

Standard protocol for fetal cardiac assessment using 3D/4D ultrasound.

PRACTICE GUIDELINES

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INTRODUCTION

Fetal heart is one of the most difficult organs to examine during fetal ultrasound. Conventional two-dimensional ultrasound displays only those planes that were visualized during scanning [1]. The ultrasound screening of the fetal heart using a four-chamber view alone allows detection of 4.5 - 60 % of major cardiac defects [2,3]. If ventricular outflows are included in the routine screening protocol, the detection rate of major cardiac diseases may be significantly increased to 85.5 - 90% [3,4]. Therefore, the 'Ultrasound screening guidelines' proposed by AIUM (American Institute of Ultrasound in Medicine) and the ISUOG states that the left and right ventricular outflows should be included in the "optimal examination" of the fetus 'if technically feasible' [5,6]. However, this approach requires compound manipulation including sliding, rotation and angulation of the transducer during the examination, which is often felt difficult by many inexperienced examiners, especially when the fetus is active [7].

Three-dimensional ultrasound has recently been proposed as a valuable adjunctive technique to conventional 2D fetal echocardiography. A number of 3D technologies, including 3D Multi-planar imaging, 3D Extended Imaging (3D XI) and Spatial Temporal Image Correlation (STIC), can be used for fetal cardiac examination [8-11]. As 3D ultrasound acquires an image data set from a volume and allows multiplanar reformat, it gives a freedom to recreate an infinite number of images in various planes ranging from the standard axial, sagittal and coronal planes to the special oblique planes that are tailored for visualization of the specific regions of the heart. However, spatial and anatomical orientation during the volume analysis appears difficult to less experienced operator [12].

In this paper we introduce the standard postprocessing protocol for evaluation of fetal cardiac anatomy using 3D Multi-Planar imaging. This step-by-step approach will enable consistent visualization of the cardiac structures of crucial importance during volume manipulation.

IMAGE DATA ACQUISITION

A set of volume image data for cardiac assessment is acquired from a 3D probe placed across the fetal thorax at the level of a four-chamber plane. The acquired data are then processed

instantaneously into three planes that are perpendicular to each other. These three planes are referred to as A-plane, B-plane and C-plane (Figure 1). The images in the A-, B-, C-planes can be rotated and sliced so that the fetal cardiac landmarks can be viewed in three different imaging planes.

KEY POINT

- During navigation within the volume verify the position of the reference dot in the 'A-', 'B-' and 'C-planes' images.

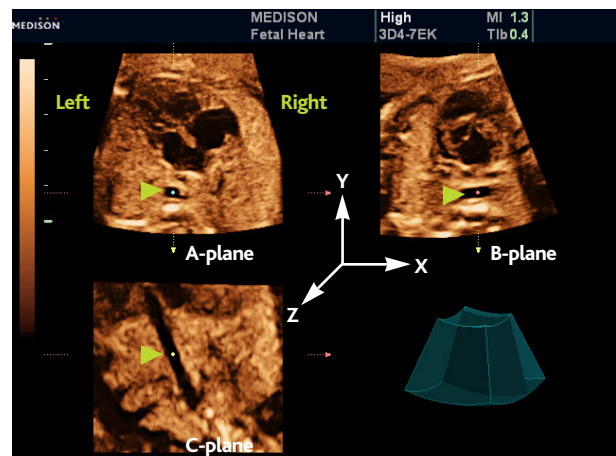


FIGURE 1. Multi-planar mode. A-, B-, C-planes. The reference dot (green arrow head) is on the descending aorta in all three orthogonal images. Right, Left - fetus sidedness.

STARTING POINT: ALIGNING THE IMAGES TO THE ORTHOGONAL BODY PLANES

In order to visualize the fetal cardiac structures in a reproducible manner, it is important to start from the imaging planes that are perpendicular to the body axis. For this purpose, the A-, B-, C-planes on the tri-planar imaging display are used for the axial, sagittal and coronal images, respectively (Figure 2).

