Mapping cortical development from morphology to microstructure

Mapping Cortical Development from Morphology to Microstructure: A Longitudinal Study in Preterms

Presented During: Poster Session
Wednesday, June 29, 2016: 12:45 PM - 02:45 PM

Stand-By Time

Wednesday, June 29, 2016: 12:45 PM - 2:45 PM

Poster Number:

4226

Submission Type:

Abstract Submission

On Display:

Wednesday, June 29 & Thursday, June 30

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E-Poster

Introduction:

The folding of human brain cortex is a complex process that mostly takes place during the second half of pregnancy. While the underlying mechanisms are still debated, the folds appearance seems to follow a stable spatio-temporal sequence with primary folds from 20 weeks of gestational age (w GA), secondary folds from 32w GA, and tertiary folds around term age. In the recent years, mapping the folding process in vivo has become possible with MRI combined with post-processing tools to extract cortical surfaces in preterm newborns [1]. By quantifying the spatial frequency structure of folding, an original method of spectral analysis of gyrification (SPANGY) [2] has further provided proxies for the developmentally-defined folds, as suggested in infants from 27w to 62w GA [3]: the spectrally-defined sulci elements corresponding to B4 band might be assimilated to primary folds, while the sharp increases in B5 and B6 bands along development might be related to secondary and tertiary folding respectively. Besides, major changes of cortical microstructure have been demonstrated in the preterm brain with diffusion tensor imaging (DTI) [4,5]. In this study, we aimed to investigate whether cortical regions at different stages of folding also show different stages of microstructural maturation.

Methods:

From a large cohort of infants born extremely preterm [5,6], we studied 13 newborns without neurological complications (5 girls, 5 twins, GA at birth: [25.3w; 27.9w]). Brain development was assessed longitudinally using 3T-MRI (Philips Medical Systems), at around 30w GA [29.3w; 31.7w] and term equivalent age [40w; 41.9w]. T2-weighted anatomical images were acquired (Fig1a) [6], as well as diffusion tensor images (DTI b=800s/mm2, 32 directions of diffusion gradients) [5].
In post-processing, brain tissues were segmented automatically for each newborn [6]. 3D reconstructions of inner cortical surfaces were obtained using morphological tools implemented in BrainVISA software [7], with manual corrections where necessary. Morphometric parameters (brain size, cortical surface, sulcation index) were measured. Then SPANGY analysis of cortical mean curvature was realized for each hemisphere to compute the band spectral powers and associated numbers of parcels [2].
Diffusion images were processed with Connectomist software [8], and corrected for motion artefacts [9] and geometric distortions based on elastic deformations [10]. DTI fractional anisotropy (FA) and longitudinal diffusivity (λ//) were quantified within the cortical thickness and averaged over B4-6 parcels.

Results:

While the cortical folding was much more complex at term equivalent age, the patterns of primary folds for each newborn were already present at around 30w GA (Fig1b). SPANGY analyses further revealed a relative stability in the labelling and localization of B4 parcels across the two time points (Fig1c), and their number did not change along development, contrarily to all other morphometric and SPANGY parameters (Fig2). Furthermore, each parameter at 40w GA (except the numbers of parcels) strongly depended on its value at 30w GA, independently from the increase in GA. Regarding the cortical microstructure, decreases in FA and λ// were observed from 30w to 40w GA (Fig3a). Within sulci, B4 parcels showed significantly lower FA and λ// than other parcels at 30w GA (Fig3b), suggesting advanced maturation. Surprisingly, the reverse pattern was observed at 40w GA (Fig3c).

