GE Healthcare

The Use of the Minimum Mode in Prenatal Ultrasound Diagnostics – Possibilities and Limitations

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ABSTRACT

Introduction:
3D/4D ultrasound has had a significant influence on prenatal diagnostics. Although the technique is often identified with surface imaging, it enables one to obtain by means of processing of a volume data set a large amount of additional information. Furthermore, this opens up new possibilities in the diagnostics of internal organs. One method offered in 3D/4D ultrasound is processing in minimum mode. In this mode fluid-filled organs are displayed in black.

Study design:
Prospective observational study during the period 1 Jan 2005 – 31 Aug 2007 .

Method:
Using a 3D-static volume data set of the thorax and the abdomen in anormal screening population in the second trimester: Additionally we analyzed fetuses with various malformations in combination with fluid filled organs.

Results:
The use of minimum mode in the 22th gw is easy, especially when the fetus is in a dorsoposterior position. We were able to demonstrate the typical signs in fetuses with various malformations (lung, diaphragmatichernia, kidney, bladder, neck, heart). Because of using the volume ultrasound the method allows us often a much better spatial visualization of the organs.

Conclusion:
Minimum mode is an additional tool in 3D/4D ultrasound, enabling the visualization of fluid-filled organs in a volume data set. This makes it possible to obtain information about the spatial relationship of the organs.

INTRODUCTION

The use of 3D/4D ultrasound has become very widespread in recent years in prenatal diagnostics, and represents today the field with the greatest growth potential (Chaoui et al, Benaceraf et.al.). Technically, so-called volume ultrasound lies behind 3D/4D technology. This means that one obtains a volume consisting of data sets which one can subsequently process in the most varied ways (Chaoui et al). The medical usefulness of volume ultrasound has been sufficiently demonstrated in various studies (Chaoui et al; Mittermayer et al; Timor-Tritsch et al)

In recent years a number of publications on volume ultrasound have appeared describing its various diagnostic methods - for example, the surface mode (surface imaging), the maximum mode (for imaging bones), the minimum mode (for imaging fluid-filled organs) or the inversion mode (for imaging fluid-filled organs, where only the fluid is shown, in white). (Benoit et al; De Vore; Espinoza, Mittermayer et al; Timor-Tritsch et al., Chaoui et al). However, most of the publications describe surface imaging and, if needed, imaging of the bones, as well. Only a few papers so far have dealt with the possibility of imaging inner organs. Romero and co-workers, for example, (2004) published a paper on the use of the minimum mode for fetal heart diagnosis, employing the STIC technology (Spatial Temporal Image Correlation).

In a prospective study the current authors investigated the use of minimum imaging in prenatal diagnostics. The goal of the present paper is to provide information on the possible clinical uses of the minimum mode.

BASICS AND METHOD

The basis of volume ultrasound is the acquisition of a data set for a volume block of the fetus. This data set can relate to any part of the body of the fetus. As regards the basics see our previously published papers on the technique (Chaoui et al). All the examinations were performed with Voluson 730 Expert and Voluson E8 System from GE Healthcare. Once the data set has been acquired it can be processed in various ways by means of rendering technology. This processing can be done both on-line at the ultrasound equipment and offline at the computer using the software application „4DSonoview" from GE Healthcare.

For imaging in minimum mode one sets the render mode to minimum and obtains an image of a fluid-filled organ (for example, the stomach or the urinary bladder) and the vessels. This means that everything that is filled with fluid is shown now in black. Since one works with a volume block, one obtains by this means over the data set a very good image of the spatial relationship of organs to each other. The advantage of this technology in comparison with colour Doppler ultrasound, for example, in the imaging of vessels is the better image quality due to the higher image sequence rate, as well as the imaging of other fluid-filled organs, which is not possible in colour Doppler ultrasound. When one acquires a volume for processing in minimum mode one proceeds from an optimal B-mode image quality with a high image sequence rate (i.e., with a high frequency [Hz] rate). If one examines the flow of blood by means of colour Doppler the image sequence rate decreases considerably due to the additional „feature" of colour Doppler, which generally has an effect on the quality of the image. The orientation can also prove to be a disadvantage, although one can learn quickly to deal with this.

