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The use of modern ultrasound tridimensional techniques for the evaluation of fetal cerebral midline structures – a practical approach.

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Abstract

Fetal central nervous system midline structures represent an essential landmark for the confirmation of normality or for the identification of severe pathology. The ultrasound examination of the fetal brain using modern 3D techniques allows the creation of high sensitivity reconstructions. The facility of 3D volume acquisition permits the identification of corpus callosum, median septum, cavum septi pellucid and cerebellar vermis even in difficult cases. The examination should rely on both static (3D) and dynamic acquisition (4D). The use of a practical ultrasound protocol in clinical settings ensures the visualization of the midline cerebral structures in the vast majorities of fetuses. In selected cases MRI can be performed.

Keywords: 3D ultrasound, MRI, cerebral midline, neurosonography

Introduction

In modern obstetrics ultrasound has become more and more important for pregnancy surveillance. Moreover, the prenatal diagnosis of major fetal anomalies has moved from the second trimester to the end of the first trimester due to major technology progress. Major cerebral malformations such as anencephaly or holoprosencephaly can be diagnosed in end of the first trimester of pregnancy, but the vast majority of them (midline anomalies or lissencephaly) can be diagnosed only after 20th gestational weeks when corpus callosum formation should be finalized or during the third trimester when gyration takes place. The International Society of Ultrasound in Obstetrics and Gynecology (ISUOG) has released guidelines for basic screening of the Central Nervous System (CNS) and also the recommendation for the advanced examination for CNS. In daily practice however it is sometimes difficult to visualize all the normal midline structures or the complex CNS malformations and to make a precise diagnosis due to many factors: the fetal movements, an unfavorable fetal position or the interposition of maternal adipose tissue. Therefore sometimes it can be extremely difficult or even impossible to visualize the appropriate section in 2D. In these situations the examination is incomplete and the patient has to be rescheduled for more examinations, and the optimal moment for an obstetrical decision can be lost.

The present paper aims to propose a practical algorithm using modern 3D techniques that will permit the acquisitions of consecutives volumes, allowing a complete identification of CNS structures and the formulation of an accurate diagnosis.

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Screening. Normal aspects.

Midline cerebral structures include nervous elements essential for the normal morphogenesis and function of the brain [1].

The presence of median echo should be assessed at the end of the first trimester [2]. After 10 weeks' gestation it is recommended to use the biparietal diameter (BPD) and head circumference (HC) sections to visualized midline, third ventricle, interhemispheric fissure and choroid plexuses [2]. Between 11 and 13 weeks and 6 days, the lateral ventricles are large, filled with echogenic

choroid plexuses in their posterior two thirds [2]. The interhemispheric fissure and the falx should be visible and the aspect of the hemispheres should be symmetrical [2]. The use of a detailed morphologic ultrasound protocol permitted an increased detection rate in the first trimester (12-14 weeks) of 69.5% major central nervous system anomalies [3].

At 20 weeks of gestation the development of the corpus callosum should be completed [4]. Other important parameters of the cerebral structure should be assessed: cavum septipellucidi, third ventricle, brain stem, cerebellar vermis, fourth ventricle and cistern magna. These particular elements are mandatory to be identified being involved in multiple anomalies. Moreover, it is important to evaluate the fetal face and profile, many of the midline anomalies showing an abnormal fetal profile [5].

In normal pregnancy (low risk patient) it is recommended to evaluate the central nervous system (CNS) using the so called basic examination [6]. Routinely trasventricular, transcerebellar, transtalamic and spinal planes are obtained [6]. For the basic examination the following structures should be checked: head shape, lateral ventricles, cavum septipellucidi, thalami, cerebellum, cisterna magna, spine [6]. It is important to take into account the gestational age. For example, failure to detect cavum septi pellucidi prior to 16 weeks is a normal finding [7].

The ultrasound is usually performed transabdominally but during the first trimester, and occasionally in fetus in vertex position, in late gestation, complementary transvaginal probes can be used [8].

