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Three-dimensional ultrasound in evaluation of fetal brain anomalies

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Abstract

Background and objective: Prenatal diagnosis of central nervous system anomalies by two-dimensional sonography is challenging because of difficulties in obtaining complete visualization of the fetal brain during routine examinations. Three-dimensional sonography has been introduced as a tool for studying the fetal central nervous system because of its ability to facilitate examinations of the fetal brain. This study aimed to visualize an intracranial structure of the fetal central nervous system anomaly using transabdominal three-dimensional sonography.

Methods: A prospective cross–sectional (observational) study in which three-dimensional ultrasound examination was performed in 82 patients between 12 and 38 weeks of gestation suspected to have fetal brain malformation detected by conventional two-dimensional ultrasound. Each anomaly was reviewed again to determine whether three-dimensional ultrasound data were advantageous compared to two-dimensional ultrasound.

Results: Three-dimensional images provided additional information in 43 (52.4%) of cases including extracerebral anomalies. The three-dimensional ultrasound was advantageous in evaluating the encephaloceles (10 of 43 cases) in that the exact location of the extracranial mass and the amount of extracranial tissue in the encephalocele was better defined with the simultaneous display of three orthogonal planes images that could not be obtained with two-dimensional ultrasound were seen with three-dimensional ultrasound.

Conclusion: Three-dimensional ultrasound is an excellent adjunctive tool to two-dimensional ultrasound in the evaluation of fetal anomalies.

Keywords: Three-dimensional sonography; Fetal brain; Brain malformation.

Introduction

Central nervous system (CNS) malformations are some of the most common of all congenital abnormalities. Neural tube defects are the most frequent CNS malformations to about 1–2 cases per 1000 births.[1] Prenatal detection and accurate definition of CNS malformations are important because these anomalies frequently have a severe prognosis and are often associated with genetic syndromes.[2] The development of the brain and spinal cord is an extremely complicated process which continues into the second decade before final maturity is achieved. Abnormality in the development of CNS are common, up to 75% of fetal deaths and 40% of deaths in infancy are due to CNS malformations.[3] The appearance of the brain changes throughout gestation; to avoid diagnostic errors it is important to be familiar with normal CNS appearances at different gestational ages. Most efforts to diagnose neural anomalies are focused around mid-gestation. Basic examinations are usually performed around 20 weeks' gestation.[1] Some abnormalities may be visible in the first and early second trimesters even though these may represent a minority they usually are severe and deserve therefore special consideration.[4] The developmental changes of the fetal central nervous system (CNS) during the second and third

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trimesters, specifically the brain, relate mostly to changes in size. However, other changes do occur in the fetal brain during the second and third trimester such as the union of the cerebellar hemispheres, development of the corpus callosum, and increasing complexity of the cerebral cortex.[5] Ultrasound has been used for nearly 30 years as the main modality to help diagnose fetal CNS anomalies.[6] It has been established in several studies that accuracy of US detection varies from 92% to 99.7% for CNS abnormalities.[7] The choice of the optimal transducer and operating frequency is influenced by a number of factors including maternal habitus, fetal position and the approach used.[6] Since the early 1980s, three-dimensional (3D) ultrasound has become a major field of research in obstetrics and gynecology. At this point in time, the clinical application of 3D is advancing rapidly, as improved 3D rendering technology becomes more widely available.[8] 3D/4D ultrasound technology has currently reached a stage where it can easily be used in daily routine examinations. In contrast to conventional 2D ultrasound, which only presents the fetus in a 2D perspective, the different 3D modes provide us with images that can never be achieved with 2D ultrasound and give the physician the opportunity to identify normal and abnormal fetal anatomy in the most appropriate mode. Concerning counseling of patients, rendered images help parents understand the severity of an existing malformation or believe the absence of fetal abnormality, particularly in cases with increased recurrence risk. Digital storage of volumes (not only of 2D images) provides many advantages: (1) the volumes can be reloaded to fully scrutinize equivocal findings in the absence of the patient, and (2) with knowledge of their content, they can be used for educational purposes.[9] The technique used to obtain an ultrasound volume is adequately described by three elements: (1) the section that is used to start the acquisition of the volume (referred to in the following as the 'start' scan); (2) the angle of rotation of the mechanical sweep of the motorized probe; and (3) the quality of the acquisition that can be varied by the operator and depends on the number of sections obtained during the acquisition [10]. The multiplanar mode is most frequently used for assessment of the fetal CNS. With this mode of display, it allows the simultaneous visualization of the three spatial planes (axial, sagittal and coronal) intersecting in a dote of the stored volume Tomagraphic ultrasound imaging (TUI) allows the simultaneous visualization of multiple parallel slices in one of the three orthogonal plans in away similar to CT or MRI.[11] This study was aimed to determine the additional information and clinical impact provide by three-dimensional ultrasound imaging the fetal brain anomalies compared to conventional two-dimensional ultrasound.