To obtain a good image with minimum mode one has to pay attention to various technical aspects: For volume imaging the gain setting of the B-mode image should be set more towards dark to obtain a contrast-rich image. In choosing the quality of the volume image "high quality" or „maximal" should be selected. It is good to deactivate additional B-mode image options (e.g., SRI), since otherwise the creation of the volume image takes too long and the possibility of errors increases. If one wants to leave these options activated one should reduce the image quality (instead of „maximal" only „high quality" or a similar setting). The additional B-mode image options increase the imaging time for the volume considerably, giving rise to the possibility of artifacts. In addition, one can set the SRI (Speckle Reduction Imaging) during post-processing. The larger the angle of the volume box, the better the image quality of the recorded volume: we usually use 60°.

The volume data set can be acquired using any section of the fetus. One should, however, have in mind on acquiring the volume set what one wants to examine. The imaging of organs in minimum mode is most successful for the thoracic and abdominal organs. The best fetal position for obtaining the volume is dorso-posterior, i.e. the transducer is placed on the ventral side and ideally in a longitudinal plane.

After acquisition of the volume data set, it should be saved on the hard drive of the ultrasound system before it is processed. The post-processing analysis is possible both at the ultrasound machine and using 4D view software at an external workstation. The file should be saved as a volume data set. In principle, the volume imaging can be done either in 3D or 4D technology. Since the image quality of the 3D technology is better (higher image sequence rate) we prefer this technique. All the volumes in the present study were obtained in the static 3D volume mode.

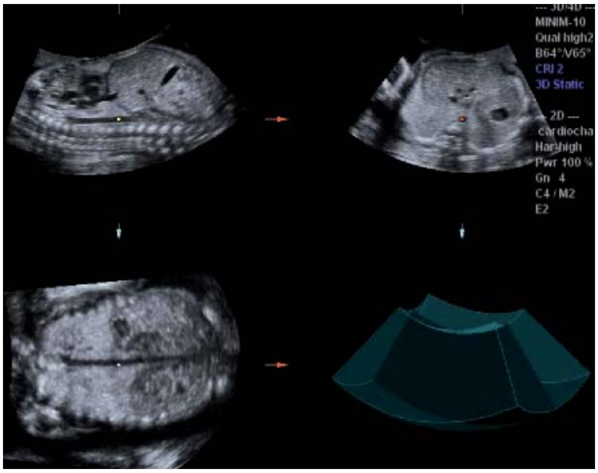


Figure 1: After acquisition of the volume data set one has a multiplanar image of the different planes. The volume box gives an idea of the volume data set.

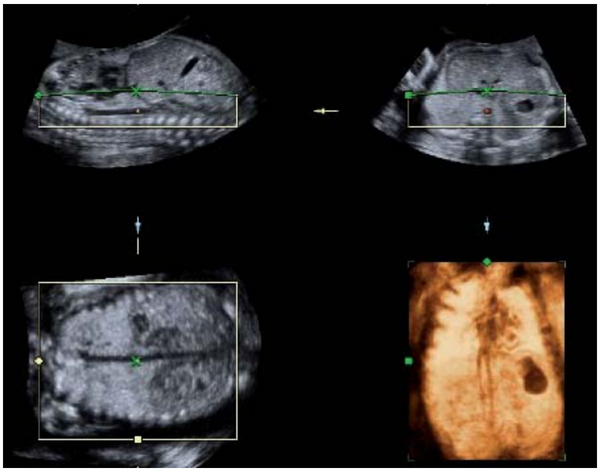


Figure 2: In the next step one chooses rendering in minimum mode. The size of the volume box is reduced. The green line shows the camera line and the side from which one is observing the organs.

POSSIBLE CLINICAL USE

There are some regions of interests using minimum mode, especially in the thorax and abdomen.

Abdomen

STOMACH: Double bubble

The different filling states of the stomach from the perspective of atresias were imaged very clearly and graphically. In these cases we also used 4D imaging, which enabled us to image the resistance peristalsis (Figure 3).

DIAPHRAGMATIC HERNIA :

The imaging of hypoechogenic structures in the thorax located beside the heart can be done very quickly. The shift of the heart and the abnormal anatomy of the vessels can also be imaged. Since a volume data set is obtained one obtains a graphic idea of the organs (Figure 4, 5).