In patients being at increased risk of CNS anomalies or in cases of suspicious finding on the basic examination a fetal neurosonogram is recommended, that should be accomplished by an experimented physician [6]. The neurosonographic examination includes multiples scans on axial, coronal and sagital plans. The sagital plans are difficult to obtain in conventional 2D ultrasound requiring an experienced skilled ultrasonographer and a longer examination period especially for midsagittal brain plans and a favorable fetal positions [9]. Therefore, in order to achieve a satisfactory visualization of median structures it is necessary to use the classic examination together with modern techniques.

The transvaginal approach can be used for CNS examination during the first trimester or for fetuses in cephalic presentation in the second and third trimester when it brings additional information [10-11]. In all other situations there is not benefit of its use for CNS examination.

The brain development is far from being completed because during the third trimester processes as neuronal proliferation, migration and organization occurs [10]. Therefore, factors that exert its action upon CNS during the third trimester will interact with the fetal neuronal development; also other pathological conditions such as hemorrhage, thrombosis, or calcifications can occur in late gestation [12]. Consequently a normal 20 weeks ultrasound scan does not guarantee a normal CNS development, so it is mandatory to reassess the brain structures in the third trimester [13, 14].

Major cerebral midline anomalies

This group contains very heterogeneous conditions sharing similar etiological and pathological mechanisms [15-16]. The classification of midline anomalies first reported by De Meyer and later revised by Fitz et al includes two main categories: closure defects and diverticulation disorders [15-16]. The ontogenesis of cerebral midline takes place after the seventh week of amenorrhea known as ventral induction related closely to the development of the midface [17]. In the literature in these groupsother anomalies that arise in the midline such as Galen vein aneurysm, arachnoid cysts, or neoplasm even if from the embryological point of view they do not belong to this category [17]. The classification of midline cerebral anomalies is depicted in table I.

Table I. Classification of cerebral midline anomalies [15-17].

Disorders of diverticulation	Holoprosencephaly	Lobar
		Semilobar
		Alobar
Disorders of closure	Facial clefts	
	Cranioschisis	
	Corpus callosum	Complete agenesis
		Partial agenesis (short CC)
		Thick corpus callosum
		Arrest in the growth of CC at consecutive examinations
		Interhemispheric cyst
		Interhemispheric lipoma
		Probst bundles
	Chiari malformation	
	Dandy-Walker malformation	

2D versus 3D techniques

Routinely it is recommended that the fetal brain to be analyzed using three plans: trasventricular, transcerebellar, and axial transtalamic [6]. In case of an abnormal finding or in fetuses belonging to a high risk group the above mentioned plans are not sufficient; sagittal and coronal views are needed [6]. Obtaining these sagittal and coronal view requires experience, a prolonged examination time especially for the medio-sagittal cerebral axis. The transvaginal approach can be useful during the first trimester or in fetuses in cephalic presentation [11]. The 2D methods can be difficult, incomplete, or with low relevance.

The necessity of detailed information but also the development of 3D acquisition probes and post-processing software has opened new possibilities for the CNS examination [8]. 3D methods bring new significant data in a short period of time; the data are reproducible once the volume has been acquired and can be reanalyzed [18]. The 3D acquisition allows the navigation inside the volume and the reconstruction of particular sections or the achievements of high significant condensed volumes [19]. The major 3D techniques that can be used of midline cerebral structures analysis are: multiplannar view, tomographic ultrasound imaging (TUI), volume contrast imaging in sagittal plane (VCI-C) and frontal acquisition using VCI-A.

