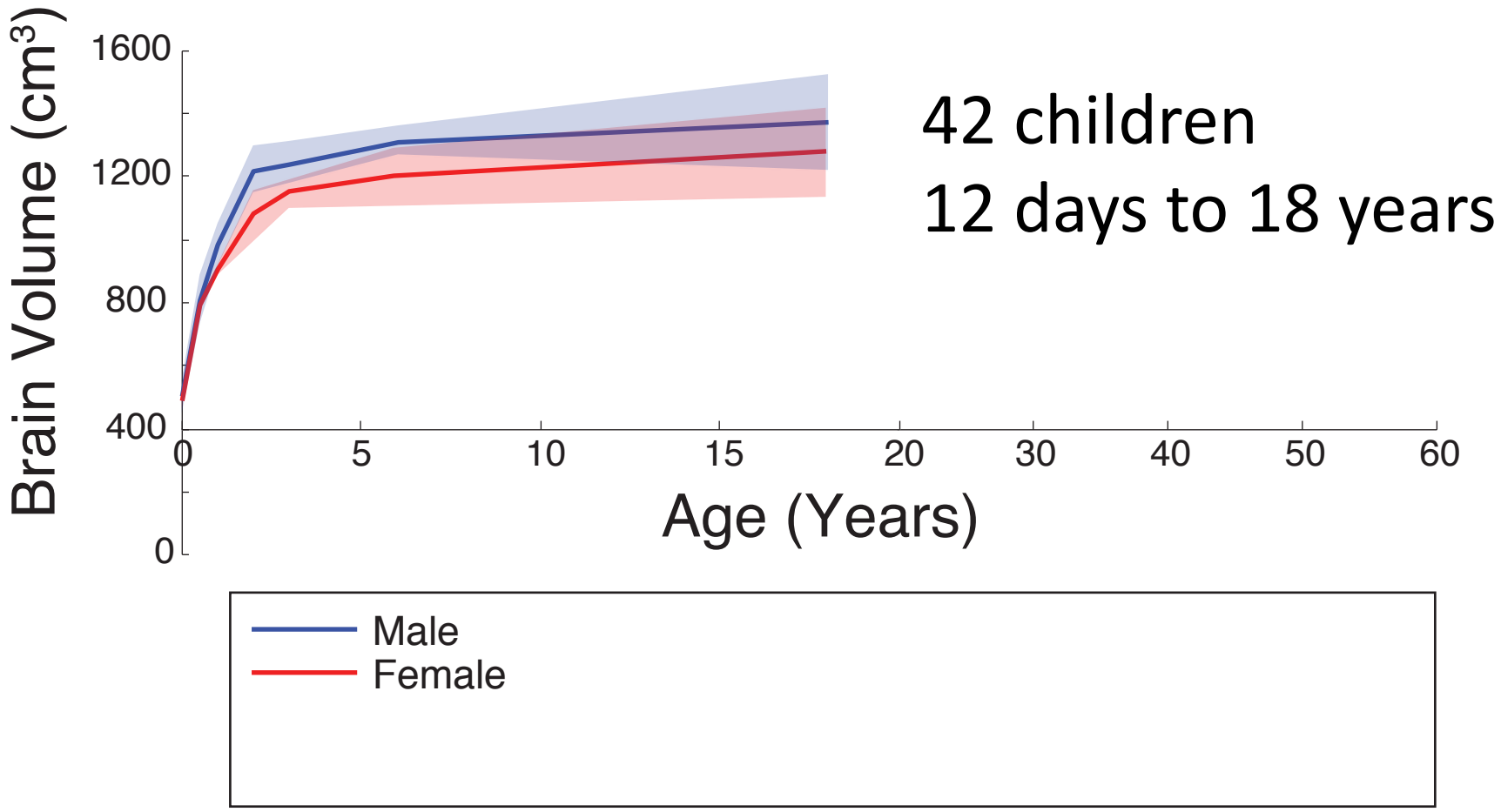


From the extracted area

- What is brain?
- What is fluid?