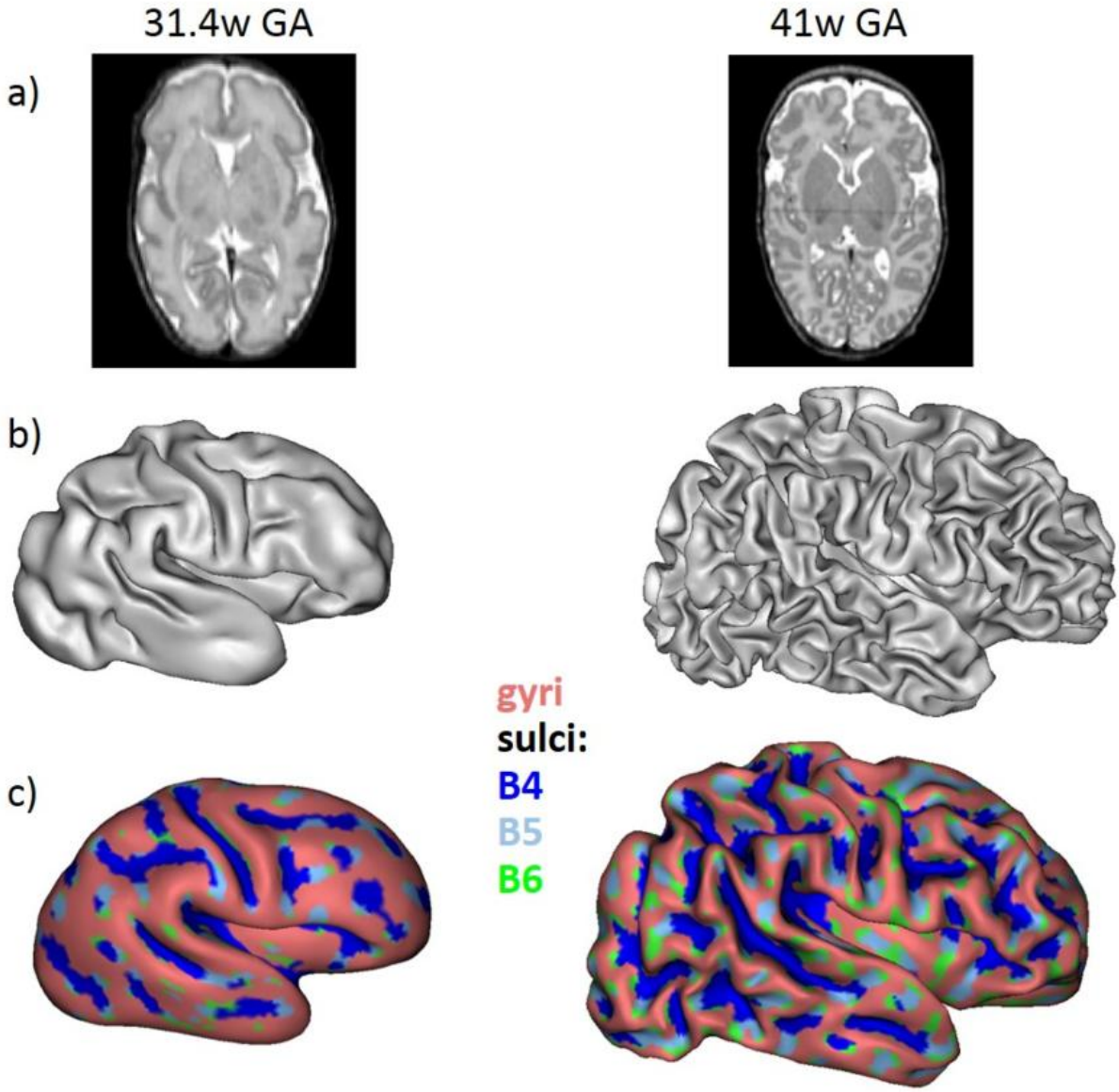

Figure 1: Examples for a single newborn (at around 30w / 40w GA: left / right rows) of T2w images (a), 3D meshes of inner cortical surfaces (b) and SPANGY segmentations projected on smoothed meshes (c).

