Birth the hardest journey in life and a brain warping experience. A deformation field morphology study of fetal brain during labor

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Introduction: Neonates of Old World monkeys have the longest gestational development phase among comparably sized mammals, and as a consequence, the neonatal heads approach the size of the birthing canal. This can lead to cephalo-pelvic limitation, a situation in which the size of the birthing canal presents a physical limit on the size and shape of neonate during parturition. Here, we present the findings from a study that provided a rare opportunity to map deformations experienced by the neonatal brain during the contractions associated with normal labor.

Methods: Animal subjects. One pregnant dam (Papio hamadryas Anubis) in the 25th week of pregnancy of the 26 week term, went into labor while undergoing a fetal brain perfusion study. Animal handling and anesthesia are described elsewhere[1]. All experimentations were performed under IACUC-approved protocols.

Sequence details. Imaging was performed with a gradient echo EPI pulse sequence having high temporal (TR=3sec) and spatial (1.2 × 1.2 x × 1.9mm) resolution, acquiring 15 slices for full fetal brain coverage with no slice gaps. Respiratory gating was used to reduce diaphragm related motion artifacts. Six hundred full resolution fetal brain volumes were acquired over 30 minutes of labor.

Image analysis. We used a non-linear, regional spatial normalization algorithm, Octree Spatial Normalization[3] (OSN) to register the fetal brain images before contractions began to those during contractions, and to compute a one-to-one non-linear transformation to register homologous spatial features of the fetal brain before and after contractions. Next, we used a deformation field analysis[2] to map the degree of regional shape distortion[3]. This analysis produces a deformation field (DF), a 3-D array with 3-D displacement vectors encoding regional transformations These vectors provide a mapping from points in the source brain to corresponding points in the target's volume space, or vice versa.

Results. Preliminary results were obtained by analyzing the deformation that occurred between two consecutive frames in the middle of the labor (Figure 1). In the 3 seconds separating the frames, the fetal brain was subjected to large scale (3-7mm) regional distortions that produced compressions and expansions in the inferior temporal and occipital areas, and that shifted the midline by as much as 5 mm.

Discussion. We observed that this fetal brain had undergone large-scale deformation during labor. Deformation analysis reported shifts of up to 5-7 mm induced by contracting pelvic muscles, with substantial midline shifts of the occipital lobe (Figure 1) and compression of the posterior temporal wall. Upon discovery that the animal had gone into labor, the study was halted and an emergency c-section was performed. MR imaging of the fetal brain six hours later showed no observable damage. Deformations on the scale observed in this study would undoubtedly be lethal to a fully myelinated adult brain. However, as only the inner core of the fetal brain (brainstem and basal ganglia) is myelinated at term, these deformations produced no apparent damage. We are in the process of analyzing the pattern of regional deformations of the cortical and subcortical structures for all 600 data sets.

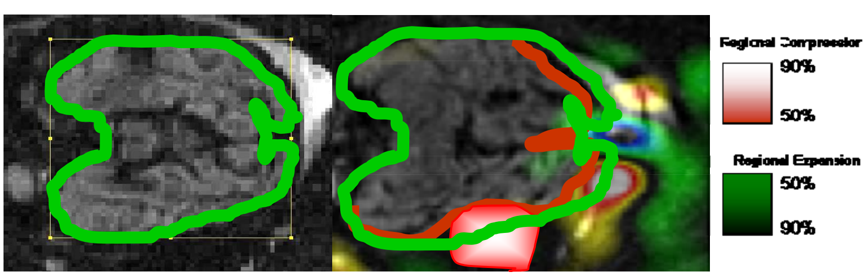

Figure 1. Regional deformation of the fetal brain during labor area shown on an axial slice at the level of the inferior temporal and occipital lobe. Large scale (3-7mm) regional compression and expansion producing midline shift were observed between normal (green line) and contracted (red line) states

Conclusion: This primate imaging study shows the dramatic scale of the regional deformation (compressions and expansions) that fetal brain undergoes during normal labor.

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