KEY POINTS

- Find a four-chamber position in the A-plane
- Place the spine (it means that also descending aorta) on the 6 o'clock position and the sternum on the 12 o'clock position by rotating the 'A-plane' image
- Use descending aorta for orientation and place the reference dot on the aorta in the 'A-', 'B-' and 'C-plane' images
- Aorta on the 'C-plane' image vertically orientated with the head and neck on the top

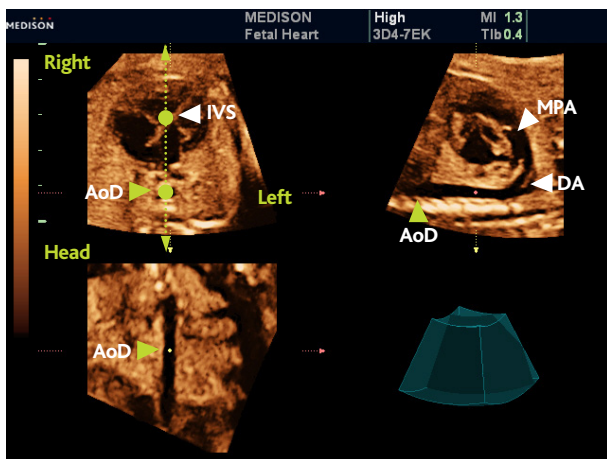


FIGURE 2. Multi-planar mode. A four-chamber image in the A-plane with the spine on the 6 o'clock and the sternum on the 12 o'clock position is used as the 'starting plane'. The reference dot (green arrow heads) was positioned on the descending aorta (AoD) in the 'A-, B- C-planes' images. 'A-plane' image: four chambers in an axial view; 'B-plane' image: ductal arch in a sagittal view; 'C-plane' image: descending aorta in a coronal view. In the A-plane, dotted green line (that corresponds to the virtual Y-axis) is drawn through two anatomical landmarks of ductal arch on the four chambers view: 1- aorta and 2- level of insertion of the septal leaflet of the tricuspid valve at the interventricular septum (IVS). MPA - main pulmonary artery; DA - ductus arteriosus

- Rotate the 'A-plane' image showing the four chambers around Z-axis (A-plane is active) until the spine is located on the center of the lower margin of the image (6 o'clock position), the sternum is located on the center of the upper margin (12 o'clock position) and the ribs are symmetrically aligned.
- Move the reference dot in the 'A-plane' image to the descending aorta. This procedure will automatically place the reference dots in all planes on the descending aorta.
- Rotate the 'C-plane' image until a coronal view of the thorax is shown like a frontal chest x-ray (head and neck on the top) with the descending aorta vertically oriented. Check that the descending aorta seen in a sagittal view in the B-plane is horizontally oriented. If it is not, rotate slightly the B-plane image until the descending aorta is perfectly horizontal.

VISUALIZING THE BASIC VIEWS FOR CARDIAC ASSESSMENT according to S. Yagel and S-J Yoo criteria

KEY POINT

Gentle scrolling along the descending aorta in the coronal plane allows navigation through the axial fetal cardiac images from the upper abdomen to the upper mediastinum

In the C-plane, navigate the reference dot from the bottom to the top along the descending aorta. This will allow you to visualize the following axial images in the A-plane:

- 1) Upper abdomen with the stomach
- 2) 4-chamber view
- 3) 5-chamber view, where the aortic root is visualized

4) Main pulmonary artery with bifurcation to the corresponding left and right pulmonary arteries

5) Three-vessel and trachea view (Figure 3, A-E) [13,14]

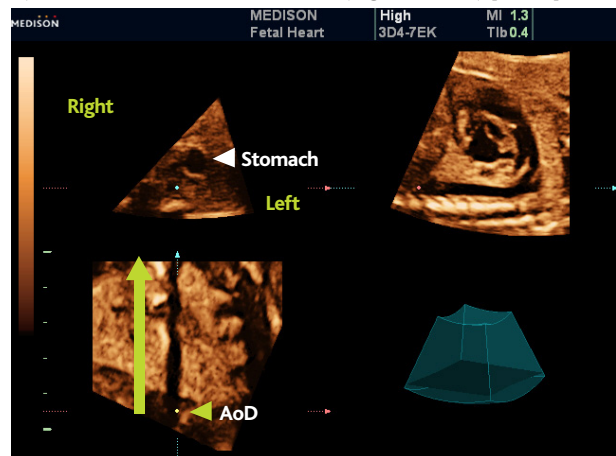


FIGURE 3A. Multi-planar mode. In the 'C-plane' image the reference dot (green arrow head) was positioned on the lower part of the descending aorta in the upper abdomen of the fetus. This position of the reference dot in the C-plane brings the stomach in the 'A-plane' image. The stomach (white arrow head) is on the left side of the fetus. Right, Left - fetus sidedness.

