2D, 3D, 4D ultrasound in Obstetrics: Best evidence practice

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Introduction

Recent advances in prenatal diagnosis and therapy has been made possible with the invention of newer imaging modalities including 3D and 4D ultrasound. Two dimensional ultrasound remains the method by which most fetal structural abnormalities are screened and diagnosed, however 3D and 4D are being used increasingly for the examination of the human fetus. Two dimensional scanning allows visualisation of static images while 3D and 4D imaging adds a further dimension to fetal study by allowing interaction with volume data sets to examine anatomic structures of interest in planes of section.[1] This article will focus on the role of 2D, 3D and 4D ultrasonography in the diagnosis of fetal malformations and their value as a primary or adjunct diagnostic tool.

The Fetal Face

The examination of the fetal face by 3D ultrasound has generated a great deal of interest by both the medical fraternity and prospective parents. The "photographic-like" images are easily recognised by both the layperson and expert alike. Facial expressions such as mouth-opening, tongue protrusion and yawning may be studied in detail using 4D ultrasound.[2] This has lead several investigators to hypothesise that the adjunctive use of 3D/4D ultrasound would improve the diagnostic accuracy of 2D ultrasound. In a review of 11 studies comparing 2D with 3D ultrasound for the diagnosis of facial anomalies, 7 studies reported additional information with 3D ultrasound while 4 studies found no difference between the two modalities.[3] The advantage of 3D ultrasound was an improvement in the diagnostic accuracy to detect clefts of the palate and decrease in the number of false positive diagnoses. Other authors have reported that subtle facial features such as micrognathia, midface hypoplasia and frontal bossing are more confidently interpreted with 3D imaging.[4]

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Fetal Central Nervous System

Data comparing 2D and 3D ultrasound in examining the fetal central nervous system are limited in numbers. Fetal neurosonograms will continue to consist mainly of 2D images because 2D ultrasound allows sharper resolution of anatomic details which may be critical especially when dealing with abnormalities.[5] Potential benefits of 3D ultrasound include[6]:

1. The ability to determine the severity, location and extent of central nervous system abnormalities
2. The possibility of reconstructing and visualising the corpus callosum in the sagital plane from volume data sets.
3. The ability to visualise the 3 horns of the ventricular system in a single plane (3 horn view)
4. The possibility of increasing the speed of fetal neurosonography performed by 2D transvaginal ultrsonography.

The ability to visualise the level of defect in cases of spina bifida using 3D imaging is important in counselling regarding prognosis and treatment. In a study by Lee et al, the spinal level agreed to within 1 vertebral segment in 8 of 9 fetuses examined by 3D ultrasound versus 6 of 9 with 2D ultrasound.[7] An intact meningeal sac was visualised in 5 of the 9 subjects in the 3D ultrasound group.

3D/4D ultrasound of the fetal lung and thorax

Conditions such as diaphragmatic hernia, skeletal dysplasias and preterm premature rupture of membranes (PPROM) are associated with risk of pulmonary hypoplasia. Prognosis is dependent on the residual size of the affected lung. A study comparing 3D imaging with 2D ultrasound or MRI in the evaluation of the fetal lung in normal pregnancies found that

3D- obtained lung volumes were comparable to MRI measurements in normal fetuses.[8] Other studies have found that 3D lung volume measurements have a better prognostic accuracy for pulmonary hypoplasia than 2D biometric measurements in cases of PPROM, intra-uterine growth restriction and renal and skeletal abnormalities.[9,10]

3D/4D fetal echocardiography

The normal 2D ultrasound screening using the standard 4-chamber view as a screening tool will only detect between 25 to 39% of fetal cardiac anomalies.[11] In order to improve the screening, several guidelines state that the left ventricular outflow tract (LVOT) and the right ventricular outflow tract (RVOT) should also be examined.[12,13] Studies showed that this approach will improve the detection rate up to 57% .[11,14]

3D Imaging aspects[15]

The acquisition plane is the starting point from which the volume will be acquired and this correlates to the A plane. The A plane has the highest resolution. The best 3D plane correlates to the best 2D examination plane for the 4 chamber view.[15]

The region of interest determines the height and width of the acquired volume but it affects the frame rate, and should be set as narrow as possible. The region should include the vertebral body and the cardiac apex.[15]

The acquisition angle is determined by the gestational age of the fetus. In the second trimester the angle is set between 20 to 25 degrees. An adequate angle will allow the operator to visualise the stomach bubble and the three vessel view at the two ends of the sweep.[15]

The acquisition time affects the resolution of the B and C planes. A longer time improves the image resolution but it also increases the risk for artefacts due to fetal movement.[15] The time ranges between 7.5 and 15 seconds.