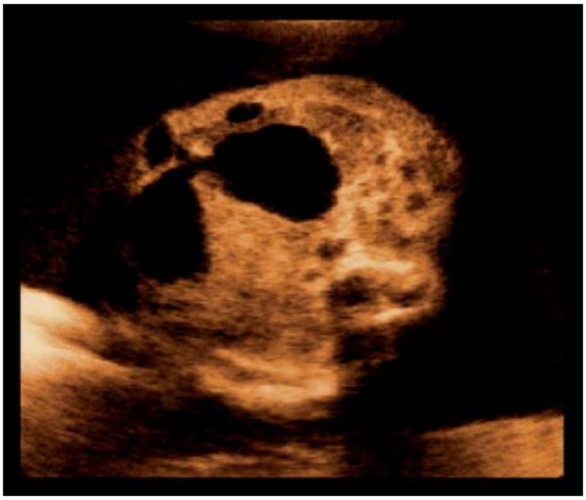


Figure 3: Image of a case with duodenal atresia. One can clearly seen the stomach, the pylorus and the upper duodenum.

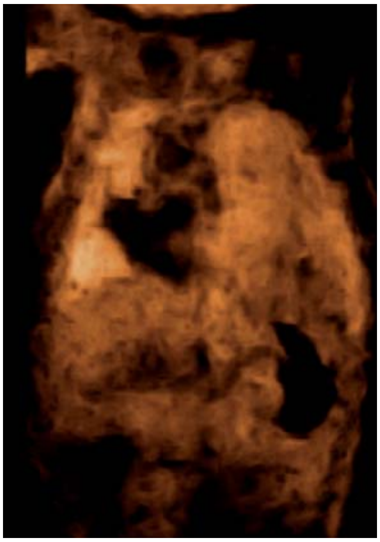


Figure 4: Image of a right-sided diaphragmatic hernia, 22nd gw. In a frontal plane one can see the stomach and the the heart on different sites.

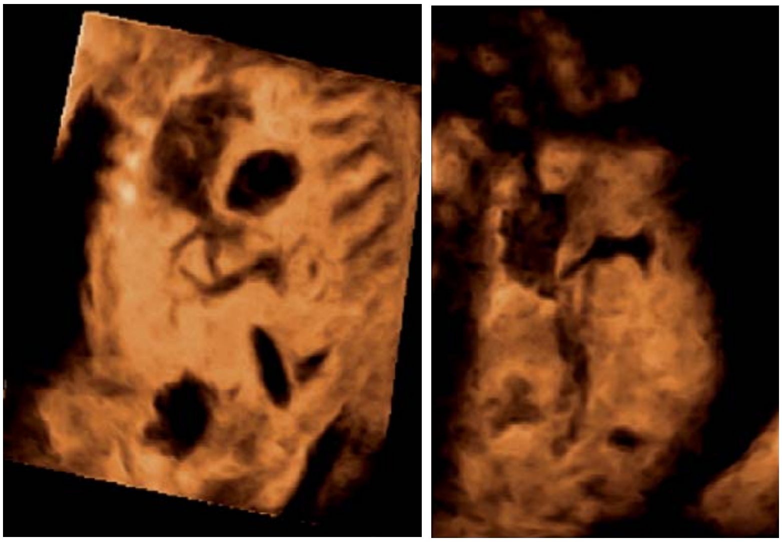


Figure 5: Left-sided diaphragmatic hernia with displacement of the stomach into the thorax.

Urogenital Tract

MALFORMATIONS OF THE UROGENITAL TRACT :

The malformations of the urogenital tract involved kidneys with urinary obstruction with expanded ureters, or fetuses with megacystis. In all cases we quickly obtained an image of the expanded renal pelvis and also of the expanded ureters over their whole course. Further, the imaging of the megacysti was very graphic, which makes possible calculation of the volume. The beginning of the urethra (keyhole phenomenon) was also visible. (Figure 6, 7, 8, 9).

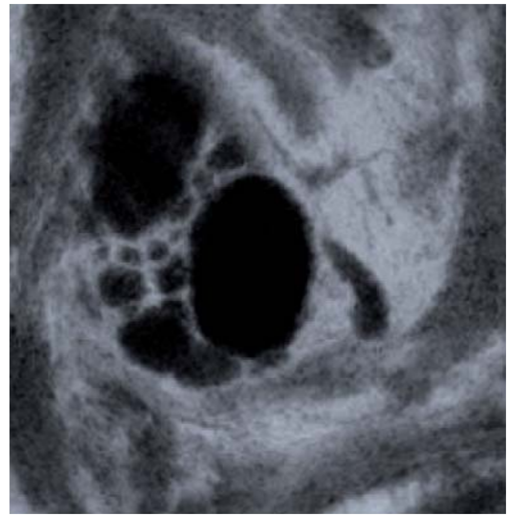


Figure 6: Image of a polycystic kidney in minimum mode. The differentiation of the various cyst´s is easily possible.

