Automatic Detection and Measurement of Cisterna Magna in Fetal Brain

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Abstract: The Cisterna magna (CM) width reference ranges were constructed based on the measurements obtained from 80 healthy fetuses with normal postnatal outcome undergoing routine first-trimester ultrasound at 11–13 weeks, using the Lambda-Mu-Sigma method. CM was measured in the fetal midsagittal view, as routinely used for nuchal translucency assessment. A mixture model grouping algorithm is presented for robust ultrasound image segmentation in the presence of partial volume averaging. The method uses additional classes to represent estimating tissue class parameters volume voxels of mixed tissue type in the data with their probability distributions modelled accordingly. The image model also allows for tissue-dependent variance values and voxel neighbourhood information is taken into account in the clustering formulation. The final result is the estimated fractional amount of each tissue type present within a voxel in addition to the label assigned to the voxel.

Keywords: Lambda-Mu-Sigma method, Cisterna magna (CM), mixture model grouping algorithm.


1 Introduction

Most posterior fossa anomalies are detected after visualization of an abnormally sized posterior fossa, which can be either enlarged or reduced [1]. Dandy–Walker malformation, Blake’s pouch cyst, mega cisterna magna and posterior fossa arachnoid cysts frequently present with an enlarged posterior fossa, while Joubert’s syndrome, cerebellar atrophy and Chiari malformation typically present with a reduced cisterna magna (CM) [2]. During the second-trimester anomaly scan, the CM is one of the structures routinely assessed together with the cerebellum [1–3]. In recent years, the diagnosis of many fetal structural anomalies has been made in the first trimester [4, 5], and since 2009 some groups have described intracranial markers of open spina bifida at 11–13 weeks 6–11. In 2010 Chaouli and Nicolaides [8] suggested the size of the fourth ventricle in a sagittal view of the fetal head, the ‘intracranial translucency’, as an early marker for spina bifida. More recently their group suggested the ratio of brain stem diameter to brain-stem-to-occipitalbone distance (BS/BSOB) as a better marker [10]. First-trimester reference ranges for the posterior fossa structures have been reported recently by two groups. Egle et al. [12] constructed reference ranges for transcerebellar diameter and the anteroposterior diameter of the CMand of the fourth ventricle in axial views using transabdominal sonography.

In contrast, Papastefanou et al.[13] used a mid-sagittal view, the same one adopted by Lachmann et al.[10] to describe the BS/BSOB ratio, to establish their CM reference ranges. For practical reasons, the midsagittal view is preferable, given that this is the plane routinely used for nuchal translucency measurement and because the midbrain has become a landmark to define the correct mid-sagittal view. Surprisingly, there are substantial differences between these two reference ranges for CM diameter.

The use of ultrasound imaging has resulted in the assessment of fetal structures along with various developed organs. In the past, gestational age has been established by a combination of the historical information and physical examination. Predictions were passed based on the menstrual history index, maternal sensation of fetal movement, assessment of uterine size by bi-manual examination in the first trimester, the initial detection of fetal heart tones by Doppler and uterine fundal height measurement. [1-6] Even in the best known cases it is reported that the menstrual history index and fundal height measurement techniques have been resulted in error [7]. With the known date of conception, the Timed Ovulation and in vitro fertilization the gestational age is expected to calculate accurately. But in most cases the date of ovulation or conception cannot be estimated accurately which
ultimately results in calculating the gestational age using other methods [8-22].

II. Fetal Cisterna Magna Methods

A prospective cross-sectional study between March 2010 and February 2011, involving 69 normal pregnant women between 18 and 24 weeks was performed. This study was approved by the Research Ethics Committee of the Irmandade da Santa Casa de Misericordia de Sao Paulo, Brazil, and the patients who agreed to participate signed a term of consent. This study was carried out at the Department of Obstetrics and Gynecology, Faculty of Medical Sciences of Santa Casa of S’ao Paulo (FCSMSP). The patients were randomly selected, and all evaluation made by a single examiner (FSBB), with five years experience in obstetric ultrasound. The examinations were performed on a SonoAce X8 (SamsungMedison, Seoul, Korea) device equipped with multifrequency volumetric convex transducer (3–7 MHz). The criteria for inclusion were (1) unique pregnancy with live fetus and (2) gestational age evaluated by last menstrual period and confirmed by ultrasound performed until the 14th week (crown-rump length-CRL: 4–84 mm). Exclusion criteria were (1) pregnant women carrying fetuses with structural anomalies detected at the time of the examination and (2) pregnant women carrying chronic diseases that would interfere with fetal growth.