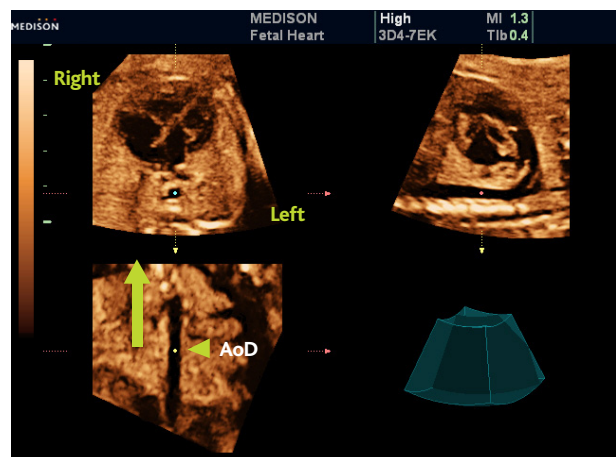


FIGURE 3B. Multi-planar mode. In the 'C-plane' image the reference dot (green arrow head) was moved toward the fetal head along the descending aorta (AoD) until a 4-chamber view appears on the axial image in the A-plane. Right, Left - fetus sidedness.

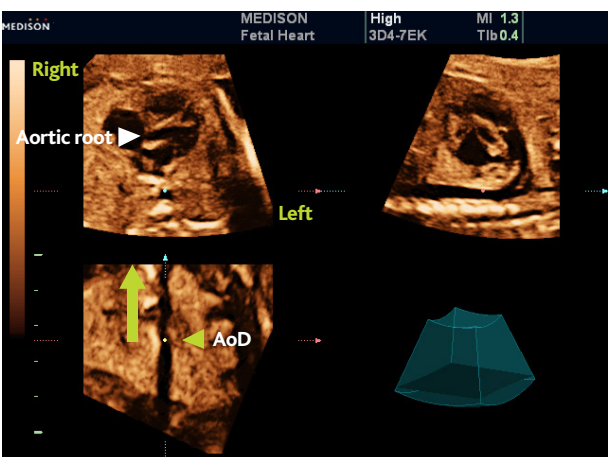


FIGURE 3C. Multi-planar mode. Further slight upward navigation of the reference dot (green arrow head) along the descending aorta (AoD) on the coronal image in the C-plane brings a 5-chamber view, where the aortic root (white arrow head) is visualized on the axial image in the A-plane. Right, Left - fetus sidedness.

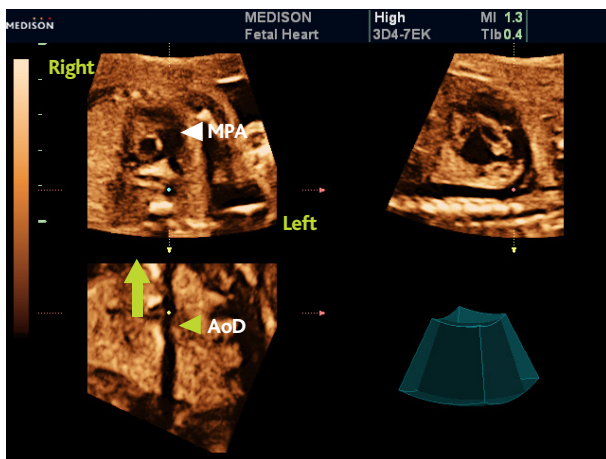


FIGURE 3D. Multi-planar mode. Further upward navigation of the reference dot (green arrow head) along the descending aorta (AoD) in the C-plane brings the main pulmonary artery (MPA) (white arrow head) bifurcating into the branch pulmonary arteries on the axial image in the A-plane. Right, Left - fetus sidedness.