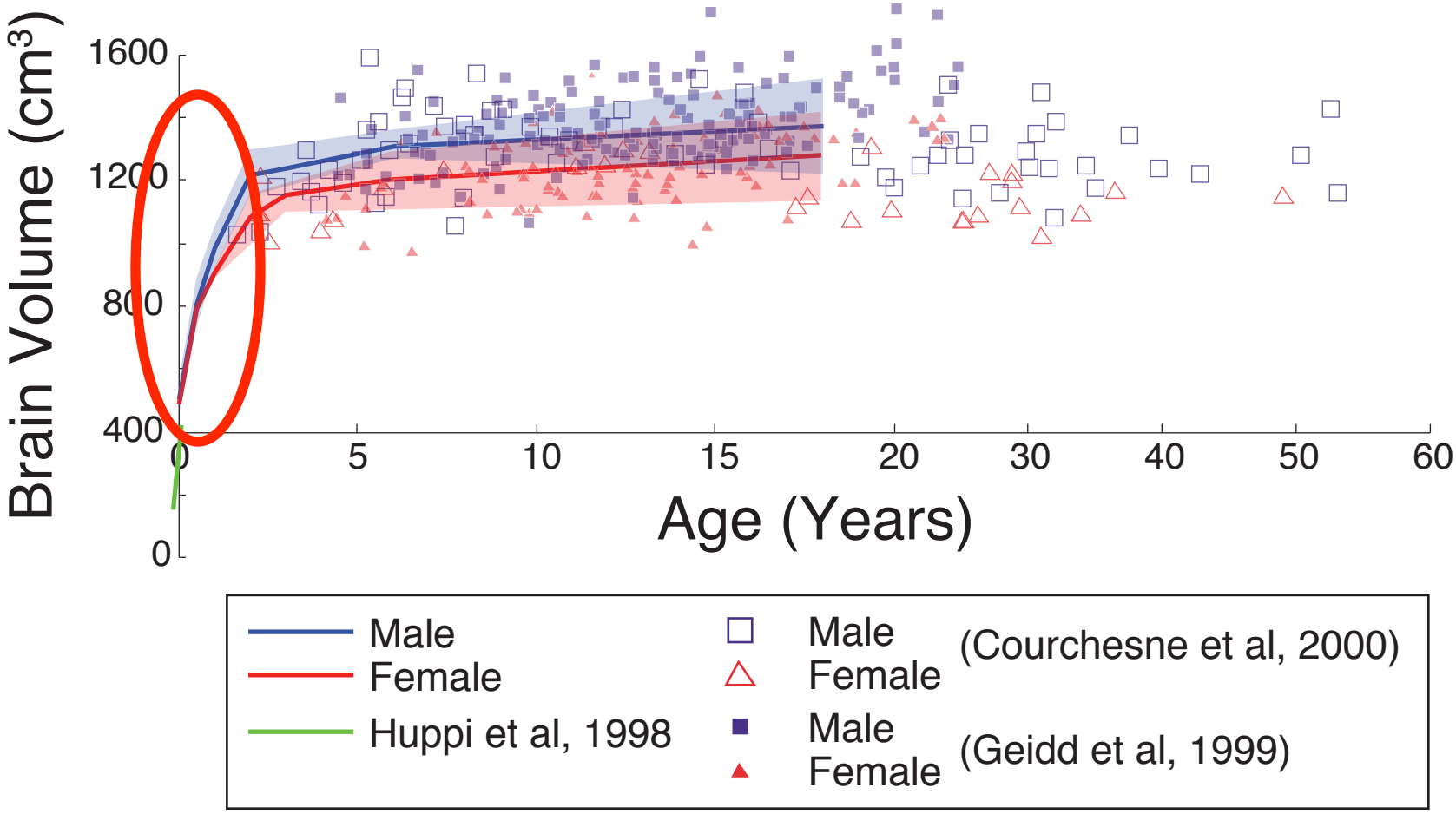
Normative Brain Growth



42 children

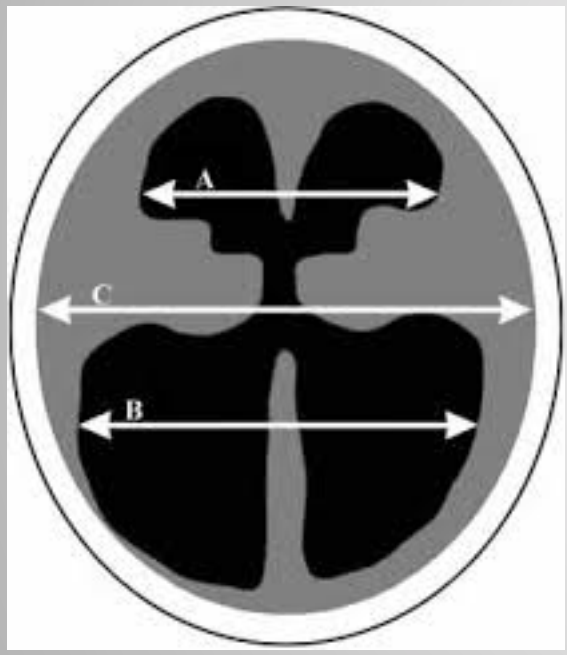
12 days to 18 years

Normative Brain Growth



Do brain and fluid volumes predict neurocognitive outcome in children with hydrocephalus?

Warf et al (J Neurosurg Peds 2009) Does treatment correlate with outcome?



FOHR = (A+B)/(2*C)

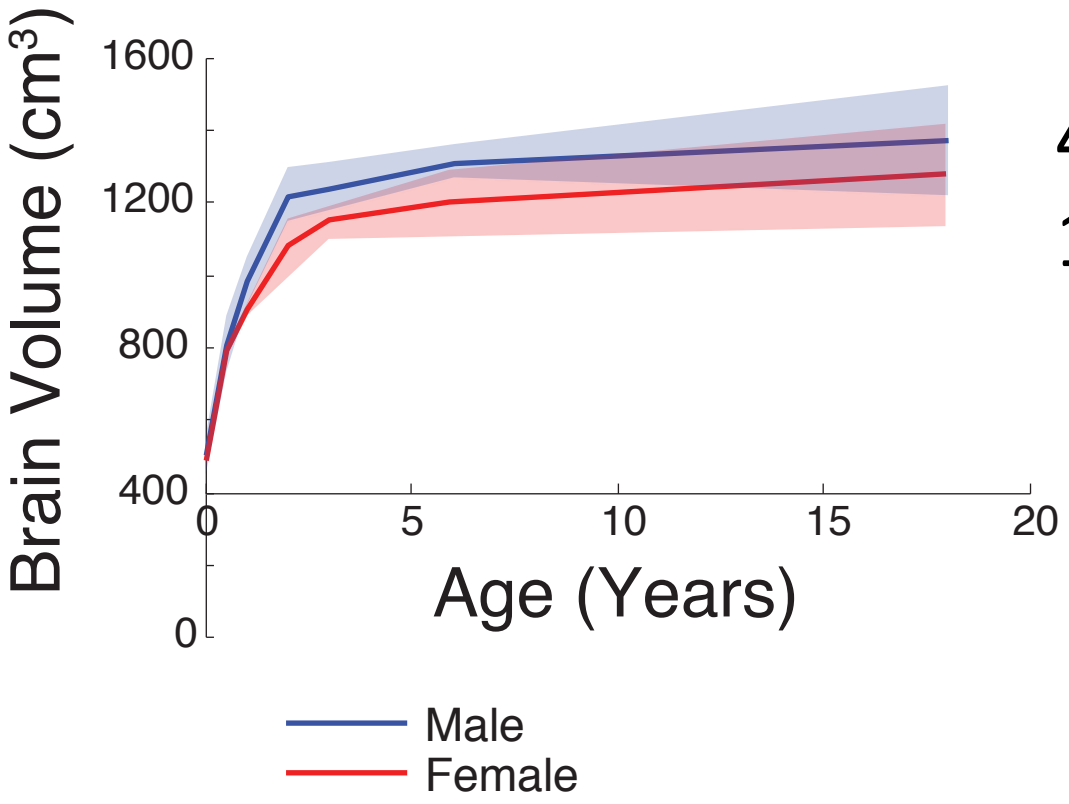
Kulkarni et al, Pediatr Neurosurg 1999;31:65-70