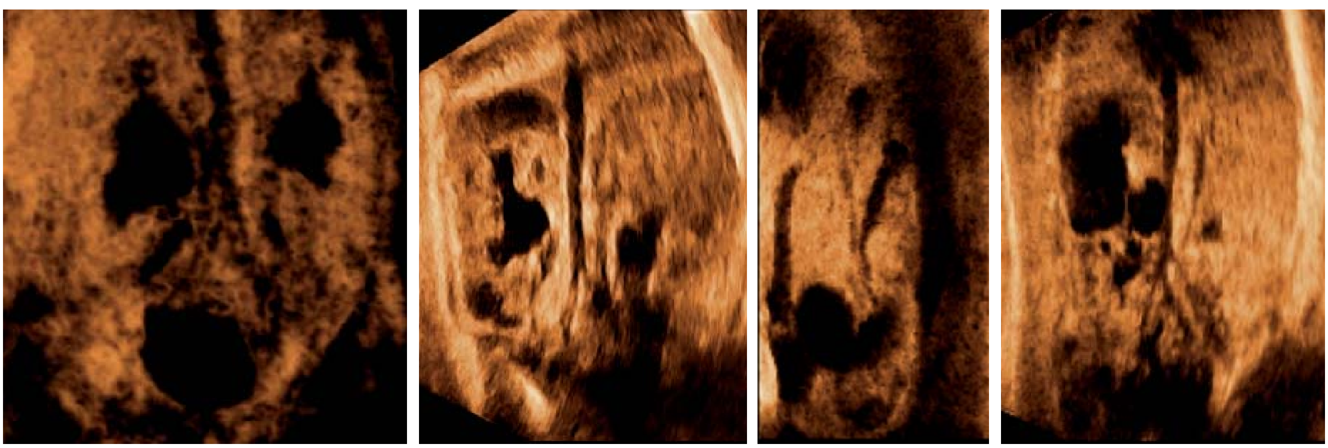


Figure 7: Frontal view in fetuses with bilateral hydronephrosis (22nd gw)

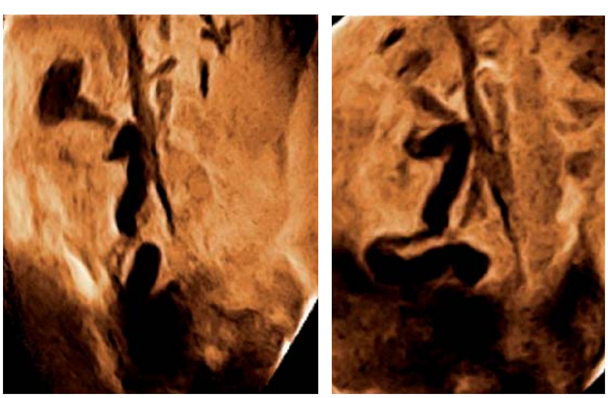


Figure 8: Visualization of the dilated ureter in a fetus with unilateral renal duplication seen from different angles.

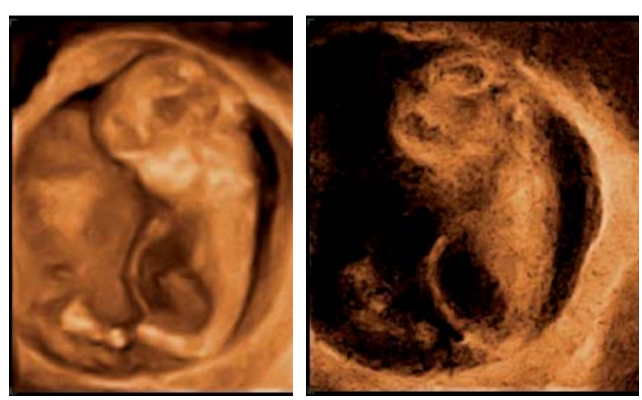


Figure 9: Comparison of surface mode and minimum mode in a case of megacystis.

Thorax

CYSTIC MALFORMATIONS IN THE THORAX :

Fetuses with cystic malformations of the lung were examined. In minimum mode a clear differentiation from the stomach was possible, with the location on different sides of the stomach and heart being immediately perceptible. In addition, one obtained a very graphic image of the lung (Figure 10, 11, 12).