Since the A, B and C planes are important to standardise the imaging axis these planes are not helpful in examining the volume. Here multiplanar imaging techniques are of value.[15] These techniques compare to magnetic resonance imaging and computed tomography.

There are two imaging techniques available as multiplanar imaging namely[15]:

- Tomographic ultrasound imaging where a parallel images in a 3D volume are displayed in a multi slice display. The operator is able to choose different thicknesses for the slices
- Volume computer-aided diagnosis (VCAD) uses modified arrangements in imaging planes that accounts for the physiological anatomic orientation of the traditional cardiac imaging planes.

Spatiotemporal Image Correlation (STIC)

The fetal heart should be examined in motion but with standard 3D the spatio and temporal resolution of the image is limited.[15] It is further complicated by motion artefacts. The disadvantage of the cine-loop playback is that the image acquisition and cardiac cycle are not synchronized.[15] With STIC a fixed portion of the image is correlated spatially over a period of time. During a single sweep over 7.5 to 30 seconds a 3D volume is created. For example if a 10 second sweep with a 25 degree angle is used the fetal heart beats 20 to 25 times. The STIC then analyzes the rhythmic movement to create 40 consecutive volumes that reconstruct the cardiac cycle in an endless loop.[15] This allows the operator to store images of the cardiac cycle and these images can then later be reviewed.

STIC also makes it possible to evaluate the fetal heart during the first trimester screening. Turan and co-workers found that it was possible to evaluate the individual fetal landmarks in 89.7 to 99.1% of cases using STIC and tomographic imaging.[16]

Fetal cardiac function

There are different techniques available to evaluate fetal cardiac function. These techniques include[17]:

- Doppler estimation of stroke volume.
- 2D and M-Mode estimation of stroke volume.
- STIC can also be used to calculate the stroke volume.

Since there is yet no gold standard to evaluate fetal cardiac function it seems that M-Mode to evaluate ventricular shortening fraction and Doppler of the precordial veins are important methods to use.[17]

From recent studies it has became clear that 3D/4D sonar application can aid in diagnosing fetal cardiac anomalies but that there are still too many limitations with these techniques to use it for routine screening.[11,15,18,19] Uittenbogaard and co-workers found that although 80% of acquired volumes were of sufficient or high standard, only 46.6% of the volumes could find all 4 planes to evaluate the fetal cardiac anatomy.[18]

Maternal-fetal bonding

Studies comparing maternal-fetal bonding after mothers were exposed to 2D ultrasound only, to those exposed to both 2D and 3D ultrasound show varying results. In a study by Ji et al, mothers exposed to 3D ultrasound had a greater tendency to form a mental picture of their baby after the examination and consistently scored higher for all categories of maternal-fetal bonding. In another randomised study there was no difference in the Maternal Antenatal Attachment Scale scores between mothers randomised to 2D ultrasound compared to 2D plus 4D -ultrasound.[12]

Limitations of 3D/4D ultrasound

1. Specialised training is required to manipulate and analyse archived volumes.
2. Most physicians are generally more accustomed to standard 2D ultrasound – this may have resulted in the lack of benefit from 3D ultrasound found in some studies.
3. Image quality is influenced by technical aspects such as fetal position and movement.
4. 3D/4D ultrasonography is not perfect – artifacts can lead to false reassurance or misdiagnosis.
5. For STIC the operator needs an ultrasound window that allows visualisation of the entire ventricle.[17]
6. The fetus must be quiet for at least 7.5 seconds to obtain the volume.[17]

Conclusion

Three- and 4-D ultrasound have strengthened the diagnostic means available for prenatal diagnosis. These imaging tools allow detailed visualisation of certain fetal organ structures like the face and central nervous system, evaluation of fetal lung volumes and fetal echocardiography. They may also assist mothers in forming a mental picture of their baby, which is especially important in preparing mothers for the birth of a baby with congenital facial abnormalities. In other system abnormalities like hand and feet abnormalities, 3D/4D can also aid in the diagnosis. However, 2D ultrasound is still the screening tool of choice to examine the fetus. As with 2D ultrasound the technical ability and understanding of the fetal anatomy plays an important role in visualisation and diagnosing abnormalities in the different fetal organ systems. A good quality scan does not depend on the modality used but rather on a detailed and systemic evaluation of each of the fetal organ systems.

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