- 93 Ugandan Children with SB
- No treatment, ETV/CPC, VPS
- Different treatments Did Not Correlate With Cognitive Performance (BSID)
- FOHR Did Not Correlate With Cognitive Performance (BSID)

Our Study Cohort

- 33 patients ages 2 weeks to 6 years
  - No treatment (7), ETV/CPC (17), VPS (9)
  - All patients were analyzed together
- Brain and fluid volumes measured from CT
- Modified BSID-III administered post-operatively (mean age 15.6 months)

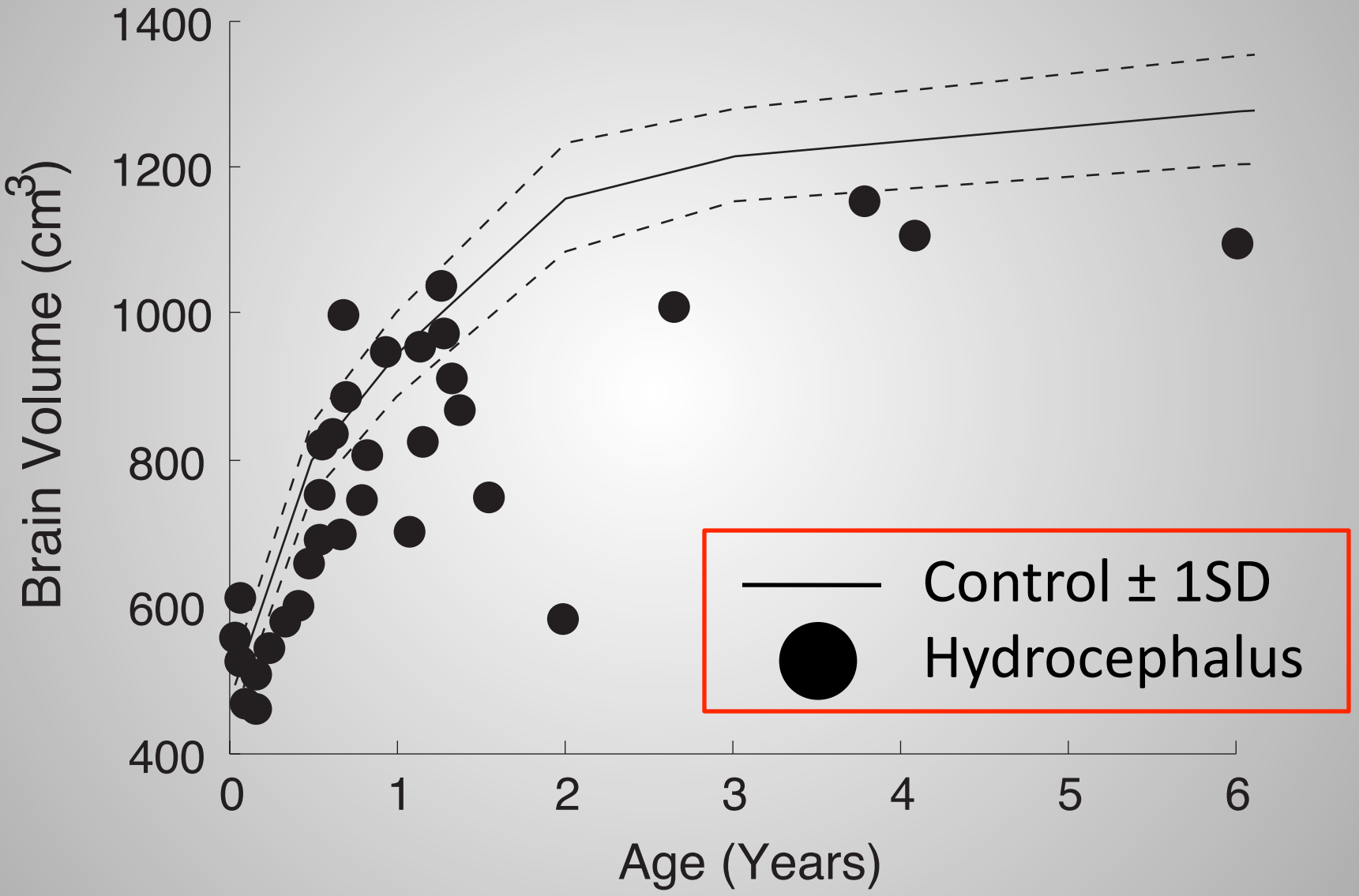
Normal Controls



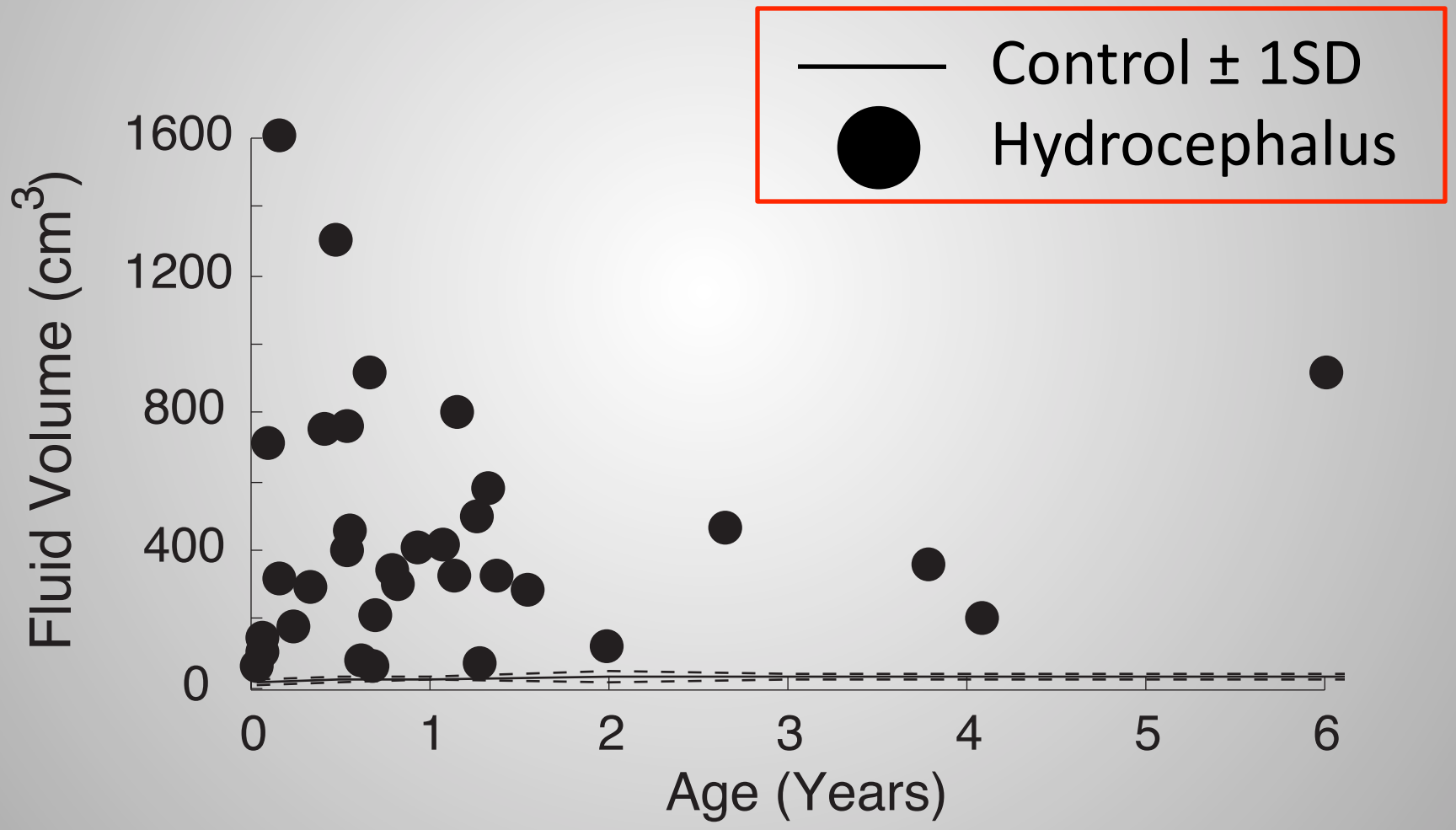
42 children

12 days to 18 years

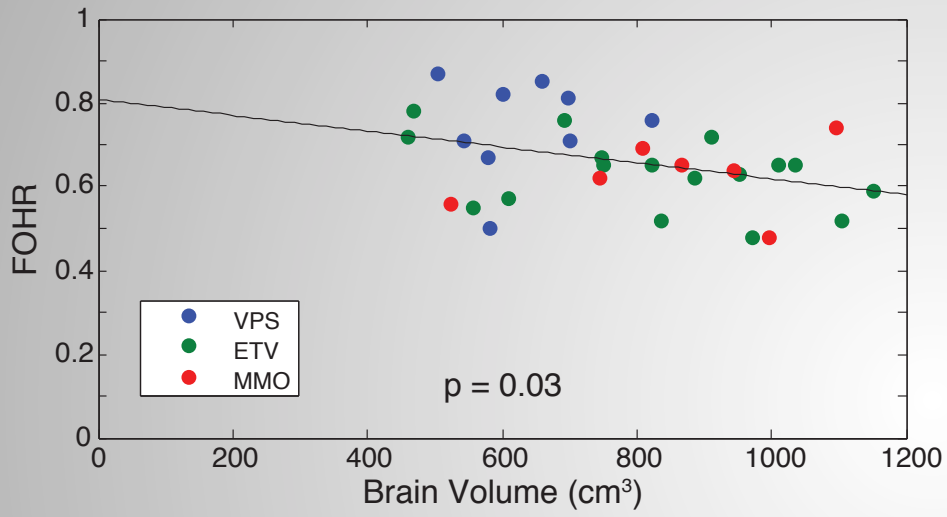
Brain Volumes

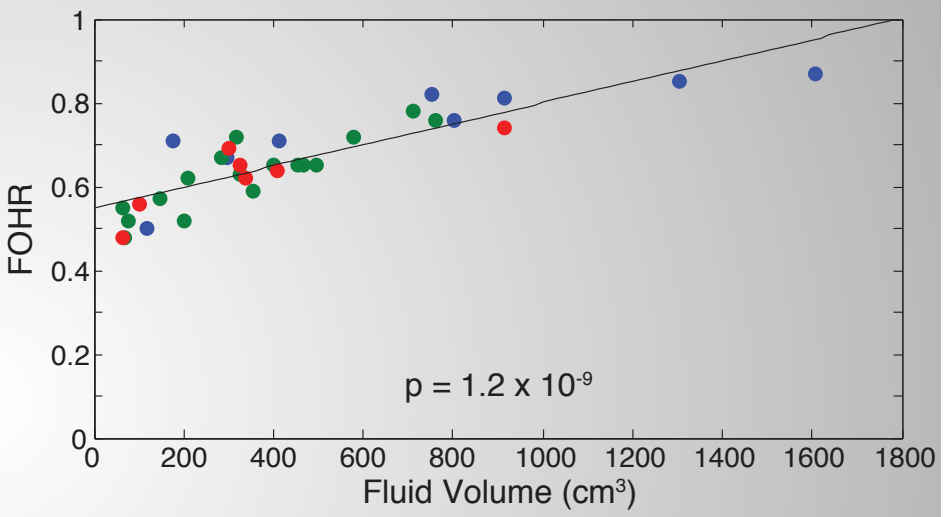


CSF Volumes


Control ± 1SD
Hydrocephalus
Fluid Volume (cm3)
1600
1200
800
400
0
0
1
2
3
4
5
6
Age (Years)