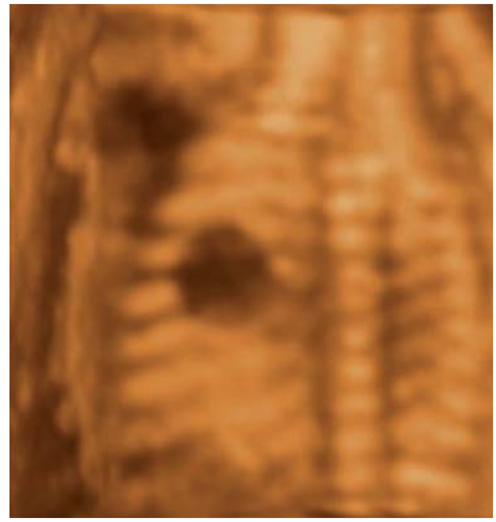


Figure 10: Image of a large lung cyst associated with a congenital, cystic-adenomatoid malformation (CCAM) of the lung.

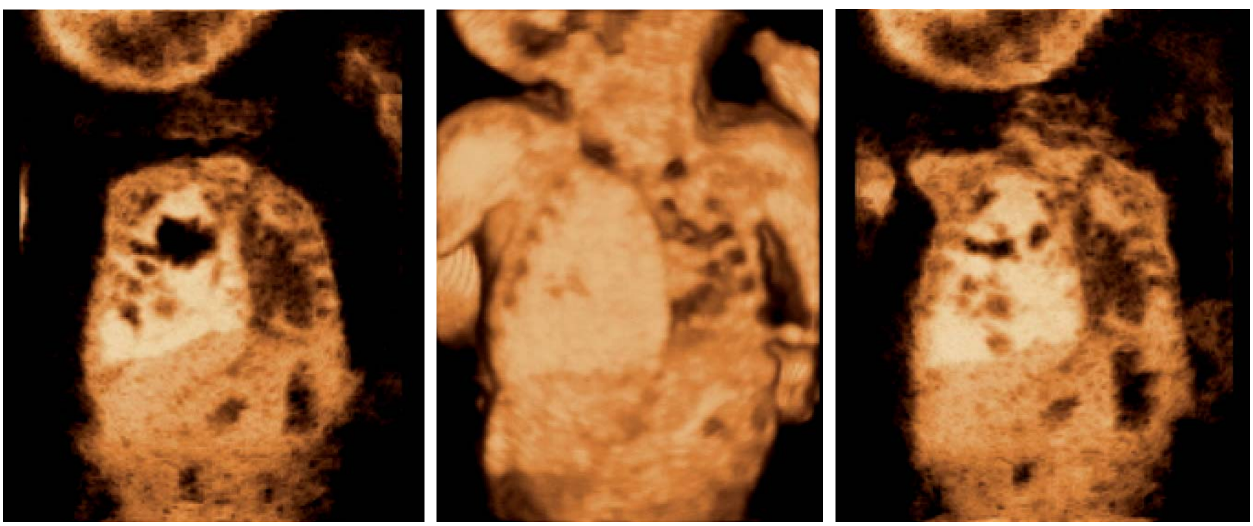


Figure 11: Visualization of the cystic structures in a case with pulmonary sequestration.

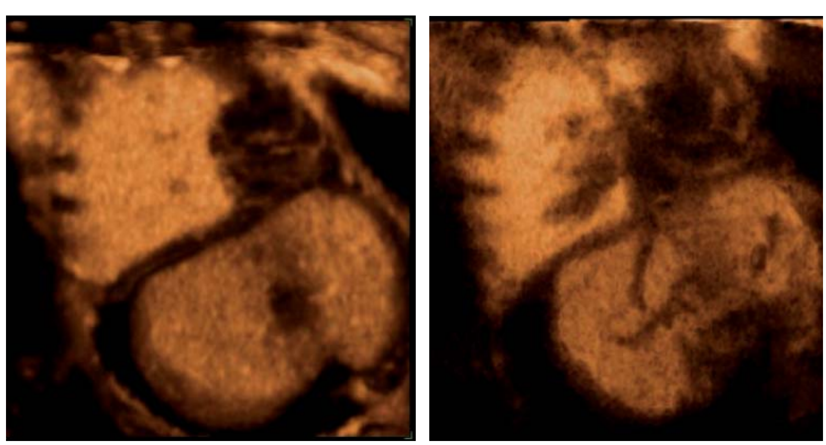


Figure 12: With minimum mode it is easy to see the dilated bronchi in a case with unilateral bronchial atresia.

Heart

HEART DEFECTS:

We performed a static volume acquisition in all cases of heart defect. The size of the volume corresponded to the thorax, and we took care to include the stomach in the volume. The presentation of the volume data in the minimum mode technique is advantageous, in particular, for imaging the course of the great vessels (aortic arch, ductal arch) (Figure 13, 14, 15, 16).

