Impact of Altered Head Shape on Talairach Parcellations of Neonate Brain Images

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Background: Investigation of brain tissue volumes segmented from volumetric Magnetic Resonance Imaging (MRI) has advanced the understanding of brain injury in neonates. Assessment of specific brain regions is essential to understand the diverse patterns of brain injury. In the popular Talairach parcellation scheme, previously used in the case of neonates [1], planes are aligned with a set of deep brain structures to achieve partitioning of the brain. Non-synostotic dolichocephaly describes a bitemporal narrowing of the skull in preterm infants caused by immobilization and subsequent pressure on the immature skull. Preterm infants at term equivalent age exhibit a high rate of dolichocephaly [2]. The influence of dolichocephaly on the shape of the brain parenchyma and a possible subsequent shift of the brain tissue and brain structures has not yet been investigated. Such a shift might further compromise the validity of the Talairach parcellation scheme.

Methods: 24 preterm and 20 fullterm infants were scanned at 42 weeks post-menstrual age. The shape of the skull and parenchyma in preterm and fullterm infants was investigated by several descriptors of the size and shape. We measured, for example, the cerebral index, the ratio of the largest occipitofrontal to the largest bitemporal diameter and angles at the skull base and also computed shape differences by analyzing the transformation space of a population registration algorithm [3]. Segmentation of brain tissue volumes and a Talairach parcellation [4] were carried out using the anterior (AC) and posterior (PC) commissure and the corpus callosum (CC) as landmarks. Tissue volumes as well as the volumes and surfaces of resulting regions were compared between both groups. Selected sulci and gyri were manually segmented. Cramer's test [5] was used to determine if these sulci and gyri are consistently positioned with respect to the Talairach landmarks. To compare the position of the AC, PC and CC inside the skull, the distances between the structures, the angle describing the CC curvature, the distance to the skull base and to the calvarium, were evaluated.

Results: The fullterm infants were found to have mesocephalic head shapes (cerebral index: 78.4 ± 3.0 standard deviation (SD)), whereas the preterm group displayed dolichocephalic head shapes (cerebral index: 71.4 ± 2.9 SD; $p < 0.00001$). Registration matrices were significant different for scaling in the x direction ($p = 0.0115$) and shearing in xy ($p = 0.0139$), xz ($p = 0.0149$) and yz ($p = 0.044$; Image 1A and 1B). Brain tissue volumes were not significantly different between both groups (total brain parenchyma preterm: 434.1 mL ± 41.0 SD; fullterm: 429.4 mL ± 41.0 SD; $p = 0.6$). Volume and surface of the frontal region and the volume of the superior intra-cranial cavity resulting from the Talairach parcellation were significantly larger in preterm infants. The superior temporal gyrus (p: 0.008), the Sylvian Fissure (p: 0.012 and the precentral sulcus (p: 0.006) had shifted significantly across parcel borders compared to fullterm infants (Image 1C and 1D). The position of the Talairach landmarks was not different with regard to each other or the skull base, but the distance to the frontal, occipital and superior calvarium were increased in preterm infants.

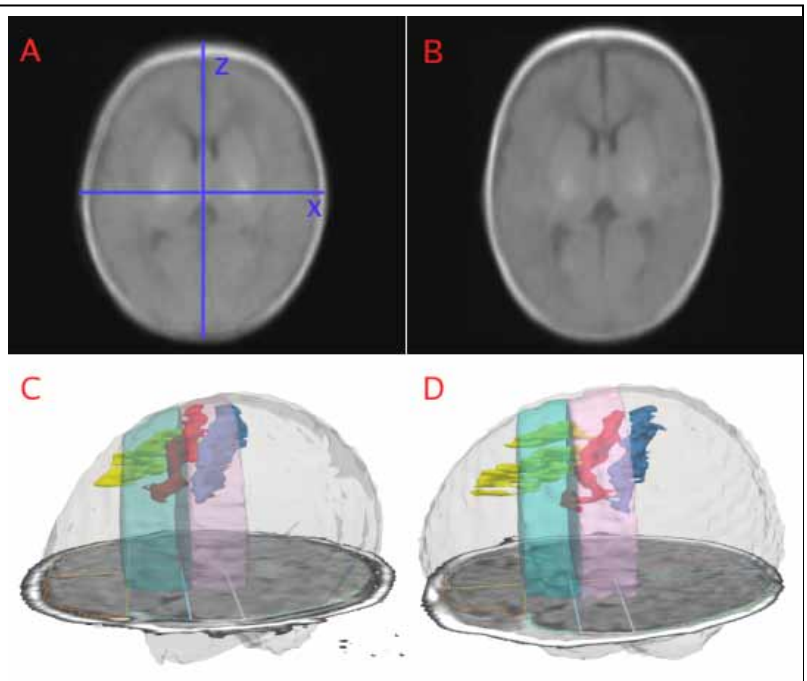

Image 1: Part A and B show the result of congealing fullterm (A) and preterm (B) infants scans. Note the smaller bitemporal diameter (x) and the larger occipitofrontal diameter (z) in the preterm infant. After population registration of all scans, resulting registration transformations were analyzed using a permutation test. Significant differences were found for the scaling and shearing ratios. Part C (fullterm infant) and D (preterm infant) show the segmentation of the superior frontal (yellow) precentral (red) and central (blue) sulcus located with regard to the precentral (opaque blue) and central region (opaque rose). Note how the precentral sulcus is shifted almost entirely into the central parcel in the preterm infant.

Discussion: We found a displacement of cortical structures in preterm infants with dolichocephalic head shape and no sign of brain injury compared to fullterm infants with normal head shape. Internal landmarks were consistently positioned and we concluded that external pressure on the skull influences superficial brain structures, but not internal structures anchored to the skull base. Since corresponding cortical brain structures were localized to different parcels and certain regions of a Talairach parcellation scheme were enlarged in the presence of these head shape differences, we concluded that the validity of the Talairach parcellation scheme is compromised when comparing groups with divergent head shapes. This important source of error should be considered when dealing with parcellation of infant MRI, especially since rates of skull deformations are increasing in infants due to the success of the "back to sleep" program [6].

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