·Figure 1

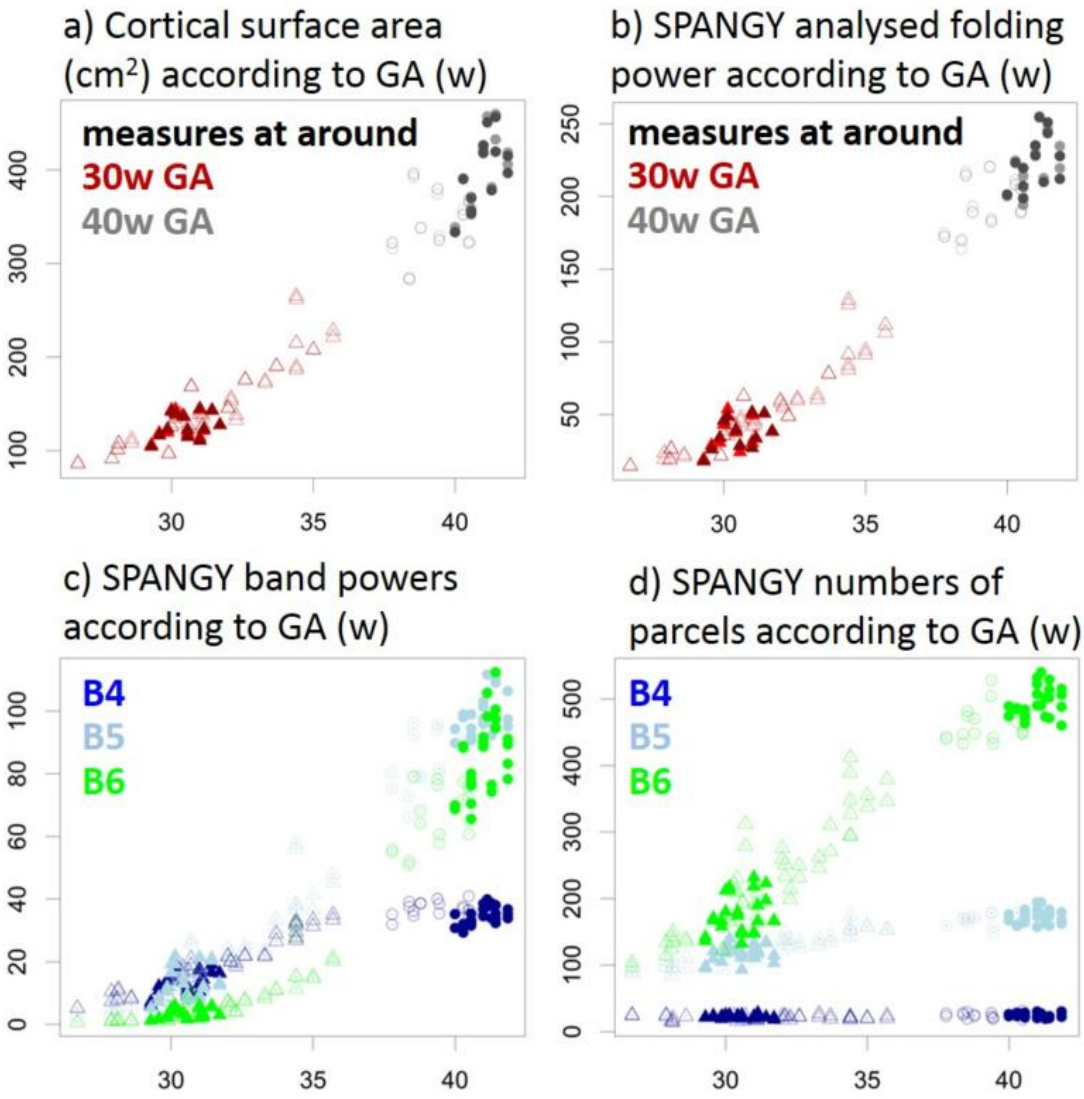

Figure 2: Age-related changes in total cortical surface (a) and folding power (b), in spectral powers (c) and numbers of parcels (d) associated with the 3 frequency bands B4-6.
For comparison, the study measures (filled symbols) were superposed to measures from [3] on other cohorts of newborns (empty symbols).

