

Three-dimensional Modeling and Volume Assessment of the Fetal and Neonatal Intracranial Ventricles

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Introduction

The diagnosis of ventriculomegaly depends on accurate measurements of ventricular size and volume both in the fetus as well as in the neonate. In the antenatal period the ventricular size is determined by ultrasound measuring the transverse width of the lateral ventricles at the level of the atria. Measurements of 10 mm or less are considered normal (1). Evaluation of the ventricular size is important in the detection of ventriculomegaly both in the fetus and the neonate. In the neonatal period US and other imaging modalities are used to assess ventricular size. The frontal and occipital horn ratio has been used in the evaluation of hydrocephalus (2), but errors can be induced by image plane selection.

In our pilot study we used 3D magnetic resonance imaging of fetuses in utero and neonates of different gestational age to determine absolute volumes of the ventricular system during early development. These images were post processed with advanced image analysis tools to reconstruct three-dimensional (3D) models of the ventricular system. The assessment of the absolute volume and 3D-morphology assessment of the ventricular system may represent a more objective way to determine normal and abnormal development in the fetus, as well as in the neonate. Our goal is to establish a normative set of data and compare this to clinical subjects.

Methods

Fourteen preterm neonates underwent magnetic resonance imaging (MRI) of the brain as part of a study on normal brain development. Fetal MRI was undertaken for exclusion of malformation. One fetus underwent MRI in utero at 24 weeks and 28 weeks gestation for exclusion of malformation. The gestational age of the group ranged from 24 weeks to 40 weeks.

MR images were obtained on a 1.5 T SIGNA GE system with interleaved double echo spin echo sequences (voxel size 0.7x0.7x3.0mm) and spoiled gradient recalled sequence (voxel size 0.7x0.7x1.5mm) (SPGR) for the neonatal examinations, whereas single shot fast spin echo sequences (SSFSE) (voxel size 0.8x0.8x4.0mm) were used for the imaging in utero. The images were electronically transferred to a workstation (Sun Microsystems, Mountain View, CA). The ventricular system was manually segmented by using advanced multiplane image analysis software developed in our laboratory and usable both for UNIX workstations as well as PC's (www.slicer.org) and 3D models were generated (Fig 1). The volume of the lateral, third and fourth ventricle was determined by adding up the number of the single pixels in each model. This number was multiplied by the volume in of each voxel to obtain the volume in cc. The completion of the postprocessing required in average 30 minutes. Interrater variability was less than 5%.



Fig. 1: 3D-model of ventricular system: Lateral ventricle in black, third ventricle in white, fourth ventricle in grey

Results

All image series were successfully postprocessed and analyzed. The lateral ventricle volume increased from 3.94 cc to 12.42 cc. The volume of the third ventricle ranged from 0.12 to 0.58 cc and of the fourth ventricle from 0.03 to 0.36 cc. The correlation coefficient of gestational age and lateral ventricle volume in our pilot study is $r=0.56$, gestational age and third ventricle is $r=0.48$, and gestational age and fourth ventricle is $r=0.65$.

Discussion

The volumetric assessment of the ventricular system from 24 to 41 weeks gestation has revealed a linear increase of absolute ventricular volume with gestational age with a wider variability in the fetal assessments than in the postnatal determination of ventricular volume. The third and fourth ventricle are extremely small structures with volumes as little as 0.03cc, for which volume assessment showed larger variability. The evaluation of the third and fourth ventricle is more demanding, due to the small size of the structure in of question. The establishment of a normogram displaying specific intracranial ventricular volume correlated with the gestational age will be achieved with a larger number of subjects in the study. This will facilitate the evaluation of the ventricular system of the fetus in utero as well as in the newborn and help identify reliably infants with early ventriculomegaly and will allow the detection of ventricular pathology. Serial examination may be used in the follow up of patients with ventriculomegaly to determine timing of interventions.

References

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