Data and experiments

- 22 Fetal MRI cases

  – 1.5-T TwinSpeed Signa system (GE Healthcare) with an 8-channel phased-array cardiac coil.

  – without maternal sedation or breath-hold.

  – Multiple SSFSE MRI with in-plane resolution of 0.7 to 0.8 mm and slice thickness of 3 or 4 mm.

  – The gestational age (GA) range of 19.28 to 38.43 weeks (mean 27.892, stdev 6.876).
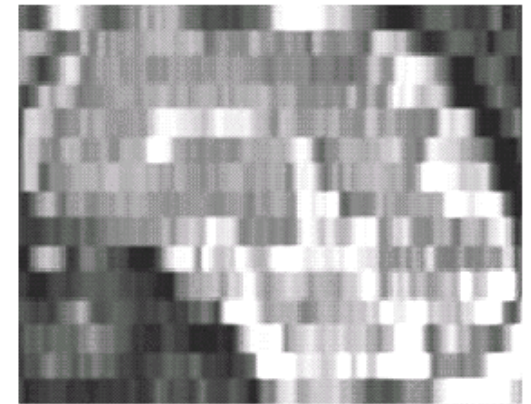
Results – 19 week fetus
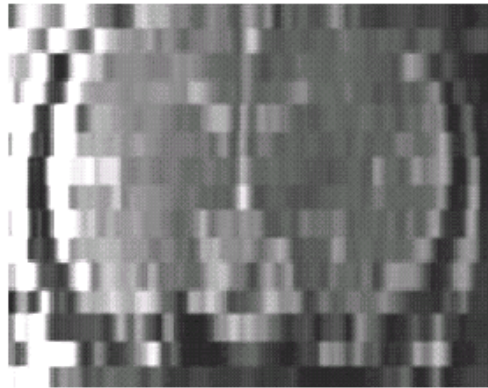
Axial SSFSE 4 mm slices

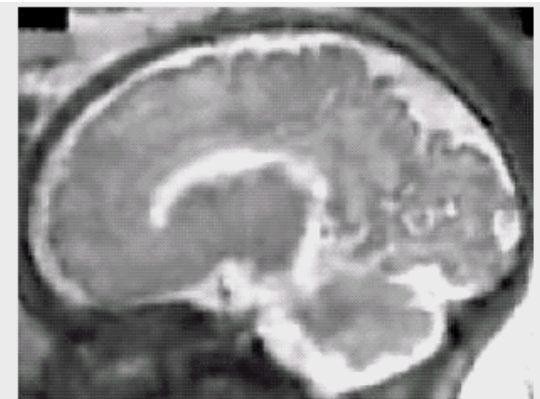3D recon. Volume 0.8 mm
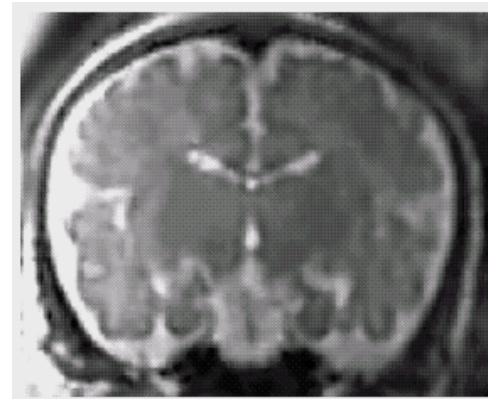

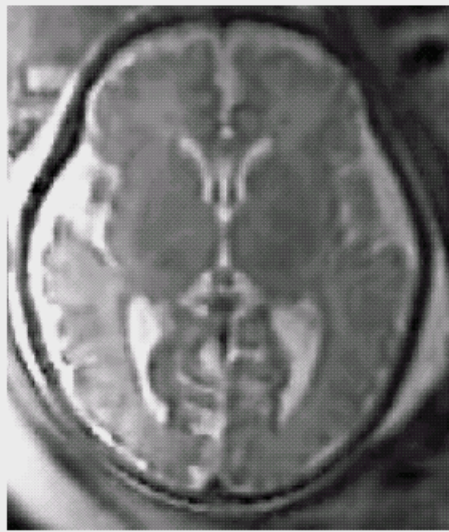axial plane   coronal plane   sagittal plane

