Cortical Surface-based Mapping of Maturation-related MR Tissue Intensity Changes in Preterm Neonates

Sinchai Tsao[1], A. Kitsch[1], M. Liu[1], S. Seshamani[1], S. Miller[2,3], V. Chau[2,3], K. Poskitt[3] and C. Studholme[1]

[1] Biomedical Image Computing Group, Departments of Pediatrics, Bioengineering and Radiology, University of Washington, Seattle, WA, USA

[2] Division of Neurology and the Center for Brain & Behaviour, The Hospital of Sick Children, Toronto, ON M5G 1X8, Canada

[3]The Children & Family Research Institute, 950 West 28th Avenue, Vancouver, BC V5Z 4H4, Canada

Biomedical Image Computing Group

Depts.washington.edu/bicg

INTRODUCTION

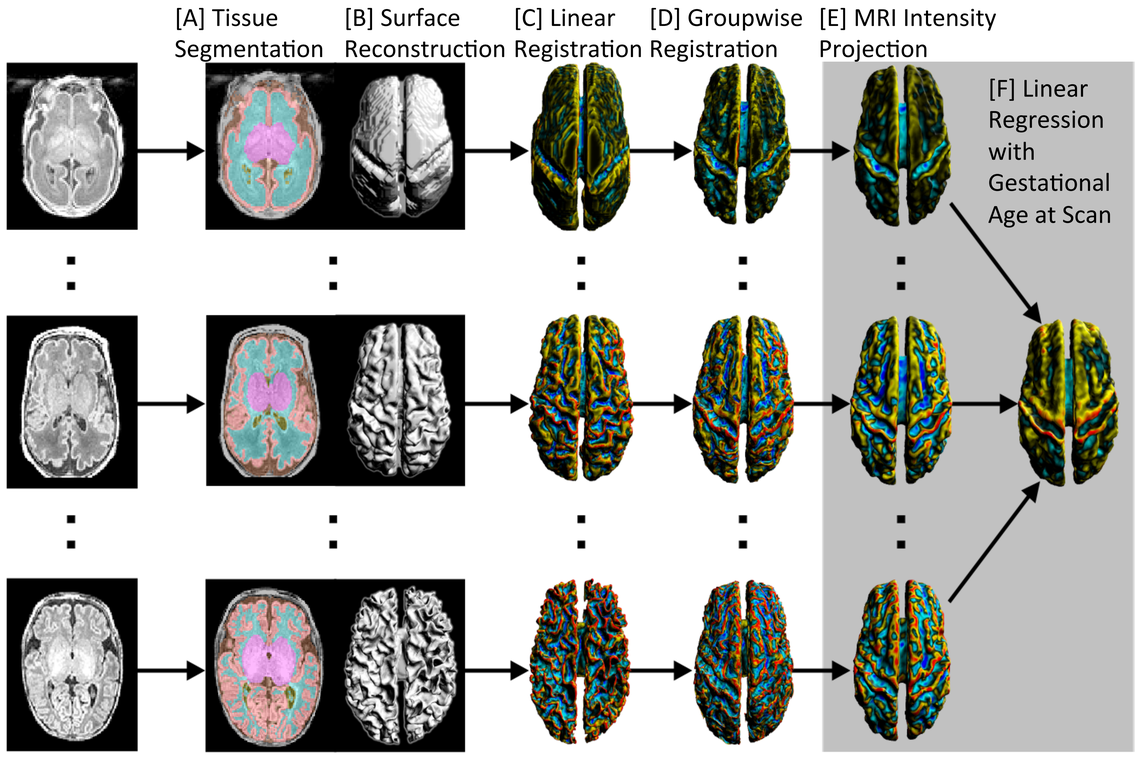
- First attempt at mapping Contrast Changes in the Cerebral Cortex during early development.
- MRI contrast changes on the cerebral cortex and have been shown to correlate with age in both postnatal development [1] and aging [2]
- These contrast changes have been shown to be independent of cortical thickness and may index other neurobiological processes such as myelination [2,3].
- Contrast changes have been shown to appear just prior to related developmental behavioral changes [1]