FOHR as an estimate of volume

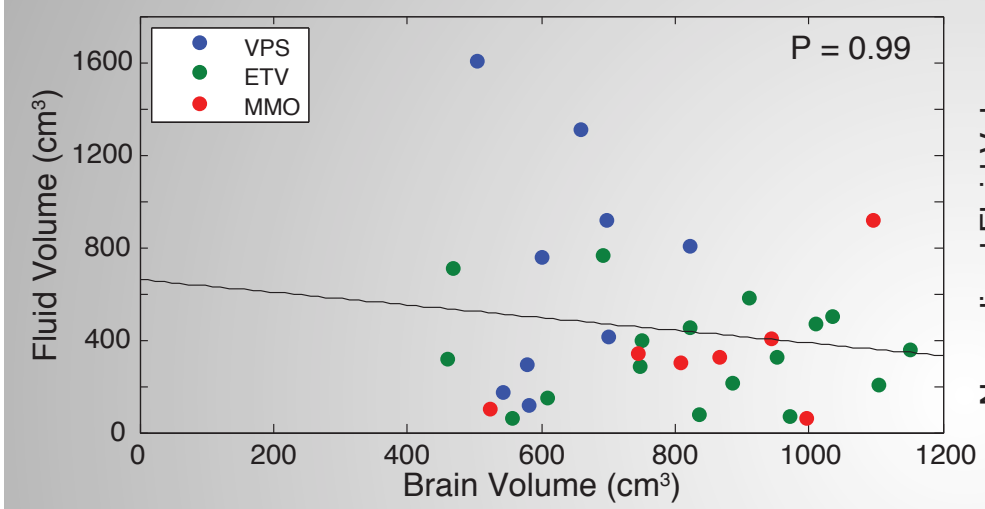


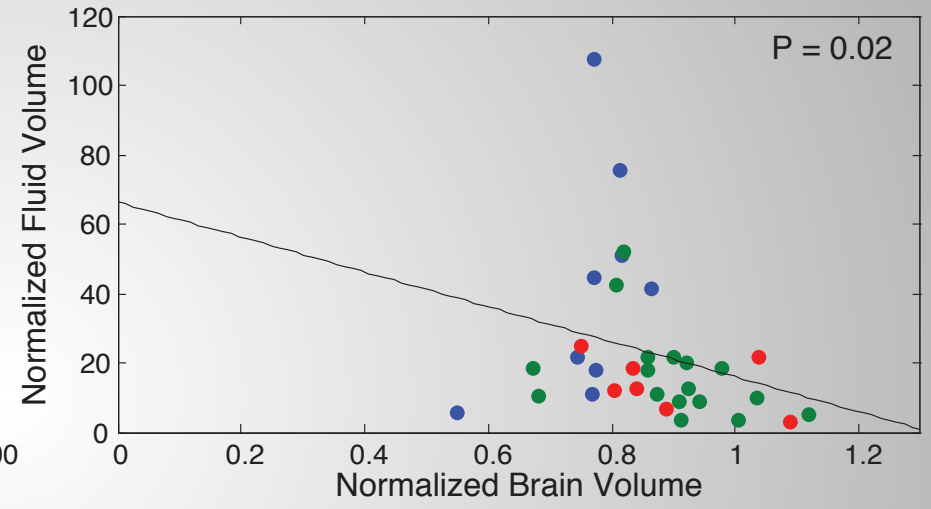


FOHR does not correlate well with brain

FOHR correlates very well with fluid

Brain & fluid develops independently

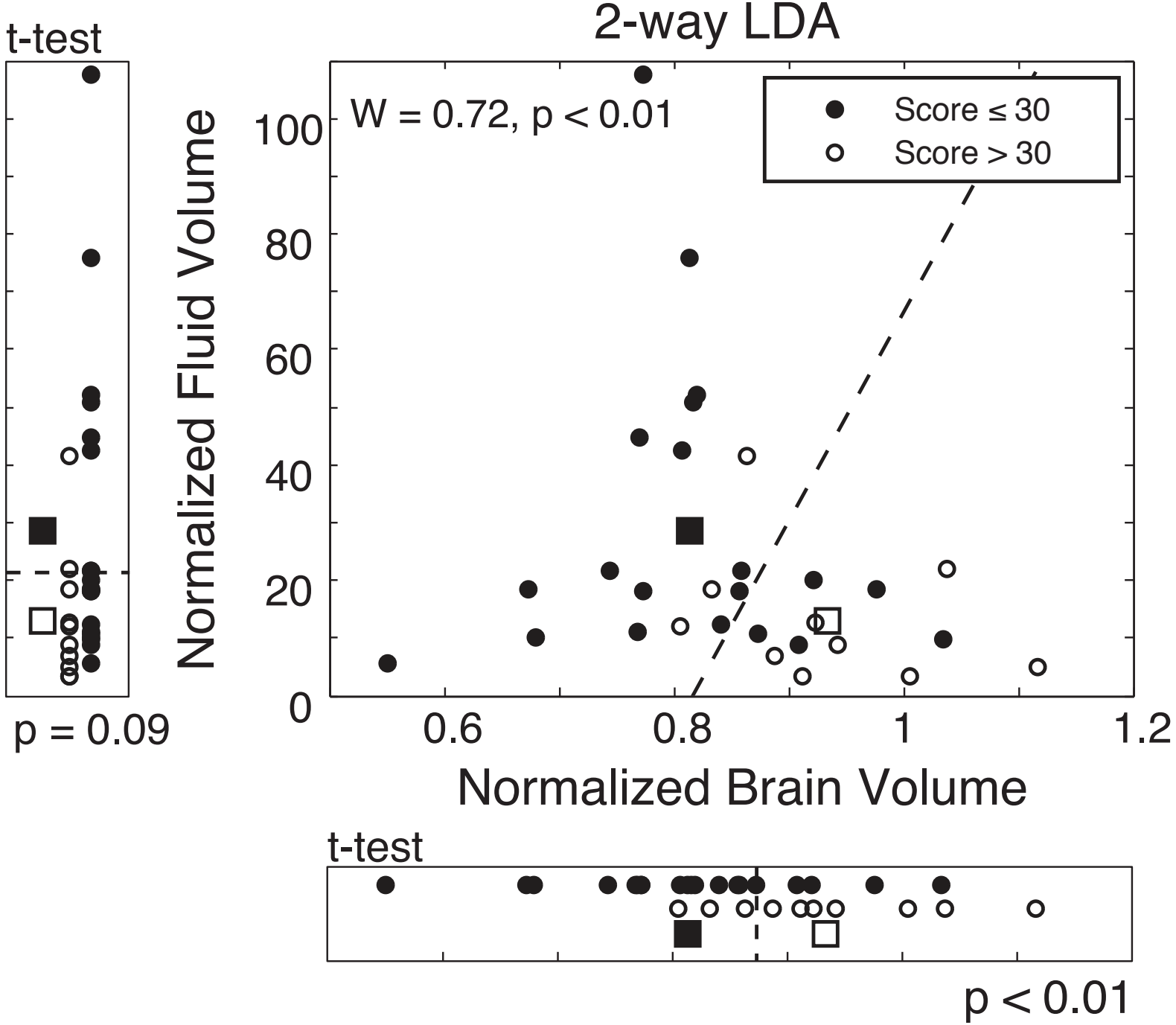


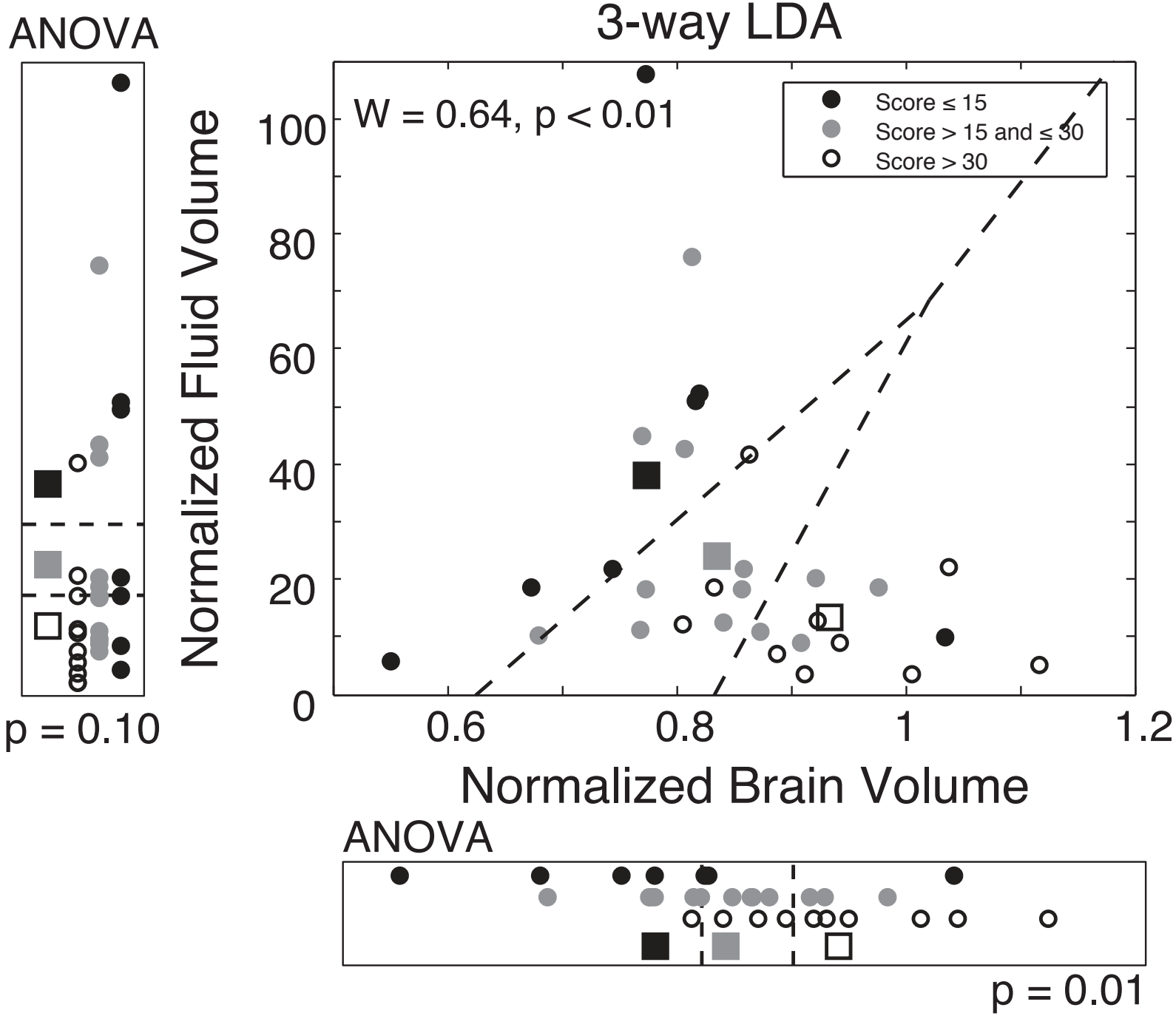


Fluid volume does not correlate with brain volume