Results – 36 week fetus

Axial SSFSE 6 mm slices

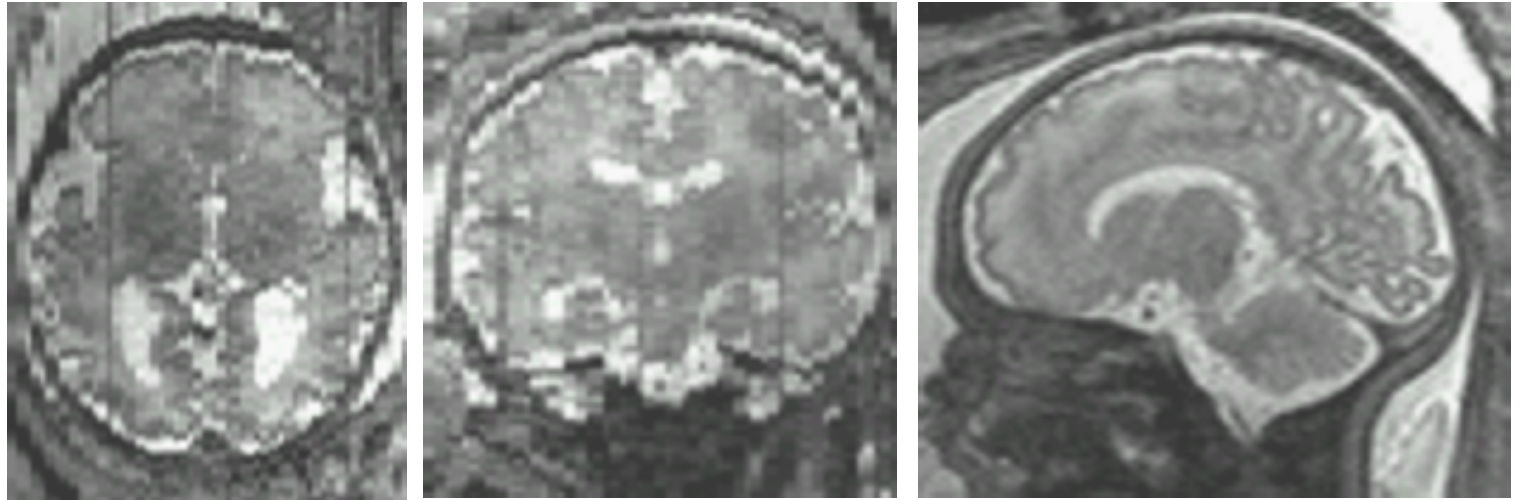3D recon. Volume 0.8 mm

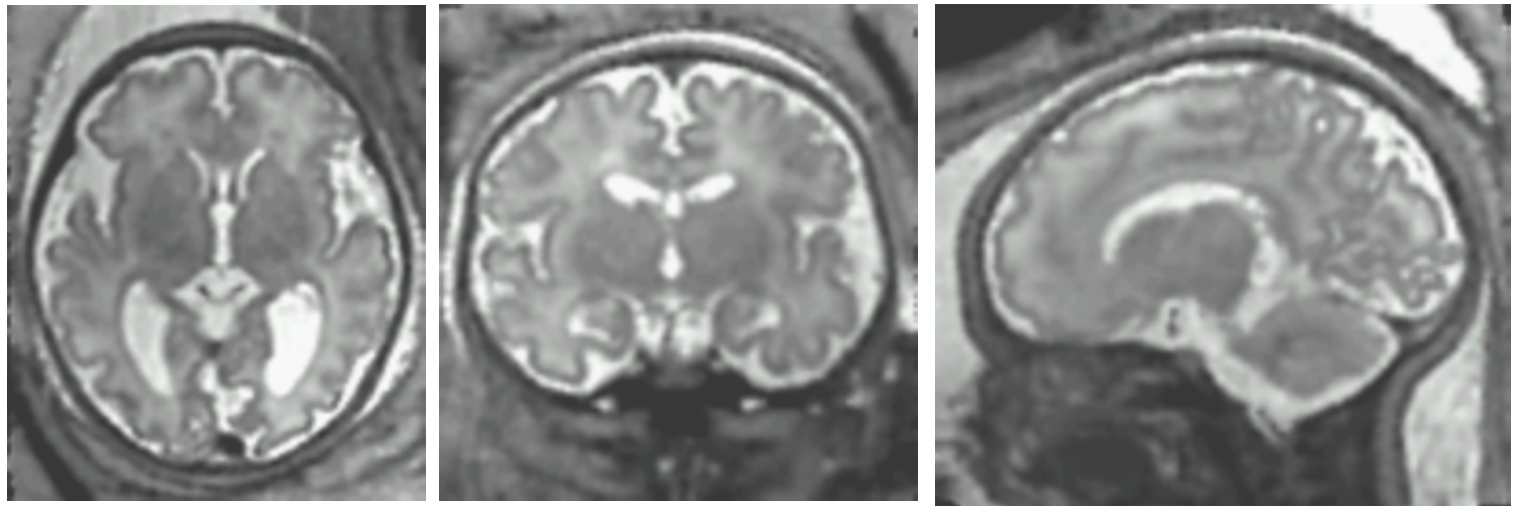axial plane   coronal plane   sagittal plane
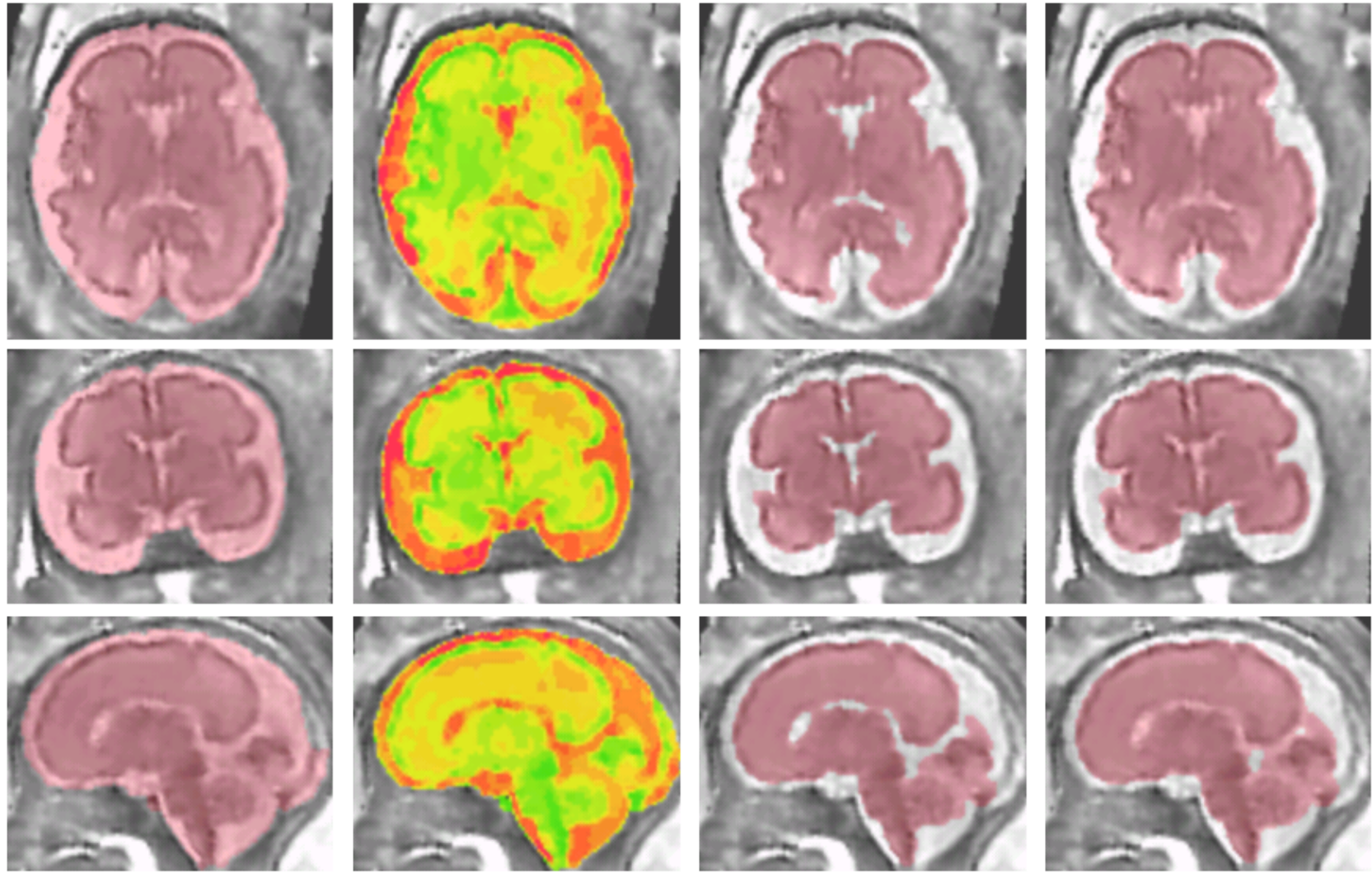
Results – 2mm slice acquisitions

SagittalS
SFSE
2 mm
slices

3D
recon.
Volume
0.8 mm

Supervised automated segmentation

intracranial volume   tissue types   parenchyma   brain volume

Fetal brain MRI segmentation

- Evaluation of brain segmentation
  - Comparison to manual segmentation for 5 randomly chosen cases
  - Dice overlap measure, and
  - specificity and sensitivity measures