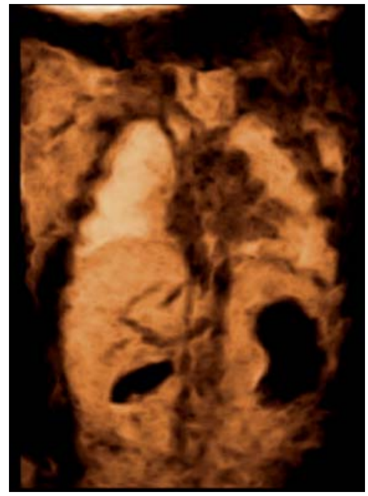


Figure 13: The volume processed in minimum mode can then be observed in a frontal plane, or from a longitudinal sagittal plane, or from any other plane one wishes. In the frontal plane one sees the heart and stomach on the same side, with the aorta and vena cava inferior on different sides. The lung is very graphically visible separate from the liver. From the longitudinal sagittal plane the heart with the origin of the great vessels can be seen. The veno-atrial connection is imaged well. This is also the case for the aorta and the vena cava inferior.

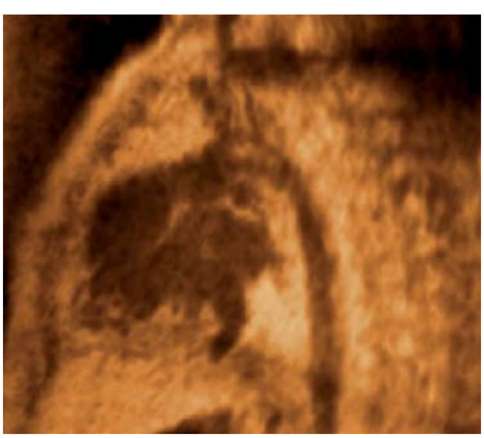
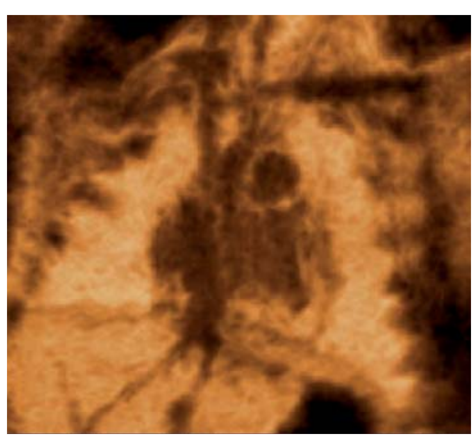


Figure 14: In fetal echocardiography the minimum mode can be used to obtain a good image of the origin of the great vessels with the aortic arch and the ductal arch. Viewed from a frontal plane the inflow of the liver veins and the vena cava inferior into the heart can be seen very clearly. From a longitudinal sagittal plane the imaging of the differentiation of the aortal arch and ductal arch is good and the origin of the stem vessels is visible.



Heart deffect TGA

Heart deffect common arterial trunc

Figure 15: Parallel course of the great vessels in a fetus with transposition of the great arteries.

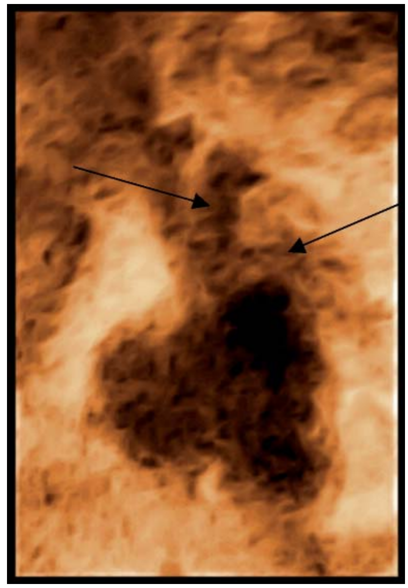


Figure 16: Common arterial trunk with right sided aortic arch (arrow left) and a narrow pulmonary artery (arrow right).

Other organs, for example brain, eyes, neck

Depends of the kind of disease or malformation there are other possibilities for using minimum mode in examination these organs (figure 17, 18, 19).

