Segmentation of fetal pericerebral spaces based on reconstructed high-resolution MRI

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PURPOSE. MRI is an essential tool for studying *in-utero* the early human brain development. The recent development of new methods of image reconstruction allows the acquisition of motion-corrected 3D volumes of the fetal brain from 2D MR stacks. This provides access to a better understanding of normal brain development, maturation variability and limits of normality in the fetus. Pericerebral space (PCS) measurement, integrated in the fetal MRI radiological report, can be described either as increased, due to clastic lesions or normal variants explaining a benign macrocephaly, or as reduced, especially in obstructive pathologies. Therefore, the aim of our study is to determine the feasibility of segmentation for PCS analysis, which, to our knowledge, has never been reported and relies currently on subjective approach.

METHODS. Ten patients with a mean gestational age of 30 weeks (range 25-35w) were included in this study and underwent a fetal MRI. One of them underwent a second MRI for follow up. MRI indications were randomly selected. Five fetuses suffered from ventriculomegaly (three of which of obstructive origin), two presented with a non-pathologic macrocephaly due to a benign enlargement of the PCS, three had a normal exam performed for cerebral pathologies observed in a previous pregnancy (n=2) and for a microcephaly (n=1). MRI were performed on a 1.5T Philips Achieva system using a TSE Single Shot T2-weighted sequence (TE/TR =200/1255 ms) to acquire sagittal, axial and coronal slices of 5mm thickness (voxel size of 1.25x1.5mm, matrix of 280x217, and FOV of 350x330 mm). MRI indications, maternal and gestational ages at the time of the exam, cephalic circumferences, and radiological reports were collected. Data processing consisted first in a reorientation step of the acquired MRI stacks using SLICER 3D (1). Inner cranium mask (including PCS and brain) was then manually delineated using MITK (2). High-resolution reconstruction using motion compensation BTK (3) was applied to obtain volumetric images (figure 1). Afterwards PCS were extracted using FAST from FSL (4); a semi-automatic segmentation with a 0.6 intensity threshold was realized, requiring expert manual slice-to-slice corrections for software tissue mis-assignments (figure 2). Then, ventricular system was manually removed to access PCS volume. Ventricular system was then computed by deducting PCS volume from the total cerebral fluid volume. The PCS volumes were analyzed with respect to cephalic biometries, ventricular volumes, global cerebral volumes and gestational ages.

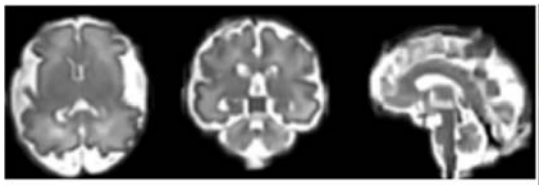

Figure 1: 3D isotropic super-resolution reconstruction using 2D MR stacks

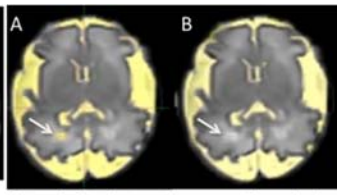

Figure 2: Semi-automatic segmentation of the cerebral fluids allowing a segmentation of PCS and ventricules (A).

Manual correction for tissue distribution was necessary for analysis accuracy (arrow) (B)

Patients	Total fluid volume	PCS	Ventricles
1	23,73%	21,92%	1,82%
2	25,86%	24,62%	1,24%
3	16,32%	15,97%	0,35%
4	34,85%	24,65%	10,20%
5	25,14%	24,26%	0,88%
6	23,66%	6,95%	16,71%
7	25,33%	22,31%	3,02%
8a	15,99%	9,15%	6,84%
8b	25,80%	0,97%	24,83%
9	24,75%	14,93%	9,81%
10	18,70%	17,50%	1,20%

Figure 3: Quantified volume of PCS and ventricles normalized on the total intra-cranial volume

RESULTS. PCS stood for 16 to 22% of the total intracranial volume in normal fetus. A ventricular system volume increase over 5% of the total cerebral fluid volume was noticed in every case of ventriculomegaly. (figure 3)

DISCUSSION. PCS segmentation was successfully achieved, albeit time-consuming. Our preliminary results suggest a PCS volume evolution throughout normal pregnancy. Moreover, a PCS volume variation was observed in some pathological cases. In particular, decreased PCS volumes were observed in obstructive ventriculomegaly cases. Ongoing work on a larger cohort of patients and healthy controls is needed to elaborate norms of PCS volume with respect to gestational age.

CONCLUSION. Our study demonstrated the feasibility of PCS segmentation based on 3D high-resolution reconstruction of the fetal brain. However, this technique remains time consuming and expert-dependent, requiring generalized automation. Quantitative PCS measures constitute a potential index for fetal cerebral pathology diagnosis, which could be used in clinical routine for fetal brain imaging.

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