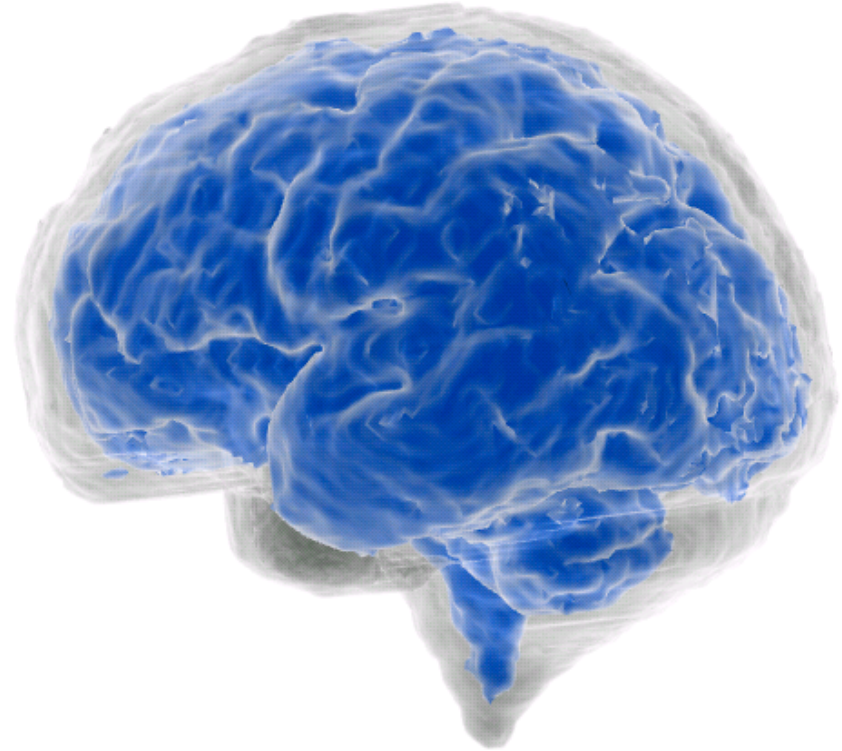|	C3	C6	C11	C13	C16
Dice index	0.9330	0.9206	0.9480	0.9575	0.9700
Specificity	0.9977	0.9948	0.9984	0.9953	0.9978
Sensitivity	0.9498	0.9444	0.9205	0.9594	0.9943

Intracranial and brain volumetry
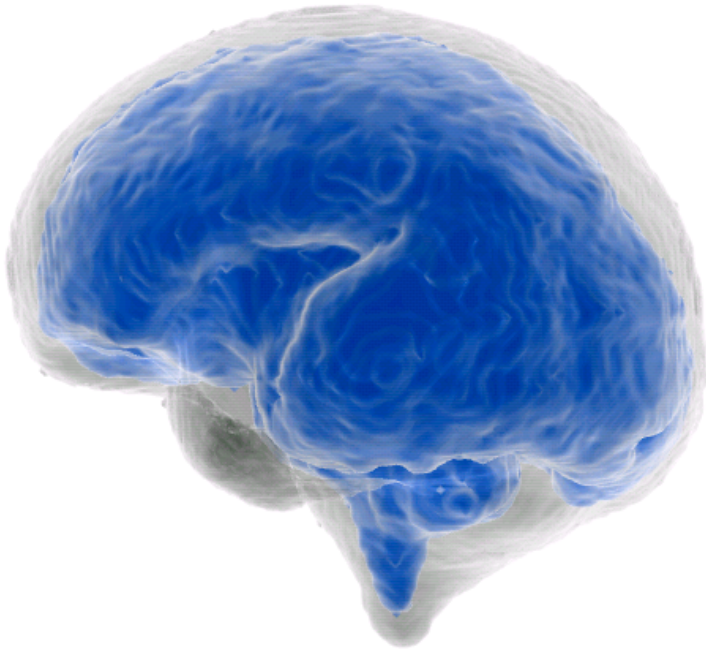
27.86 week fetus

Intracranial volume 210.13 mL

Brain volume 160.13 mL

31.43 week fetus

Intracranial volume 308.57 mL

Brain volume 202.52mL

Automated brain volumetry

- Comparison of Brain Volumes (BV) (in milliliters) using our volume reconstruction and supervised automated segmentation algorithm vs. using manual segmentation on high-resolution volumetric images.

	C3	C6	C11	C13	C16
BV (estimated)	79.01	39.14	416.96	137.96	325.50
BV (manual)	77.17	38.45	416.00	133.49	313.17
BV (% error)	2.33 %	1.76 %	0.23 %	3.25 %	3.79 %