Initially, a realtime 2D evaluation was performed in order to evaluate the biometry, morphology, and quantification of amniotic fluid volume. For the 2D measurement of transverse cerebellar and anterior-posterior cisterna magna diameter, it was performed a modified transversal slice of the fetal head slightly angled, through the thalamus, cerebellar hemispheres, cisterna magna, cave of septum pellucidum, the occipital bone, and nuchal fold. An insonation angle of the occipital bone was chosen, taking care that it was focused on an angle of 30°. It was performed a single measurement of transverse cerebellar and anteroposterior of the fetal cisterna magna diameter in each mother, and this image is saved in the memory of the device. The three-dimensional volume acquisition was performed on the same 2D plane in which was performed the measurements of the transverse cerebellar diameter and anterior-posterior cisterna magna, to encompass the entire fetal skull (ROI-region of interest) (Figure 2(a)). In order to standardize all 3D measurements, the following preset was used on the device: scanning—3D static; display mode—three-dimensional extended imaging (multislice view); scanning speed—slow; angle scanning—70°; overall gain of the device—50%. After the threedimensional scanning, the image was displayed in the multplanar mode (axial, sagittal, and coronal) (Figure 2(b)). The volumes were saved in the device memory and then stored on compact discs (CDs) and transferred to a personal computer. The analyses were performed offline in the same apparatus in a time period of 30 to 120 days after the volumetric capture.

A. Research Contribution

Automatic detection and measurement of cisterna magna in fetal brain. In the LMS method, LMS parameters are estimated from the data, smoothed, and then used to create the desired percentiles. The lambda-mu-sigma (LMS) method calculates the lower limit of normal for Spirometric values as the percentile of the distribution of scores. The cistern magna observations are features computed from LMS method neighborhoods surrounding the objects. In our algorithm, the order is selected such that the uncertainty of the detections is minimized. The analyses were performed offline in the same apparatus in a time period of 30 to 120 days after the volumetric capture.

B. Block Diagram

III. Methodology

This was a retrospective study. CM width reference ranges were constructed based on the measurements obtained from 80 healthy fetuses with normal postnatal outcome undergoing routine first-trimester ultrasound at 11-13 weeks, using the Lambda-Mu-Sigma method. CM was measured in the fetal mid-sagittal view, as routinely used for nuchal translucency assessment. In addition, first trimester ultrasound images in 11 fetuses with open spina bifida or posterior fossa anomalies, most of which were diagnosed later in pregnancy, were retrospectively reviewed, and CM measurements were compared against reference ranges. It have an good results in the automatic segmentation.

Fig 1 Block Diagram of Proposed Work
A. Lambda-Mu-Sigma

Method The LMS method summarizes the changing distribution by three curves representing the skewness expressed as a Box–Cox power (L), the median (M) and coefficient of variation (S). The resulting L-, M- and S-curves contain the information needed to draw any percentile curve. Degrees of freedom for each curve (L, M and S) were selected according to changes in the model deviance. In the LMS method, LMS parameters are estimated from the data, smoothed, and then used to create the desired percentiles. The lambda-mu-sigma (LMS) method calculates the lower limit of normal for Spri metric values as the percentile of the distribution of scores. Only 10 principal components to represent the changes of shape since they captured 90% of the total variation.