METHODS

Surface Reconstruction

A. Scans were manually segmented into:
   - Tissues: cortical Grey Matter (GM), White Matter (WM), Deep Gray Matter (DGM), ventricular CSF, subarachnoid CSF
   - 8 lobe regions: hemispheric left and right frontal, temporal, parietal, and occipital lobes.
- The WM label was corrected for holes and topology inconsistencies through region growing and intersection detection algorithms

B. A topology-preserving level set method and marching cubes algorithm was used to generate WM surfaces [5]



Group Analysis

- All 30 manual segmentations were collectively aligned using a symmetric groupwise registration to form a minimum deformation shape average.

C. The surface meshes were linearly transformed to the group space, where local surface folding was determined by vertex-wise mean curvature measurements [4]

D. The groupwise volume transformations were used to bring each of the surfaces into common 3D alignment in the average anatomy.

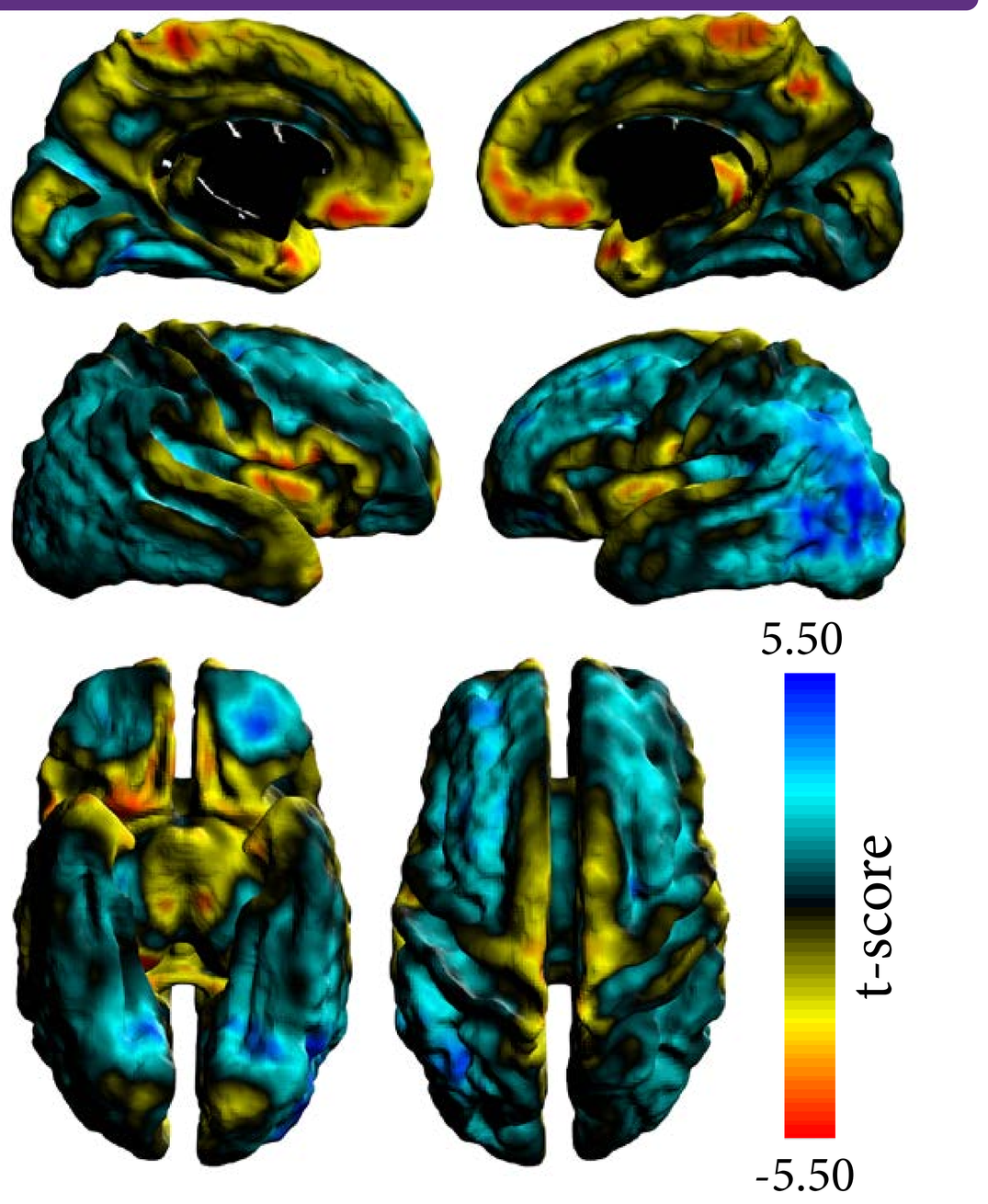
E. Local measurements of MRI Intensities sampled from voxels between the WM and GM were mapped to a population average group surface by a normal projection