Brain volumetry Analysis

- Brain volume vs. gestational age (22 fetuses)
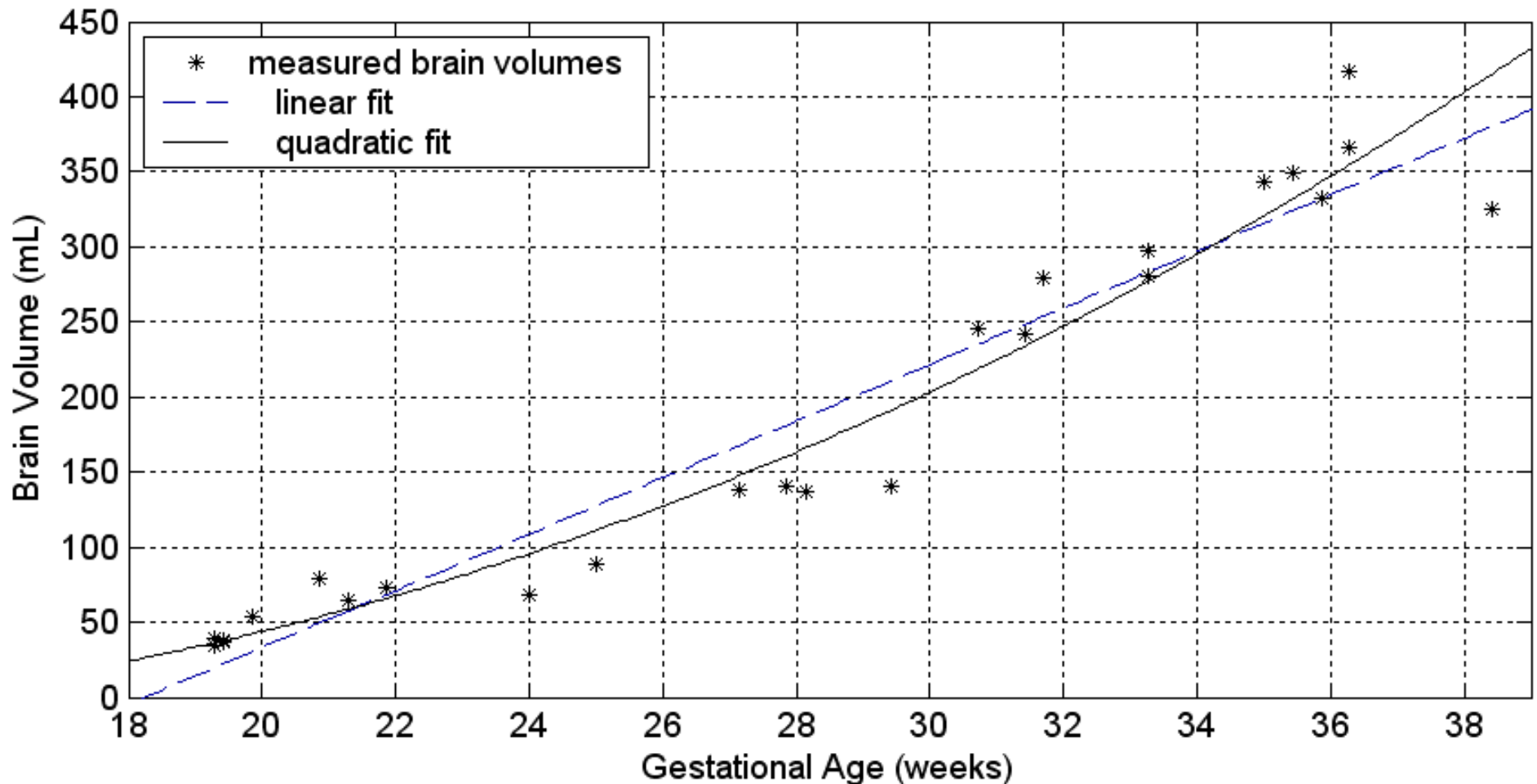
Brain volumetry analysis

- The coefficient of determination (r^2) goodness-of-fit measures for linear, quadratic, and exponential model fittings to the volumetry data
    - suggests that a quadratic model best describes the BV, ICV, and PV changes vs. GA.

|	r^2 (ICV)	r^2 (BV)	r^2 (PV)
Linear fit	0.912	0.925	0.937
Quadratic fit	0.916	0.940	0.949
Exponential fit	0.810	0.850	0.829