The evaluation of the cerebral line includes the following structures: hypothalamus, optical chiasm, lamina terminalis, septum pellucidum, cerebral commissures (anterior comissure, fornix, and corpus callosum), cerebral vermis and cisterna magna. Also both adeno- and neurohypophysis have to be assessed [17]. The normal structures of median vascular structures can be visualized including: Galen vein, inferior and superior sagital sinus, arterial vascular structures from medial face of cerebral hemispheres (Anterior Cerebral Artery, pericallosal artery). Due to important changes in the normal fetal anatomy, it is important to analyze the fetal face including the frontal region, nasal region, parts of the nasal cavities, upper lip philtrum, the alveolar part of the maxilla that contains the superior incisives and the palate located anterior to the incisive foramen.

The multiplannar view allows a simultaneous analysis of the acquired volume in all three planes: axial, coronal and sagital. It is used as the first step in the process of volume acquisition being the prerequisite for later analysis. In this mode the section plans can be oriented so that the cerebral midline to be on the horizontal axis in A and B plans. When this alignment is properly realized in C plan, one should be able to identify directly the sagital plane containing corpus callosum, the third ventricle and cerebral vermis. This view has many advantages: allows a fully anatomical structures evaluation on three spatial axes, permit the navigation inside the acquired volume and the spatial connection between normal or abnormal structures (fig 1)

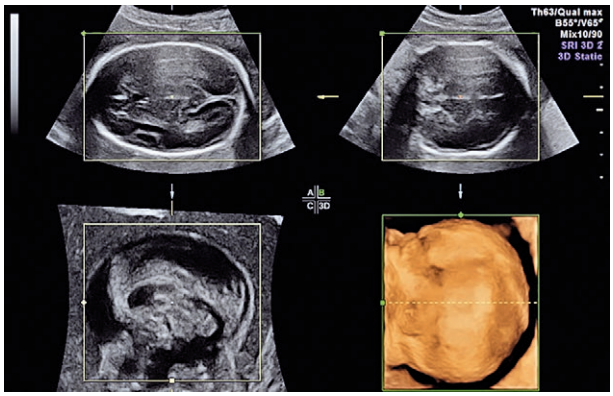


Fig 1. Multiplanar view section at the level of the midline-brain, at 90°.Up-left original axial midline transtalamic plane, up-right coronal plane reconstructed, down-left sagital median plane reconstructed with corpus callosum, cerebellum and cavum septum pellucid.

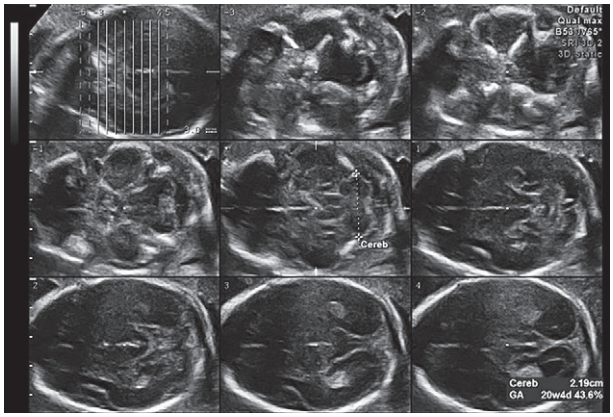


Fig 2. TUI – tomographic section of the fetal brain aligned on the vertical.

Tomographic ultrasound imaging (TUI) is considered a step forwardin relation with the multiplannar view allowing the realization of parallel sections in all the three axis of the acquired volume: A, B, C. The distance between the sections and the focus area can be adjusted by the examiner in order to target the desired structures. This type of volume analysis can be performed in all three plans. The method has many advantages: allows the establishment of the exact position of a lesion within CNS, also permits the exact evaluation of the dimensions and its extent (cyst, tumor, and infarct area) and the analysis of CNS (fig 2)

VCI-C generates a slice from the acquired volume. The thickness of the slice can be chosen by the examiner ranging between 2-10 mm. This particular method allows the reinforcement of highly extended structures with similar echostructure in slice compared to those with lower extension (tisular contrast). The use of VCI-C on the transtalamic axial plane applying the reconstruction line on the middle cerebral septum allows the rapid and efficient identification of corpus callosum structures, cerebral vermis and cistern magna. These elements are more visible because they extend also paramedian therefore appearing reinforced in slice in comparison to the surrounding structures. The use of this filter increases the contour precision with application for the vermis analysis and fourth ventricle. This mode allows the measurement of corpus callosum and of the craniocaudal diameter of cerebellar vermis (fig 3)