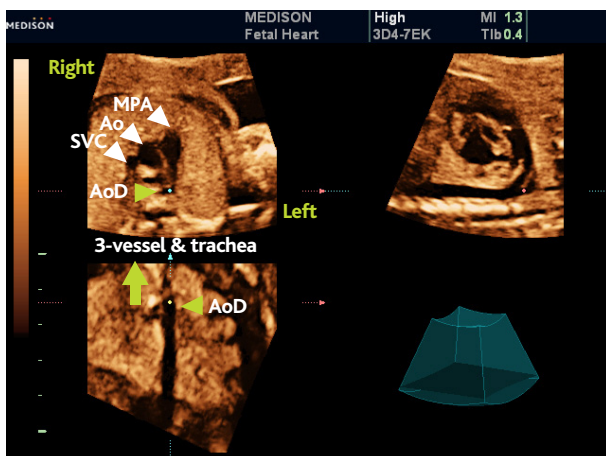


FIGURE 3E. Multi-planar mode. Further upward navigation of the reference dot (green arrow head) along the descending aorta (AoD) in the C-plane brings the three-vessel and trachea view on the axial image in the A-plane. Right, Left - fetus sidedness. MPA - main pulmonary artery; Ao - aorta; SVC - superior vena cava.

VENTRICULAR OUTFLOW TRACTS

Rotation of the image with the reference dot on the aortic valve or root will allow visualization of the ventricular outflow tracts.

KEY POINTS

- Find 5-chamber position in the A-plane
- Place the reference dot on the aortic valve/root on the axial plane

- In the 'C-plane' image, move the reference dot upward or downward along the descending aorta until the aortic root is visualized (5-chamber view) in the 'A-plane' image.
- In the 'A-plane' image move the reference dot to the center of the aortic valve/root. The 'C-plane' image will also show that the dot is in the center of the aortic valve/root.
- Rotate slightly the 'A-plane' image clockwise until the 'A-plane' image shows a left ventricular outflow tract view and the 'B-plane' image shows a basal short axis view (right ventricular outflow tract) (Figure 4).

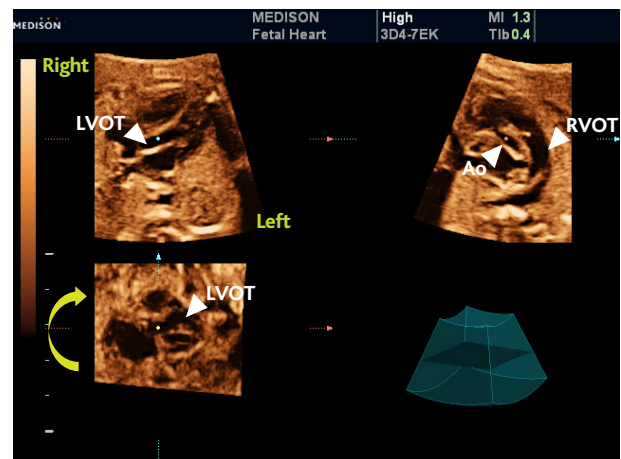


FIGURE 4. Multi-planar mode. The reference dot is on the aortic root in all planes. Ao - aorta; LVOT - left ventricular outflow tract; RVOT - right ventricular outflow tract.

AORTIC AND DUCTAL ARCHES, and SYSTEMIC VENOUS CONNECTIONS

KEY POINTS

- Find three-vessel position in the A-plane
- Ascending aorta/main pulmonary artery and descending aorta vertically aligned

- Find three-vessel position in the 'A-plane' image as shown on the Figure 3E.
- In the 'A-plane' image the reference dot should be on the descending aorta (if not, place the reference dot on the short cut of the descending aorta). In this position main pulmonary artery and descending aorta are vertically aligned; this brings the ductal arch in the B-plane (Figure 5).