3D segmentation and visualization
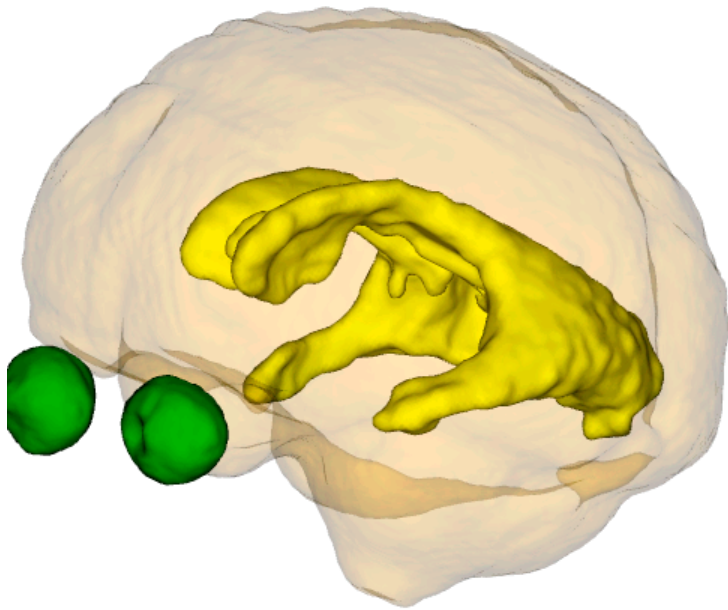
31.71 week normal fetus
Normal shape and morphology of the ventricles is appropriately visualized in 3D
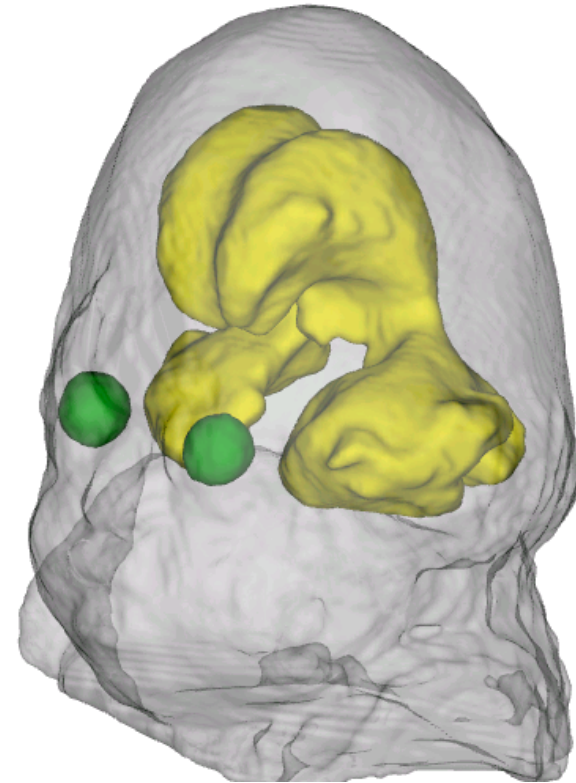
37.14 week fetus with Craniosynostosis
Abnormal head shape and the enlarged and abnormal morphology of ventricles in 3D

3D segmentation and visualization

- Surface model rendering of
  a fetus (33.28 week)
  - Body
  - Face
  - Cerebrospinal fluid
  - Orbits
  - Airways
  - Lungs
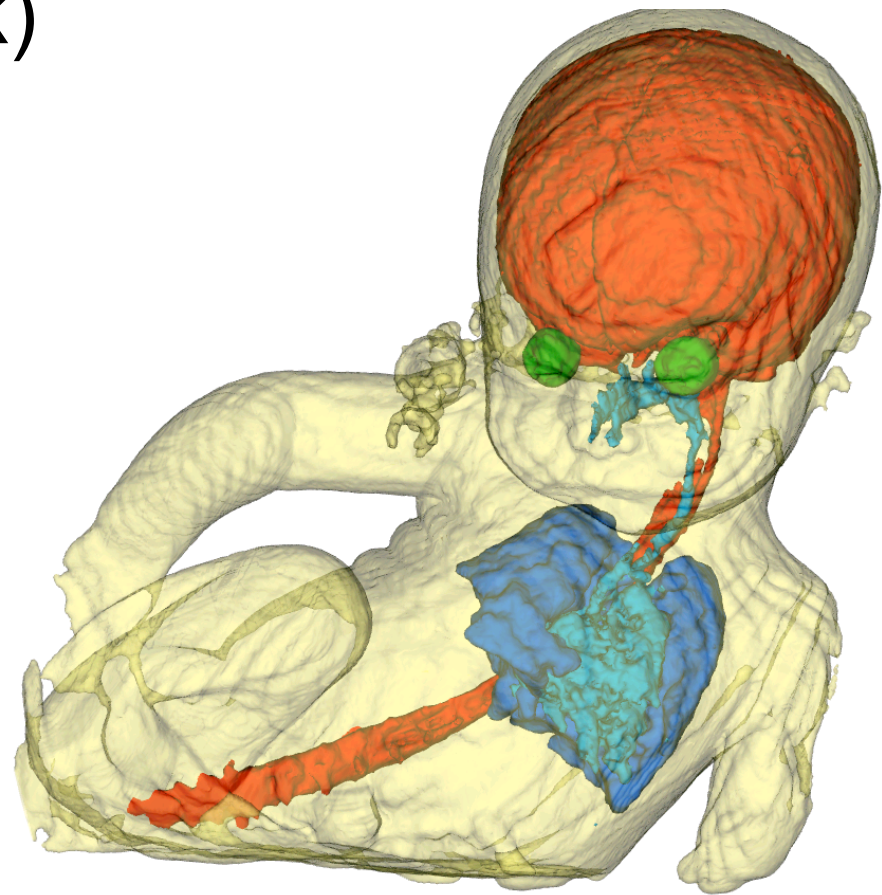
Conclusion

- We demonstrated an image processing pipeline that resolves the limitations of current fetal brain volumetry techniques by avoiding:
  - dependence on motion-free scans
  - tedious manual segmentation, and
  - thick slice interpolation.
- The algorithm utilizes motion correction, volumetric reconstruction, and segmentation techniques.
- The reconstructed volumetric images reflect anatomic details and coherent structural boundaries in 3D, which are not apparent in the original SSFSE scans.