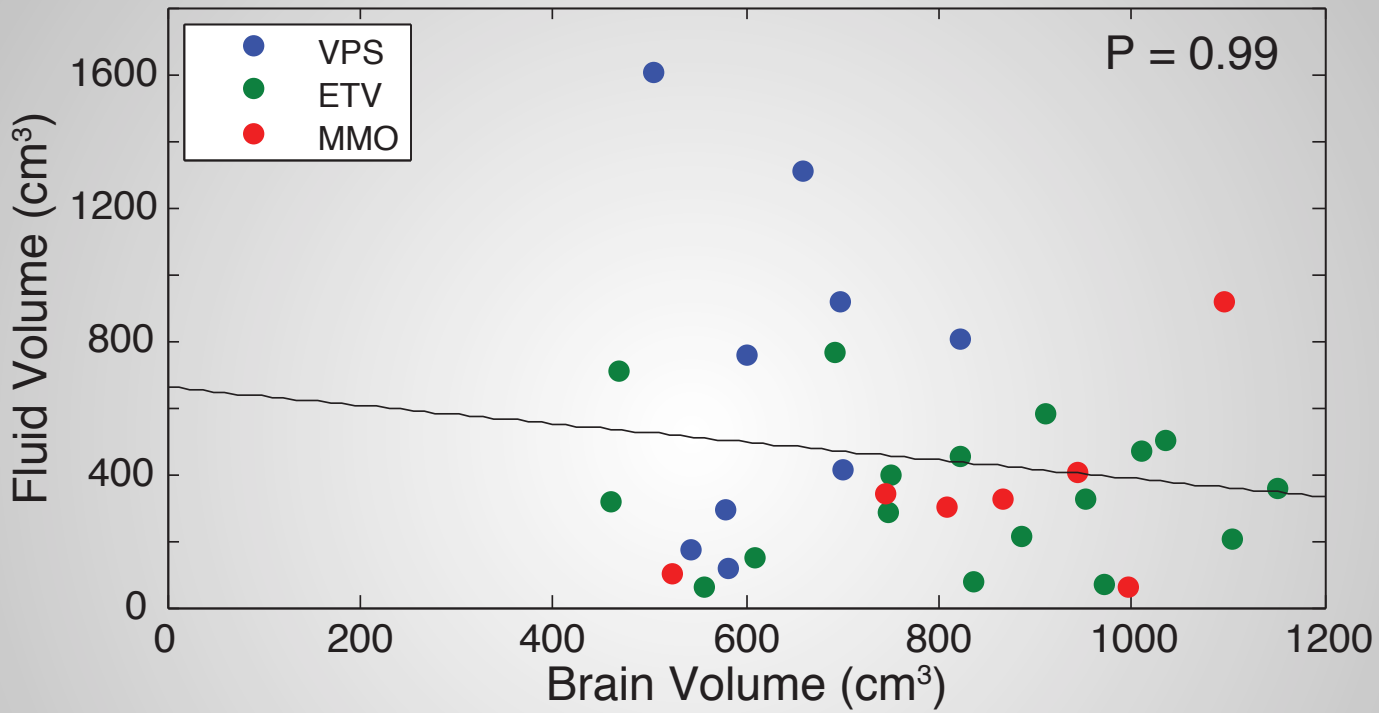
Normalized brain and fluid correlate, but does not fit linear curve well

	Normalized Brain Volume		Normalized CSF Volume	
	R	p	R	p
Fine Motor	0.40	0.03	-0.45	0.01
Gross Motor	0.14	0.45	-0.12	0.53
Expressive Communication	0.33	0.08	-0.32	0.08
Receptive Communication	0.06	0.77	-0.25	0.18
Cognitive	0.36	0.05	-0.31	0.09
Social-Emotional	0.25	0.20	0.14	0.50