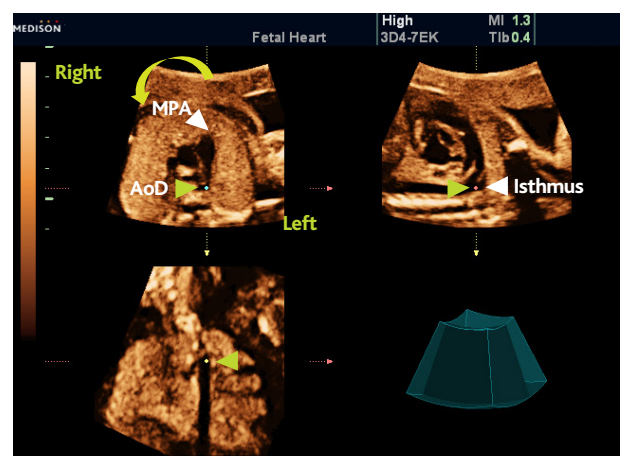


FIGURE 5. Multi-planar mode. The reference dot (green arrow head) is on the descending aorta in all planes. 'A-plane' image: axial view of the three-vessel and trachea. 'B-plane' image: sagittal view of the ductal arch. 'C-plane' image: coronal view of the descending aorta. MPA - main pulmonary artery; AoD - descending aorta; Right, Left - fetus sidedness.

- Rotate slightly the 'A-plane' image around Z-axis (around descending aorta) so that the ascending aorta and descending aorta are aligned vertically; this brings the aortic arch view in the B-plane (Figure 6).

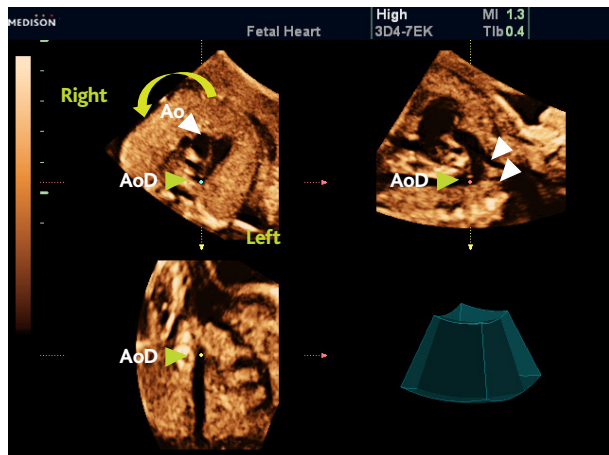


FIGURE 6. Multi-planar mode. The reference dot (green arrow head) is on the descending aorta (AoD) in all planes. 'A-plane' image: axial view through three-vessel and trachea. 'B-plane' image: sagittal view of the aortic arch. 'C-plane' image: coronal view of the descending aorta. Partly visualized brachiocephalic vessels (white arrow heads). Right, Left - fetus sidedness; Ao - ascending aorta;

- In the 'A-plane' image, move the reference dot to the superior vena cava and this brings the superior and inferior venae cavae connecting to the right atrium in the 'B-plane' image (Figure 7).

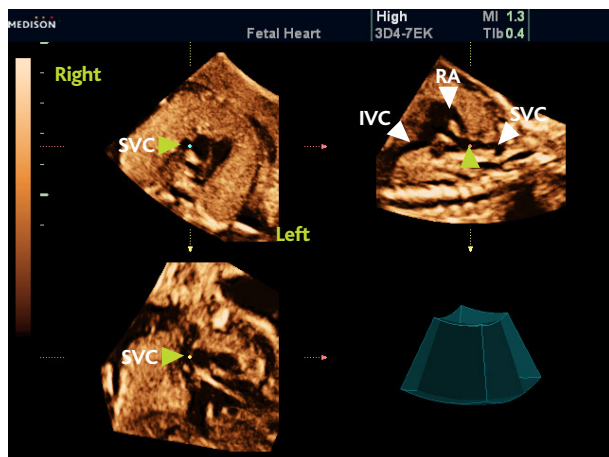


FIGURE 7. Multi-planar mode. The reference dot (green arrow head) is on the superior vena cava (SVC) in all planes. 'A-plane' image: axial view through three-vessel and trachea. 'B-plane' image: venous return to the right atrium (RA). 'C-plane' image: coronal view through the three great vessels. IVC - inferior vena cava; Right, Left - fetus sidedness.