·Figure 2

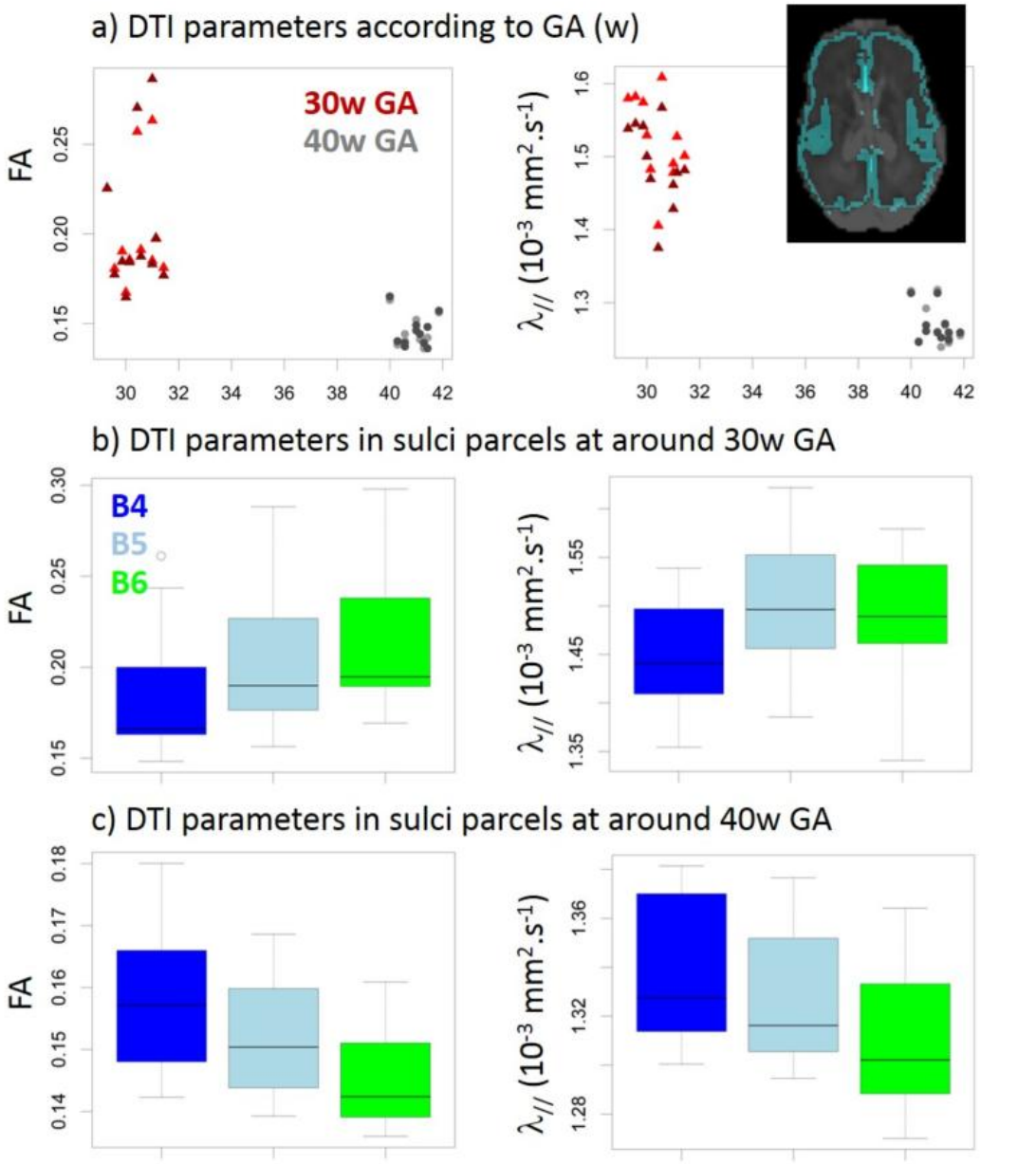

Figure 3: DTI quantification (FA / longitudinal diffusivity: left / right rows): age-related changes in the whole cortex (a), measures in sulci parcels associated with bands B4, B5 and B6 at 30w (b) and 40w GA (c).

·Figure 3

Conclusions:

These longitudinal results are in agreement with previous studies on other cohorts of babies, in terms of cortical folding [3] and microstructure [4,5]. First this paper confirms the analogy between B4 sulci parcels and primary folds developed before 30w GA. It further suggests different microstructural properties of cortical regions at different folding stages along development. Supplementary analyses will be performed on a larger cohort of preterms to validate these interesting results.

Lifespan Development:

Normal Brain Development: Fetus to Adolescence [2]

Neuroanatomy:

Cortical Anatomy and Brain Mapping
Normal Development [1]

Poster Session:

Poster Session - Wednesday

Keywords:

Cortex
Development
MRI
NORMAL HUMAN
PEDIATRIC
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[1|2]Indicates the priority used for review

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For human MRI, what field strength scanner do you use?

3.0T

Which processing packages did you use for your study?

Other, Please list - BrainVISA, Connectomist

Provide references in author date format

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