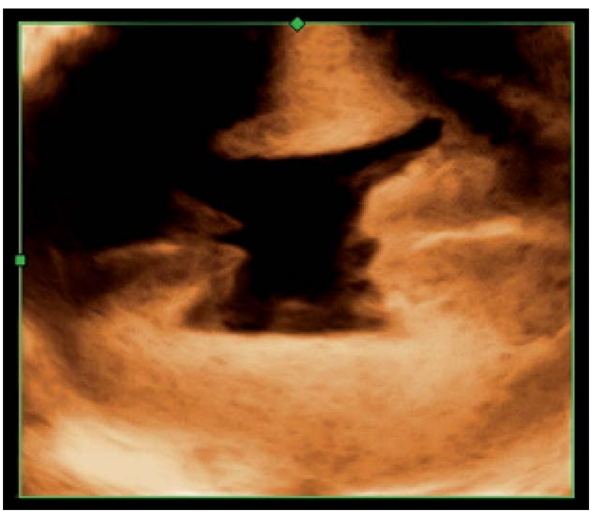


Figure 18: A case of septooptical dysplasia. With minimum mode one can seen the loss of the junction between the hemispheres.

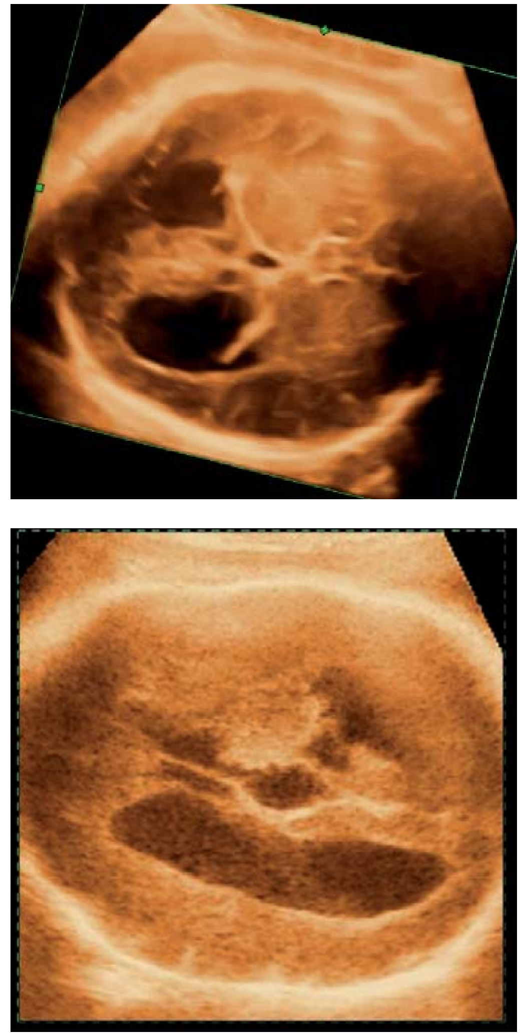


Figure 17: Mild ventriculomegaly with surface (left) and minimum mode(right).

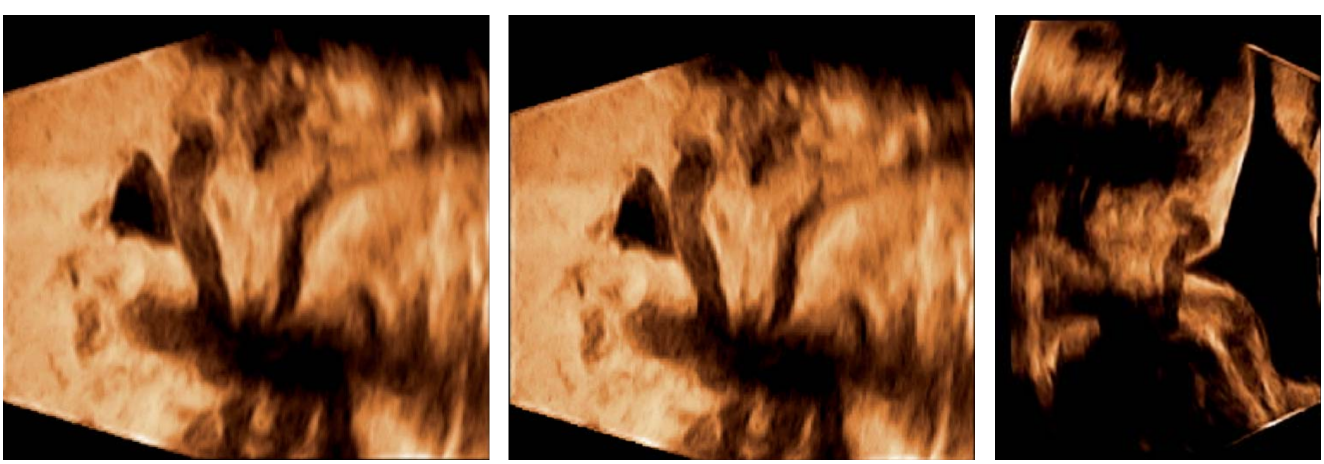


Figure 19. Dilated neck vessels in a case of aneurysm of vein of Galen.