Methods

This is a prospective cross-sectional (observational) design study, data collected from daily ultrasound clinic examining pregnant women in Erbil city, Kurdistan region, North of Iraq, from July 2012 to October 2014. A sample of 82 patients with a singleton pregnancy with a cephalic presentation in different gestational age ranging from 12 to 38 weeks, and had been referred from other clinic examining for routine obstetrical examination and suspected to have anomalies in the fetal brain. Then they were referred for 3D examination for further evaluation. Patients with the history of a previous fetus/infant with a brain anomaly or having had a transabdominal scan which documented or raised the suspicious for fetal brain malformations and patients with a history of x-ray exposure during early pregnancy or history of drug abuse were included in this study. Patients with a twin pregnancy, decrease amount of liquor and breech presentation of the fetus were excluded from the study. The study was approved by the local ethics committee. All patients were scanned by a radiologist for two-dimensional trans-abdominal probe then referred to 3D ultrasound clinic using a GE VOLUSON S8 ultrasound equipment (General Electric medical system) with an abdominal sector transducer (3-5MHz.) for 2D examination then 3D transducer (RAB 4-8)-RS for 3D examination to obtain an ultrasound volume. Once a clear 2D transabdominal axial plane of the fetal brain has been visualized according to ISUOG guidelines for basic examination of fetal central nervous system[1].The 2D US real-time scans were used to localize the region of interest. As in standard procedure in volume acquisition, the image was enlarged to at least a third of the screen; The 3D volume box was adjusted to include the whole fetal head, placing the upper reference line of the volume box close to the most anterior parietal bone, the volume was acquired, in the axial view starting at the level used to measure the biparital diameter at angle of about 45° at second trimester and increased to 60 in late pregnancy, the incident ultrasound beam and the cerebral midline was kept to minimize acoustic shadowing of the skull base on the posterior fossa in the reconstructed planes, the frequency of the probe was set at mid/high harmonics**.** With these setting the crystal arrange of the three dimensional volume transducer sweeps mechanically over the defined region of interest, sampling more than 300 consecutive slices per volume, minimizing artifacts from fetal or maternal movement. Volumes were acquired during fetal quiescence. For each fetus, two to five volume acquisitions were performed, and only the volume with the least acoustic shadowing and motion artifacts was considered for the study. Acquisition time ranged from 2 to 6 s per volume, and acquisitions were repeated if fetal movement occurred during acquisition. Then the multiplanar mode is most frequently used for assessment of the fetal CNS using the views provided by any combination of the three acquired boxes (axial, coronal and sagittal planes). When these requirements were met, the entire brain anatomy was analyzed. Only cases with an acceptable quality of cerebral mul-tiplanar images were included in the study that allowed visualization of both choroid plexuses, both lateral ventricles (from the anterior to the posterior horns, including the body and the atrium) and the entire inter-hemispheric fissure. Mid-sagittal tomographic ultrasound imaging (TUI), with a 1.5-mm interslice distance, was then displayed for the A-plane. However, only the acquisition judged to be best was considered for the study. In some cases, it was necessary to modify the brightness and contrast settings of the multiplanar images to correct their resolution. Abnormality in the brain visualized by 2D like absence of skull bone (anencephaly), cystic structure in occipital region (meningeocele) best visualized by 3D surface rendering. Abnormalities of the corpus callosum like agenesis of the corpus callosum were diagnosed when it appeared subjectively to be small and incomplete or absent in 3D. Ventriculomegaly is a frequent marker of abnormal cerebral development. Measurement of the atrium is obtained at the level of the glomus of the choroid plexus, perpendicular to the ventricular cavity, positioning the calipers inside the echoes generated by the lateral walls. The measurement is stable in the second and early third trimesters, with a mean diameter of 6–8 mm, and is considered normal when less than10 mm. The Dandy–Walker malformation diagnosed when position and morphology of the cerebellar vermis were noted in each case. Rotation of the vermis was diagnosed when a fluid-filled space was seen dislocating the vermis from the brain stem. Hypoplasia was assessed subjectively, and the diagnosis was further supported when the main landmarks of the cerebellum (fastigium and two fissures) could not be identified. All cases were followed up

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postnatally and the abnormality diagnosed by an obstetrician. 3D examination time was from 15minute to 30 minute. All examination were saved on specialized 3D software in the ultrasound equipment and offline analysis of the images done for better analysis of the abnormalities seen in initial examination.