Grey Matter: Grey matter (or gray matter) is a major component of the central nervous system, consisting of neuronal cell bodies, neuropil (dendrites and unmyelinated axons), glial cells (astroglia and oligodendrocytes), and capillaries. Grey matter is distributed at the surface of the cerebral hemisphere's cerebellum, as well as in the depths of the cerebrum, cerebellar, brainstem, and spinal grey matter. In living tissue, grey matter actually has a grey-brown color, which comes from capillary blood vessels and neuronal cell bodies. Grey matter includes regions of the brain involved in muscle control, sensory perception, such as seeing and hearing; memory, emotions, and speech.

White Matter: A second major component of the central nervous system is white matter and it is composed of bundles of myelinated axons that connect various grey matter regions of the nervous system to each other and carry nerve impulses between neurons. White matter only contains the axons of the nerve cells, and not the cell bodies, which are found in grey matter. Myelin is a lipid that forms a thin layer, known as the myelin sheath, around the axons of white matter neurons acts as an electrical insulator, increasing the transmission speed of nerve signals by allowing the signal to jump down the axon. Myelin also gives white matter its characteristic color. At the age of 20, the total length of myelinated fibers in the body, if places end to end, is 176,000 km (109.4 miles) in males and is 149,000 km (92.6 miles) in females.

B. Cisterna Magna Detetion

The cisterna magna observations are features computed from LMS method neighbourhoods surrounding the objects. The likelihood (probability) of a hypothesized state that gives rise to observations is based on a deterministic model learned using a large annotated database of images. The transition model that describes the way the poses of objects are related is Gaussian filter. Employing the sequential sampling model allows us to use fewer samples of the object pose and formally extend this class of algorithms to multiple objects. In our algorithm, the order is selected such that the uncertainty of the detections is minimized. The fetal cisterna magna increases in size throughout pregnancy. The sample from fetuses with trisomy 18 was different and had a higher rate of small and large cisterna magna. The cisterna may be so large that it extends laterally, posteriorly and superiorly far beyond the normal anatomic limits of the cisterna magna. The cisterna may also extend superiorly through a posterior dehiscence of the tentorium cerebelli. In this condition, borderline to overt ventriculomegaly and other neural/extra neural defects are generally present. Distinction between LMS variant and mega-cisterna magna in the fetus is difficult as definitive criteria have not been firmly established. The former condition should be suspected when a thin communication is found between the fourth ventricle and the cisterna magna, the latter when the cisterna magna has a depth greater than 10 mm.

C. Output Image

![Image](image.png)

IV. Discussions

The variation in size of the cisterna magna may be due to challenges in accurately measuring the cisterna magna in the third trimester. The cisterna magna is usually measured in an anteroposterior fashion from the posterior aspect of the cerebellar vermis to the inner edge of the occipital bone. Measurements of the cisterna magna should be performed at a level that includes visualization of the cavum septum pellucidum, cerebral peduncles, and cerebellar hemispheres. However, Laing et al established that if the transducer is angled in a semicoronal plane, the cisterna magna could appear falsely enlarged in approximately 40% of cases. Of the cases in which a pseudoenlarged cisterna magna was created in a semicoronal plane, approximately 70% occurred in the third trimester. Therefore, the smallest anteroposterior diameter in the axial plane from the cerebellar vermis to the inner edge of the occipital bone should be obtained, and in suspected abnormal cases, the cisterna magna should be measured in the midsagittal plane.
V. Conclusion

The proposed system constructed reference ranges for CM width at 11–13 weeks’ gestation using midtctal ultrasound images. It appears that first-trimester CM width can be used as a marker for the early detection of open spina bifida. However, our findings need to be confirmed in large prospective series. In our work presented an algorithm for Lambda-Mu-Sigma method partial volume segmentation of ultrasound images. Experimental results are comparable or superior to other published algorithms. Our method is an extension of a probabilistic grouping algorithm, to accommodate partial volume voxels and to allow class-dependent model values for the intensity variance. Although the convergence properties of the original technique are generally unknown, we have observed robust performance from our implementation as a function of the estimates used to initialize the class parameters. In the phase II work, the weighting function was augmented to favor spatially contiguous regions in the segmentation but other possibilities are being examined, including the use of prior anatomic information.

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References