DISCUSSION

The use of 3D/4D ultrasound has had a immense influence on prenatal diagnostics. The potential of this technology is clearly greater than that of surface imaging of the fetus. In the present observational study we present our experience in using minimum mode to image fluid-filled organs on the basis of a volume data set in normal fetuses and in fetuses with various malformations.

Technical limitations – in addition to the abdominal wall of the mother, which is the case for all ultrasound techniques – are, above all, fetal movements and the presence of the extremities in front of the thoracic and abdominal wall, in particular when the fetus is in a bent position. Since volume acquisition only takes a few ms one can attempt to compensate for these limitations by acquiring several volumes. In a large majority of the cases it is possible to obtain a useful volume image in the first or second attempt. The quality of the volume depends significantly on the position of the fetus during acquisition. The technically best volumes were obtained from a sagittal longitudinal plane through the fetus when the fetus was in a dorso-posterior position. Volume data sets obtained using a frontal longitudinal plane or a horizontal section are also usable, but of somewhat inferior quality technically. One has to keep in mind that the imaging plane A represents the real data set, whereas the corresponding planes are only the result of calculation.

Nonetheless, it is possible – in particular in cases of malformations in which the fetal position does not satisfy the desired criteria – to obtain useful volumes. After a short learning curve, the time needed for the examination is not influenced by use of the technique.

The use of volume technologies in the diagnosis of malformations has only been described a couple of times. For example, Heling et al. described the diagnosis of an aneurysm of Galen's vein by means of 3-dimensional Colour Power Technology, and obtained images that strongly resembled those obtained using postnatal angiography. Kalache et al. have described the use of 3D Colour Power Angiography for imaging vessel malformations. The disadvantage of this technique, however, is that if focuses on the flow of blood so that one obtains no information about the surrounding tissue.

According to Achiron et al. imaging of the right-sided aortic arch by means of ultrasound is easy to carry out. By means of the minimum mode this can also be imaged, in contrast with conventional B-mode image technology, in relation to the trachea (Espinoza et al).

Imaging of the vessels will certainly remain the domain of colour Doppler ultrasound, especially as new techniques have been developed in this area (Heling et al). However, the disadvantage of colour Doppler is that one only sees the vessel, whereas with minimum mode one obtains the spatial relationship to the surrounding organs. An advantage of the minimum mode technology that should not be underestimated is the higher image sequence rate, which means a better image quality using a pure B-mode image technology, i.e. without using Doppler ultrasound. In fetal echocardiography imaging of the heart can proceed either from a 3D static volume acquisition or from a STIC volume (Chaoui et al; DeVore)

Espinoza et al. investigated the use of minimum mode technology in fetal echocardiography. The authors said that the technology had advantages, in particular for evaluating the three-vessel view. They describe the use of the technology in fetuses with heterotaxy. The use of the minimum mode enabled imaging of the typical characteristics of the atria, in contrast with conventional 2D technology. The atrial appendages are typical signs of heterotaxy (Sharland and Cook) and it was possible to obtain an image of these appendages by means of the minimum mode.

There are only a very few reports on the use of the minimum mode for evaluating abdominal structures (Chaoui et al; Heling et al). In the present observational study we were able to show very graphically the spatial relationship of the organ systems to each other, especially in the case of malformations. Since one has a volume data set one can navigate in this data set, determining very easily which side of the body an organ is located on (stomach, vessels, heart) and also show pediatricians and child surgeons images which are very similar to those of postnatal diagnostics.

Possible future developments are the volume calculation of fluid-filled organs using the vocal technology and its use with 4D ultrasound. For example, in a fetus with a duodenal atresia a very graphic image of the resistance peristalsis can be obtained in minimum mode.

CONCLUSIONS

Minimum mode technology is an aspect of volume ultrasound. It is a special technique for processing volume data sets obtained through 3D, 4D or STIC. Minimum mode technology makes possible good imaging of fluid-filled organs. In the present observational study we demonstrate the use of the method in normal fetuses and in fetuses with various malformation. The use of the technique allows us a faster and easier diagnosis and differentialdiagnosis in fetuses with malformatioins.

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