References

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- Rousseau et al., Acad Radiol. 2006; 13(9):1072-81

- Kim et al., IEEE Trans Med Imag. 2010

- Gholipour et al., MICCAI 2009

- Gholipour et al., IEEE Trans Med Imag 2010

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Image Segmentation for Pediatric Brain MRI

Simon K. Warfield, Ph.D.

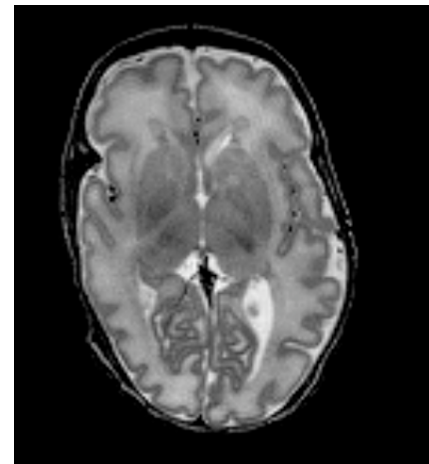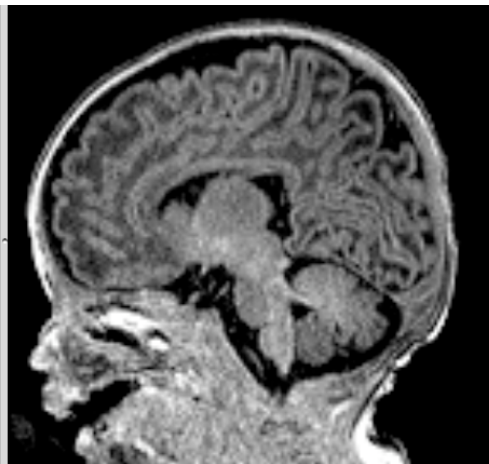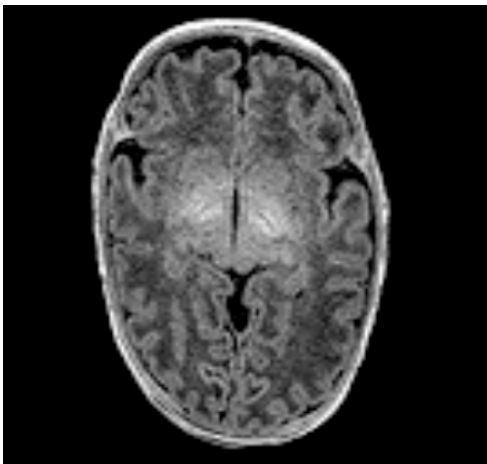Associate Professor of Radiology