Statistical Analysis

Statistical Package for Social Sciences (SPSS) version 21.0 was used for data entry and analysis. Both descriptive and analytic approaches were used; descriptive to determine the frequencies, mean and standard deviation; and analytic by Chi-square test to find the association between categorical variables. McNemar test was used to compare results obtained by 2D and 3D ultrasound of the same sample. A *P* value less than or equal to 0.05 was regarded as a statistically significant.

Ethical clearance

Verbal consent was obtained from all participants for the 3D ultrasound study and they were extremely pleased to be evaluated by 3D ultrasound as well.

Results

The current study revealed that out of total 82 patients, the age range was 17-42 years with mean ± SD of 26.8± 5.1 years. Only 17 (20.7%) were primigravida, while the majority 65 (79.3%) were multigravida. This study also showed that only 4 (4.9%) were in the first trimester, 64 (78%) were in the second trimester and 14 (17%) were in the third trimester. The mean gestational age was (23) weeks ranged between (12 – 38) weeks. Fetuses with different central nervous system anomalies include in the study.3D median plane obtained with multiplaner evaluation of static volume obtained transabdominally in all case. The frequency of each primary diagnosis among the volume data set from the fetuses with abnormalities was 14 (17.07%) with bilateral hydrocephaly and 12 (14.6%) with anencephaly and 39 (47.6%) were normal details showed in Table 1. This study showed that 4 cases of ventricular dilatation and hydrocephaly diagnosed as DWM, and 4 cases with the diagnosis of cyst in the head or occipital region diagnosed as meningeocele. This diagnosis was proved by multiplaner & TUI images. The 3D images provided additional information in 43 (52.4%) of cases including extracerebral anomalies by using simultaneous multiplanar imaging and referencing to the volume-rendered image.

Table 1: Frequency of 3D Ultrasound findings.

Anomalies	Frequency	Percent (%)
Normal	39	47.6
Bilateral hydrocephaly	14	17.07
Anencephaly	12	14.6
Meningeocele	10	12.2
Dandy-Walker malformation	4	4.9
Cyst in the brain	2	2.4
Unilateral hydrocephaly	1	1.2
Total	82	100.0

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The 3D US was advantageous in evaluating the encephaloceles (10 of 43 cases) in that the exact location of the extracranial mass and the amount of extracranial tissue in the encephalocele was better defined with the simultaneous display of three orthogonal planes and surface rendering images that could not be obtained with the 2D US were seen with 3D US (Figure 1). This study showed that 4 cases (100%) in the first trimester had abnormality finding in the 2D US, while 11 (78.6%) showed abnormality in the third trimester. This was statistically near to significant (*P* = 0.052) as shown in Table 2. e 1). This study showed that 4 cases (100%) in the first trimester had abnormality findings in 3DUS, while 10 (71.4%) showed abnormality in the third trimester. This was statistically significant (*P* = 0.031) as shown in Table 3.

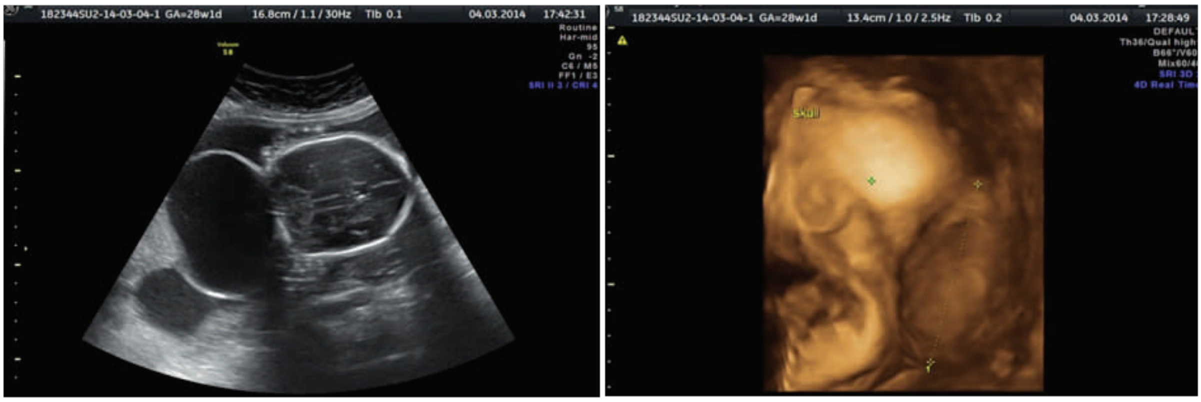

Figure 1: 2 D and 3 D surface rendered US images of occipital meningeocele at 28 weeks.

Table 2: 2D ultrasound abnormalities with gestational age.