3D transfrontal acquisition can be realized at the same time with the examination of the fetal profile. The technique is necessary for the diagnosis of craniofacial anomalies and for the phenotypic expression of genetic and chromosomal anomalies. The use of VCI-A (volume contrast imaging) filter improves the quality of the examination. The phenomena of acoustic shadowing does not appear during the axial plan acquisition from the temporal petrous portion becoming possible to evaluate the fourth ventricle, the cerebral aqueduct, the pons and brain-stem. It is recommended for the evaluation of the relation between the vermis and the brain-stem.

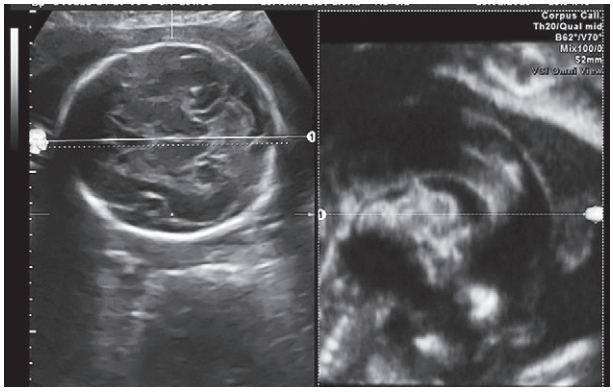


Fig 3. Left -axial transcerebelar section, right – volume contrast imaging in sagital plane; 1 – acquisition on the median line, 2 – cavum septum pellucidum, 3 – cerebellum, 4 – corpus callosum.

Practical approach

CNS examination should start with a 2D examination for general orientation followed by as correctly as possible 3D acquisition in the axial transtalamic plan with the median line perpendicular on the ultrasound beam. The acquisition could be performed either transabdominal either transvaginal depending on local conditions (gestational age, fetal position, patient BMI). The quality of image acquisition will be responsible for the quality of later post-processed images. After the initial acquisition the multiplannar mode is used; it is important that the volume would be oriented in such a position of the transducer that the central axe of the brain is horizontal in planes A and B. Once this volume is achieved and stored TUI and VCI-C should be used. This sequence of techniques guarantees a good and rapid visualization of median line structures with a rate of correct identification of these structures in more than 85%. Once the volumes have been acquired they are analyzed in order to confirm the normality of the cerebral structures. The elements of the medio-sagittal axis of the fetal brain can be completely identified from 18-20 gestational weeks (fig 4)