NOTE

If you got 'lost' during manipulation with 3D fetal cardiac volume assessment, re-start from the orthogonal planes shown on the Figure 2.

TO CONCLUDE

Three-dimensional ultrasound allows acquisition of one volume data set for complete anatomical assessment of the fetal heart. The standard protocol for 3D volume assessment of the fetal

heart described herein facilitates visualization of the 'basic' and 'extended' fetal cardiac planes that include the transverse view of the upper abdomen, 4-chamber view, 5-chamber view, 3-vessel view, ventricular outflow tract views, aortic and ductal arch views and sagittal view for the systemic venous return. Fetal cardiac examination with 3D technology and standard postprocessing protocol is less dependent on the experience and skill of the operator.

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REFERENCES

- 1) M. Scansky, D Miller, G. Devore at all. Prenatal screening for congenital heart disease using real-time three-dimensional echocardiography and a novel "sweep volume" acquisition technique. *Ultrasound Obstet. Gynecol* 2005
- 2) Buskens E, Grobbee DE, Frohn-Mulder IME et al. Efficacy of Routine Fetal Ultrasound Screening for Congenital Heart Disease in Normal Pregnancy. *Circulation*. 1996, 94: 67-72
- 3) Allan L. Antenatal diagnosis of heart disease. *Heart*, 2000, 83: 367
- 4) Stumpflen I, Stumpflen A, Wimmer M, Bernaschek G. Effect of detailed fetal echocardiography as part of routine prenatal ultrasonographic screening on detection of congenital heart disease. 1996, *Lancet* 348: 854-857
- 5) AIUM Practice Guideline for the Performance of an Antepartum Obstetric Ultrasound Examination. *J Ultrasound Med*, 2003, 22: 116-1125
- 6) International Society of Ultrasound in Obstetrics and Gynecology (ISUOG). Cardiac screening examination of the fetus: guidelines for performing the "basic" and "extended basic" cardiac scan. *Ultrasound Obstet Gynecol* 2006, 27: 107-113
- 7) Yoo S-J, Lee Y-H, Kim ES, Ryu HM, Kim MY, Choi H-K, Cho KS, Kim A. Three-vessel view of the fetal upper mediastinum: an easy means of detecting abnormalities of the ventricular outflow tracts and great arteries during obstetrics screening. *Ultrasound Obstet Gynecol* 9 1997, 173-182
- 8) Espinoza J, Goncalves LF, Lee W, et al. The use of the minimum projector Mode in 4 - dimensional examination of the fetal heart with spatio - temporal image correlation. *J Ultrasound Med* 2004, 23: 1337-1348
- 9) Meyer -Wittkoff M, Cooper S, Vaughan J, Sholler G. Three - dimensional (3D) echocardiographic analysis of congenital heart disease in the fetus: comparison with cross sectional (2D) fetal echocardiography. *Ultrasound Obstet Gynecol* 2001, 17:485-492
- 10) DeVore GR, Sklansky MS. Three-dimensional imaging of the fetal heart: Current applications and future directions. *Progress in Pediatric Cardiology*, 2006, 22: 9-29.
- 11) Leung KY, Ngai CSW, Chan BC, Leung WC, Tang MHY. Three - dimensional extended imaging: a new display modality for three-dimensional ultrasound examination. *Ultrasound Obstet Gynecol* 2005, 26: 244-251
- 12) Merz E, Benoit B, Blaas H et al. Standardization of three-dimensional images in obstetrics and gynecology: consensus statement. *Ultrasound Obstet Gynecol* 2007, 29: 697-703
- 13) Yagel S, Cohen SM, Achiron R, Examination of the fetal heart by five short-axis views: a proposed screening method for comprehensive cardiac evaluation. *Ultrasound Obstet Gynecol* 2001, 17: 367-369
- 14) Yoo S-J, Lee Y-H Kim ES, Ryu HM, Kim MY, Choi H-K, Cho KS, Kim A. Three-vessel view of the fetal upper mediastinum: an easy means of detecting abnormalities of the ventricular outflow tracts and great arteries during obstetrics screening. *Ultrasound Obstet Gynecol* 9 1997, 173-182