t-test
2-way LDA
W = 0.72, p < 0.01
Score ≤ 30
Score > 30
Normalized Fluid Volume
100
80
60
40
20
0
0.6
0.8
1
1.2
Normalized Brain Volume
p = 0.09
t-test
p < 0.01

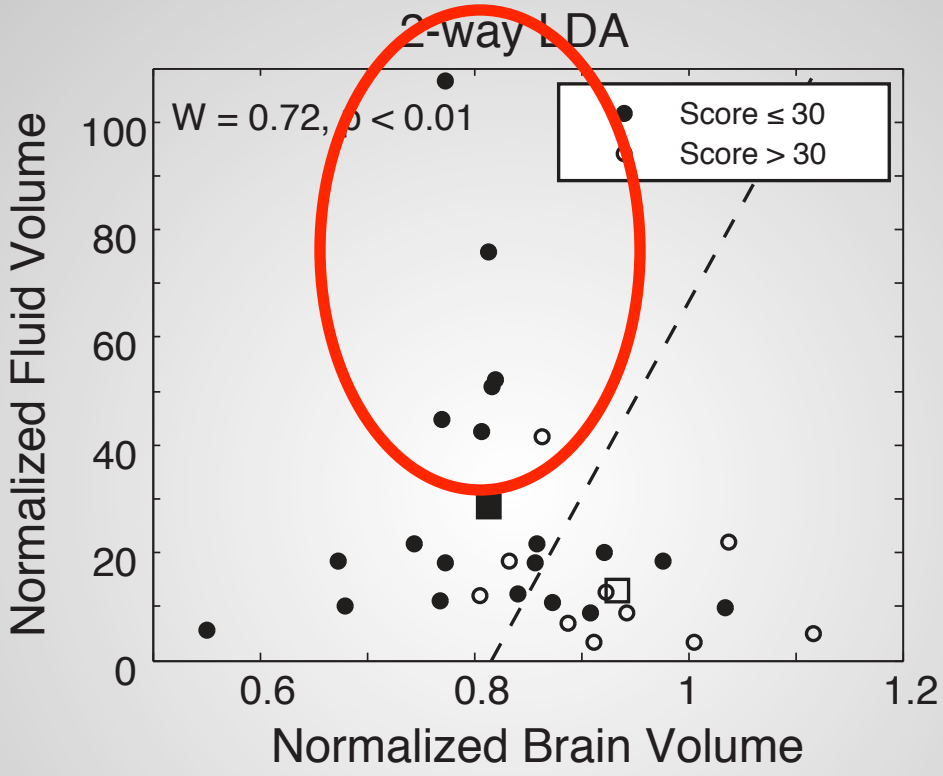

ANOVA
3-way LDA
W = 0.64, p < 0.01
Score ≤ 15
Score > 15 and ≤ 30
Score > 30
Normalized Fluid Volume
100
80
60
40
20
0
0.6
0.8
1
1.2
Normalized Brain Volume
p = 0.10
ANOVA
p = 0.01