Gestational age	2 D ultrasound abnormality No		Yes		Total		*P* value
	No.	%	No.	%	No.	%	
First trimester	0	0.0	4	100	4	100	0.052
Second trimester	30	46.9	34	53.1	64	100	
Third trimester	3	21.4	11	78.6	14	100	
Total	33	40.2	49	59.8	82	100	

Table 3: 3D ultrasound abnormalities with gestational age.

Gestational age	3 D ultra sound abnormality No		Yes		Total		*P* value
	No.	**%**	**No.**	**%**	**No.**	**%**	
First trimester	0	0.0	4	100	4	100	0.031
Second trimester	35	54.7	29	45.3	64	100	
Third trimester	4	28.6	10	71.4	14	100	
Total	39	47.6	43	52.4	82	100	

This study revealed that the degree of agreement between 2D and 3D US finding was a statistically significant *P* value by NcNemar test was 92.7% as shown in Table 4.

Discussion

Although the diagnosis of each central nervous system anomaly was made using conventional two-dimensional sonography, 3D sonography proved to be most helpful delineating the exact nature and anatomic level of the anomaly[11].Some studies show that two dimensional sonography detection rate of fetal anomalies is poor even in tertiary-care centers, only 40–50 % of cases of fetal malformations are detected prenatally by 2D US[12]. In this study the frequency of detection of fetal brain anomaly was more for hydrocephaly (14%) similar to study by Nayab alia where was (17%)[18]. There is statistically significant association between 3D findings & gestational age (P value = 0.031) 29 patients (45%) at second trimester showed abnormalities because 3D provide unique images in both planer and render format that were not visualized with slandered 2D US scans[13]. In this study 3D sonography was performed as an adjunct to 2D US and the 3D US images provided additional information in 43 (52.4%) patients, this compares to results by Merz et al. examined 204 patients with 3D US and proved that 3D US is advantageous in demonstrating fetal defects in 62 % (127/204)[14]. Hui-Xiong et al. shown that 3D US definitely diagnosed all the abnormalities in 38 fetuses (93%), whereas 2D US did so in only 32 fetuses (78%). In 35 (60%) of the 58 malformations revealed by both 3D US and 2D US, the former provided more diagnostic information than the latter[13]. Dyson et al. scanned 63 patients with 103anomalies and thought that 3D US offered diagnostic advantages and had effect on patient management in 5% of cases. All these findings are similar to findings in this study. Yigiter et al. study 3D US images provided additional information in 43 of 61 cases (70, 49%) of CNS anomalies including holoprosencephaly, hydrocephalus, Encephalocele[16].Surface and volume rendered images generally provided a more comprehensive 3D impression of fetal anatomy . Merz et al . Stated that the surface mode could be helpful in depicting the width and depth of the brain defect and evaluating the inner wall of the cystic structures. Hata et al. reported similar results using the surface and transparent

Table 4: Degree of agreement between 2D and 3D ultrasound abnormalities.

			Abnormality3D no	Abnormality3D yes	Total	P value McNemar
Abormality2D	no	Count	33	0	33	
		% within Abormality2D	100.0%	0.0%	100.0%	
		% within Abnormality3D	84.6%	0.0%	40.2%	
	yes	Count	6	43	49	
		% within Abormality2D	12.2%	87.8%	100.0%	0.031
		% within Abnormality3D	15.4%	100.0%	59.8%	
Total		Count	39	43	82	
		% within Abormality2D	47.6%	52.4%	100.0%	
		% within Abnormality3D	100.0%	100.0%	100.0%	

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modes. However, both studies only included brain anomalies associated with intracranial spaces, such as dilated ventricles and enlarged cisterna magna, so that they could render the anomaly using the surface mode[17]. Visualization of an anomaly with rotating rendered images may assist the parents in choosing a management plan even if the anomaly was adequately seen for diagnostic purposes on planer images[14]. Three-dimensional ultrasound technology can effectively be used to examine the fetal brain. The ability to simultaneously view and review a brain volume in all three scanning planes, by navigating back and fort through digitally stored data was found to be clinical important[16].The 3D US offered advantages over 2DUS imaging in terms of data storage as well. Volume data were stored on removable hard disks allowing for review with post processing capabilities and manipulation of the images by multiple physicians after the patient left the clinic[14].

Conclusion

Three-dimensional sonography (3S US) has been demonstrated to be a good technique for detecting fetal malformations. In comparison with the 2D US, 3D US improves the diagnostic capability of offering more diagnostic information, particularly in displacing fetal malformations of the cranium by multiplaner and surface rendering. The 3D US is a valuable adjunct to the 2D US in prenatal diagnosis.

Conflicts of interest

The authors report no conflicts of interest.

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