Quantitative assessments of growth trajectories of cortical thickness during the first 18 mons of life

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Purpose

Quantitative measures of cortical thicknesses (C_{TH}) have been implicated to be more reflective of the underlying neuronal and synaptic density than that obtained from volumetric measurements. Therefore, in the context of characterizing early brain development, measurements of temporal and spatial patterns of C_{TH} growth may provide more insights into brain functional development. However, the small brain size and temporal variation of gray/white contrast, particularly during the first year of life, have largely hampered our ability to obtain quantitative measures of C_{TH} in early brain development. Toward this end, our group has recently developed a novel approach capable of obtaining quantitative measures of C_{TH} in early infancy (1). Here, we report the normal temporal and spatial growth trajectories of C_{TH} during the first 18 mons of life. In particular, we aimed to determine how the growth trajectories of C_{TH} differ in five brain functional areas: primary motor, sensory, auditory, visual, and language cortices, respectively.

Methods

A total of 37 normal and healthy subjects were recruited to undergo a longitudinal MR imaging study where each subject was scanned every 3 mons starting from birth till yr 1 and again at 18 mons old. All images were acquired using a 3T Siemens scanner (TIM TRIO, Siemens) with a 32 channel head coil, allowing parallel imaging to shorten acquisition time. No sedation was employed and all subjects were imaged during natural sleep. MP-RAGE (3 min 25 sec, parallel factor = 2) and TSE T2 (3 min and 50 sec, parallel factor = 2) images were processed with a standard pipeline, including image resampling, bias correction, skull stripping, tissue segmentation, and surface reconstruction. One of the main features of our approach for obtaining quantitative measures of C_{TH} is to take advantage of the available longitudinal information from each subject (1). Therefore, the cortical surfaces of the mean image of the aligned longitudinal images of the same subject were reconstructed by a deformable surface approach. The cortical surfaces at the individual time points were then reconstructed by jointly deforming copies of the mean cortical surfaces to the respective images across time. C_{TH} then computed as the average of the closest distances between corresponding vertices on inner and outer cortical surfaces.

Results

14 (out of 37) subjects completed all 6 time points. Of which, one subject exhibited severe motion related artifacts. Therefore, results below were obtained from the 13 subjects who completed all 6 time points. Fig 1 shows the group C_{TH} during the first 18 mons of life and the insert provides lobar C_{TH} of the frontal, temporal, occipital and parietal lobes, respectively. Several important features emerge. a) The C_{TH} of the temporal and frontal lobes outgrow the parietal and occipital lobes and reach a mean of 4mm at 18 mons. b) The pre and post-central gyri exhibit a rather stable CTH (~2mm) throughout the first 18 mons of life. c) It appears that the temporal pole, orbital frontal, and the superior pre-frontal areas have the thickest C_{TH} at 18 mons. d) Finally, Sowell et al (2) reported the normative values of C_{TH} ranging from 1.5mm in the occipital regions to 5.5 mm in dorsomedial frontal cortex with a rate of 0.4-1.5mm/year during 5-11 yrs old. Comparing to our result, the C_{HT} growth rate is 0.5-1mm/yr in yr 1. In addition, our results show a C_{TH} of 3mm in the occipital lobe at 18 mons, suggesting that occipital C_{TH} may undergo thinning process with age. Fig. 2 shows the mean growth trajectories of the pre-defined five brain functional areas. The language and auditory areas exhibit the largest increase in C_{TH} during the first 6 mons of life. From 6 to 18 mons, a continuing albeit slower growth of C_{TH} in the language area is observed whereas C_{TH} remains stable in the auditory cortex. The C_{TH} of both motor and sensory areas is relatively stable birth – 3 mons, followed by a marked increase 3 – 9 mons with motor outpaces the sensory area, another stable period 9-12 mons and, finally, further increase 12 – 18 mons. Finally and interestingly, the visual cortex exhibits a relatively stable C_{TH} throughout the first 18 mons of life.

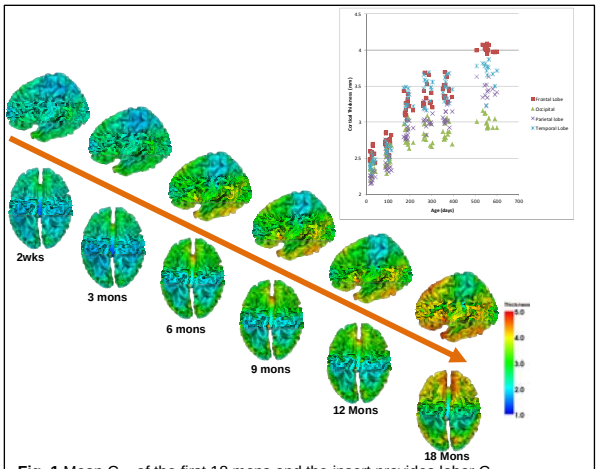
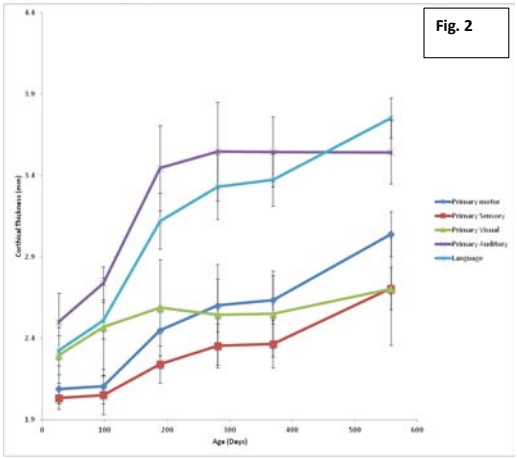


Fig. 1 Mean C_{TH} of the first 18 mons and the insert provides lobar C_{TH}.



Conclusions

Our results, for the first time, demonstrate the regional growth trajectories of C_{TH} in normal and healthy infants during the first 18 mons of life, a time period where critical brain development occurs. The rapid growth of C_{TH} in both auditory and language areas during the first 6 mons of life may suggest rapid development of these two functions postnatally while the slow increase of C_{TH} in motor, sensory and visual may suggest that these functional development may be largely done prenatally.

1. Wang L*, et al.* (2012) Longitudinally Guided Level Sets for Consistent Tissue Segmentation of Neonates. *Human Brain Mapping, in press*.
2. Sowell ER*, et al.* (2004) Longitudinal mapping of cortical thickness and brain growth in normal children. *J Neurosci* 24(38):8223-8231.