Conclusions



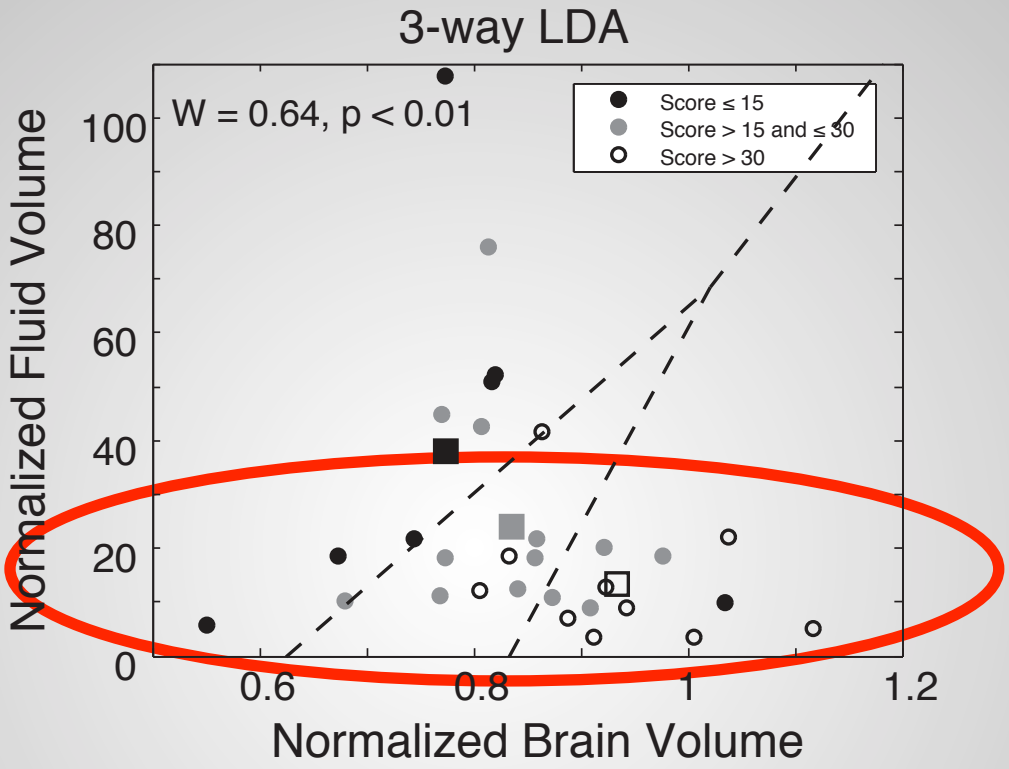
1) Brain and fluid develop independently

Conclusions



2) Very large CSF volumes (40-100x normal) lead to poor cognitive outcomes

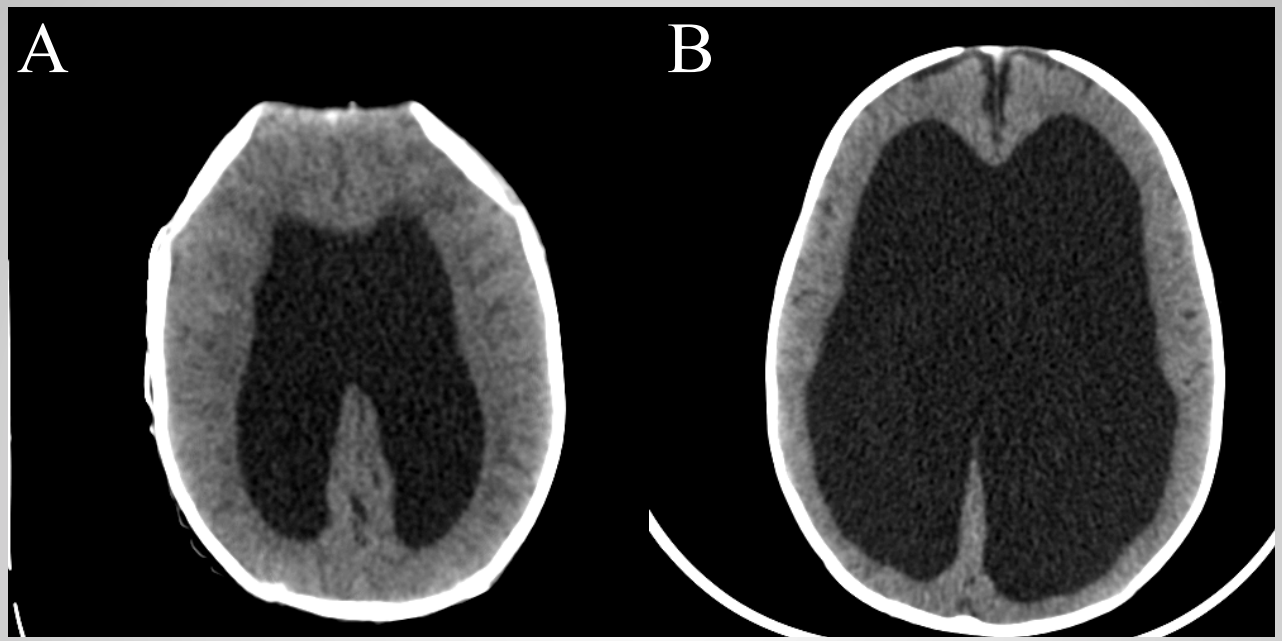
Conclusions



3) At lower CSF volumes, normal ventricle size does not equal normal brain development

4) At these levels, normal brain volume is more important than normal fluid volume

Conclusions



5) We treat hydrocephalus based on fluid

<u>Growth of brain determines cognitive development</u>

Future Directions

- Particle Filter segmention
  - Move towards more automated segmentation
  - 3D modelling
- Hydrocephalus
  - NIH surgical trial in Africa of VP shunt treatment versus ETV/CPC applying these volumetric methods based on intention to treat and neurocognitive outcome

Co-Authors

Particle Filter Segmentation

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Hydrocephalus & Cognitive Outcome

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Thank you