Harvard Medical School

MRI of Newborn Infants


Feed and wrap infant

3T MRI of infant

Motivation

- Increasing prevalence of surviving very low birth weight premature infants
- Very low birth weight infants have high rates of adverse neurodevelopmental outcomes:
  - 10-15% develop cerebral palsy
  - 50% develop significant neurobehavioral problems including
    - Lowered IQ
    - ADHD
    - Anxiety disorders
    - Learning difficulties
- Considerable educational burden with significant economic and social implications.
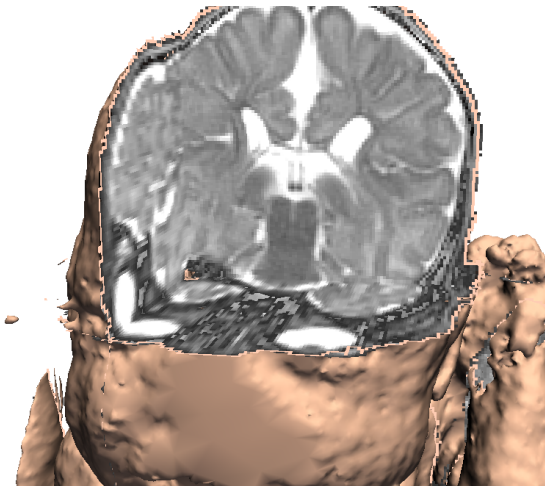
Newborn Brain: Structural MRI
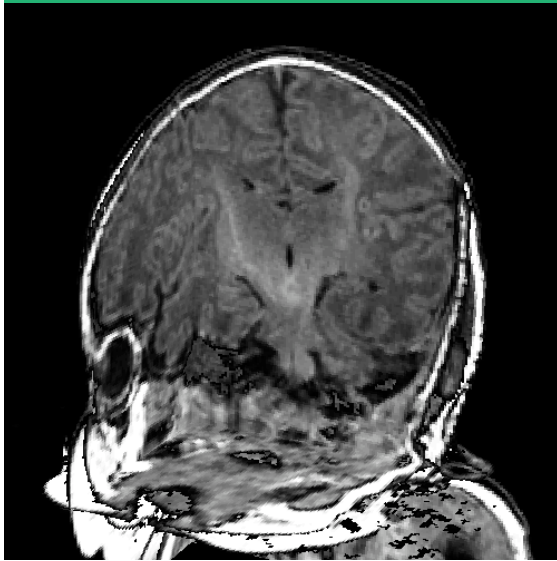
Healthy fullterm infant.
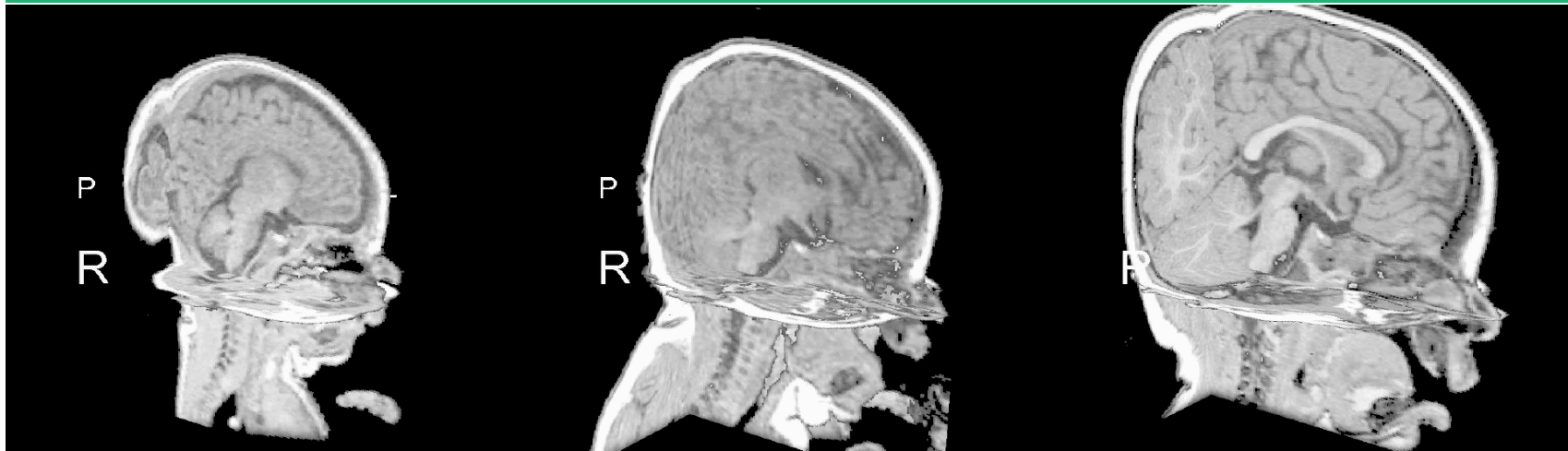
SPGR (T1w) of infant with PVL.

CSE (T2w) of infant with PVL.
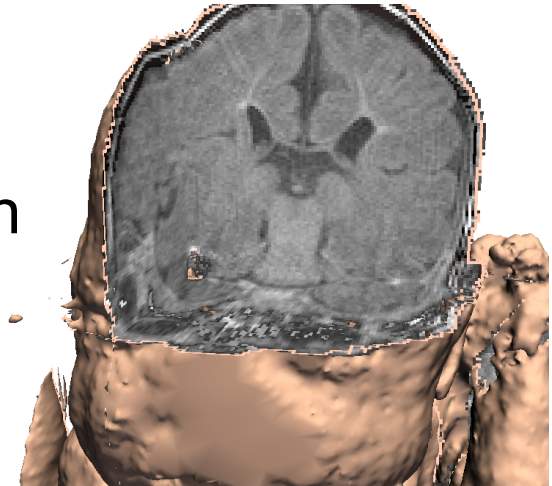
Fullterm infant with delayed development.

Skin shown in pink.

Studying Brain Development

10 weeks premature   Term equivalent age   9 months

A sequence of MRI of the same infant: shortly after premature birth, at term equivalent age, and at nine months. The sequence of growth of the brain and development of myelination in the white matter can be best followed by quantitative 3D assessment.