- Vertex-wise statistical regression was performed to correlate with gestation age at scan. To account for multiple comparisons, nonparametric p-values were generated via permutation testing.

MATERIALS

- 30 T1-weighted brain MR scans of premature neonates were acquired using a Siemens 1.5T scanner using an MPRAGE sequence
- Imaging parameters: TR = 36 ms, TE = 9.2 ms, a voxel resolution of 1.04 × 1.04 × 1 mm.
- Gestational Age (GA) at scan range:
  - 27.29 to 46.43 GW (mean: 34.63 GW; std: 5.55 GW)
- Subjects have normal behavioral outcomes as indicated by Bayley Score at 18 months.

RESULTS



p-value	t-score	# Voxels
p<0.05	t > 4.71	446
	t < -4.81	301
p<0.01	t > 5.60	17
	t < -5.67	23

- Our results are consistent with prior reports of myelination changes in the cerebral cortex as well as left-right asymmetry in the visual cortex during development.
- Our significant regions mirror those regions of the brain with the highest myelin content [6]
- These areas have accelerated MR tissue contrast changes that mirror the rapid myelination required to reach the end load.
- Significant ROI in the left parietal-temporal-occipital (PTO) association area suggest rapid development of language abilities during the third trimester.

CONCLUSION

- This is a first attempt at surface-based mapping of cortical WM and GM MR intensity changes in the developing brain.
- Regression highlight areas with the strongest correlation with gestation age and mirror prior reports of areas with high myelin content.
- left PTO association area significant ROI also suggests that MR intensity changes may index neurobiological processes that predate behavior development.
- Future work:
  - Relationship with cortical thickness-based measures
  - 300+ neonates in our database

REFERENCES & ACKNOWLEDGEMENTS

[1] K. E. Travis (2013), 'Age-related changes in tissue signal properties within cortical areas important for word understanding in 12-to 19-month-old infants', Cerebral Cortex, vol. 24, no. 7, pp. 1948-1955

[2] L. T. Westlye (2010), 'Differentiating maturational and aging-related changes of the cerebral cortex by use of thickness and signal intensity', Neuroimage, vol. 52, no. 1, pp. 172-185

[3] D. H. Salat (2009), 'Age-associated alterations in cortical gray and white matter signal intensity and gray to white matter contrast', Neuroimage, vol. 28, no. 1, pp. 21-28

[4] P. A. Habas (2012), 'Early folding patterns and asymmetries of the normal human brain detected from in utero MRI', Cereb. Cortex, vol. 22, no. 1, pp. 13-25

[5] X. Han (2003), 'A topology preserving level set method for geometric deformable models', IEEE PAMI, vol.25, no.6, pp.755,768.

[6] Glasser M. F. (2014), 'Trends and properties of human cerebral cortex: correlations with cortical myelin content', Neuroimage, vol. 93, no. 1, pp. 165-175

This work is supported by NIH grant NIH/NINDS R01 NS 061957 (PI: C. Studholme) and Canadian Institutes for Health Research (CIHR) operating grant MOP-79262 (SPM).