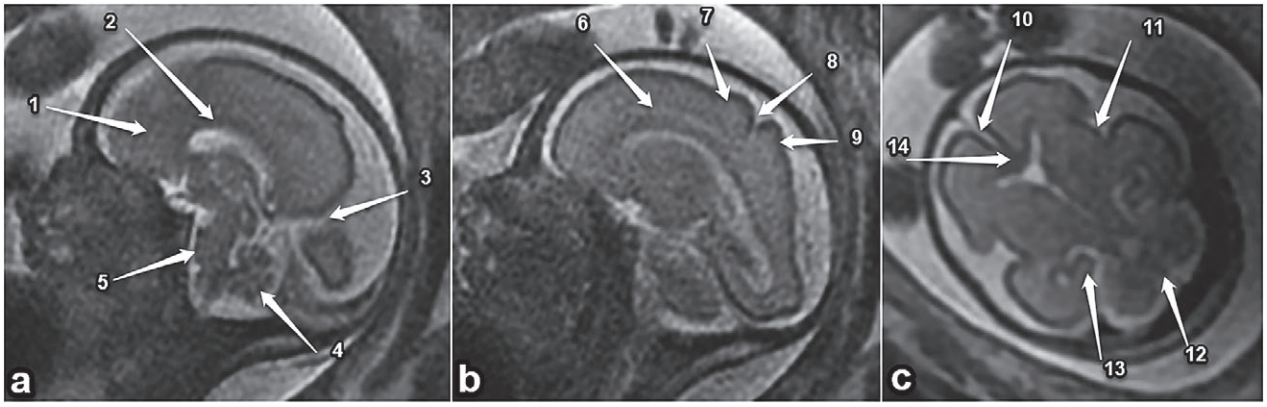


Fig 4. Fetal IRM at 26 weeks–normal aspect. Mediosagital section (a), T2 ponderated, frontal lobe (1), corpus calosum (2), parieto-occipital sulcus (3), cerebelar vermis (4) pons (5). Paramedian section (b): cingular sulcus (6), central fissure (8) and precentral gyrus (7) and postcentral (9). Coronal section, slighty oblique (c), interemisferic fissure (10)sylvian fissure (11) vermis (12) hipocampus (13) and corpus callosum (14).

Ultrasound versus MRI

Overall 3D ultrasound has achieved excellent parameters for the detection of cerebral midline anomalies. A multicenter study that had included 11 centers found the following values for the detection of fetuses with CNS defects at 18 gestation weeks: the sensitivity- 93.3% with a specificity of 96.5% with an excellent intercenter agreement [18].

The quality of 3D examination of the brain is closed to MRI acquisition especially for the cerebral midline. Supplementary 3D ultrasound has a good sensitivity [13]. The possibility to repeate the examination in case of a suspicious finding as many times as necessary represents another advantage. The sonographic examination represents a sensitive screening method. For the detection of CNS anomalies, neurosonograms, including 2D and 3D scans performed by an expert ultrasonographer in a tertiary center had an accuracy of 91.3% while MRI obtained an accuracy of 94.4% [13]. Nowadays during 3D ultrasound examination the acquisition is performed in the axial plan the other two plans representing interpolated information. New technologies are arriving that allow simultaneous acquisitions in two orthogonal plans which should generate less artifacts and an increased resolution.

MRI is use in cases of uncertain diagnosis or complex CNS malformations after the sonographic examination, only after 24 weeks of gestation or in case of gross space-occupying lesions [13]. Moreover MRI is more specific and furnishes a detailed diagnosis particularly for small lesions and allows the identification of associated lesions (migration anomalies, heterotopias, late sulcation). Unfortunately MRI can be limited by fetal movements, high prices of the machines and also the claustrophobic sensation induced to the patients [20]. Meanwhile the cost of MRI investigation cannot be compared to those of ultrasound; therefore, before it is used complementary to ultrasound. In the particular case of midline anomalies MRI confirms the condition but also allows the diagnosis of associated lesions [13].

In optimal conditions (maternal habitus, fetal presentation, and normal amniotic fluid index) the vast majority of the median head structures can be visualized by ultrasound [13]. Moreover the use of ultrasound has also the advantage of Doppler examinations of vascular structures of the brain [21]. MRI by comparison has a good resolution, the tisular native contrast and the adaptive field of view allows a detail visualization of cerebral midline structures if anatomical sections of the fetal brain are obtained [22,23]. The quality of fetal MRI is influenced byfetal movements and it is not limited by the condition regarding the fetal position required of a conclusive ultrasound evaluation [22,23].

Conclusions

Among CNS structures, midline elements represent a cornerstone for the confirmation of the normality of the fetal brain and also for the identification of its severe pathology. The best results for a complete fetal brain evaluation are obtained by the sequential utilization of 2D and 3D ultrasound techniques. The MRI should be used in complex CNC malformations, large lesions or failure of ultrasound to formulate a definitive diagnosis. The appropriate association of these techniques allows a precise diagnosis of cerebral lesions; moreover, a functional prognosis which suggests an optimal postnatal therapy or termination of pregnancy in selected cases.

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Conflict of interest: none

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