Visualization of the atrioventricular valve plane in fetuses with atrioventricular defect using STIC technique

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Synopsis:
In this study STIC-rendering and STIC-TUI acquisition in examination of the fetal heart is feasible and the technique alow visualization of the atrioventricular plane in normal fetuses and in fetuses with atrioventricular septal defect.

Abstract

Objectives: *To asses the feasibility of Spatio-temporal image correlation (STIC) -rendering and Spatio-temporal image correlation with Tomographic ultrasound image (STIC-TUI) acquisition of the AV plane in normal fetuses and in fetuses with atrioventricular septal defect (AVSD), and to ascertain whether these planes add useful information in fetal cardiac examination.*

Method: *60 ultrasound exams in normal fetuses and 5 exams for fetuses with complete atrioventricular septal defect were performed; the volumes were acquired in apical or lateral four-chamber view of the heart, with STIC-rendered and STIC-TUI acquisition. In the STIC-rendered acquisition, the render box was placed either with the render view direction in the atria at the level of the valves (the en-face view of the atrioventricular valves and semilunar valves), either with the render view direction in the ventricles close to the atrioventricular plane. Afterwards the volume acquired in apical or lateral (preferably in apical) view was set with STIC-TUI acquisition and the distance between slices was adjusted finally until an optimal analysis was possible.*

Results: *The acquisition of the cardiac volume with STIC-rendered was possible in 93,8% cases and with STIC-TUI is possible in all cases. In normal cases, with STIC-rendering acquisition we can show the position of the papillary muscle at the level of the left and right ventricle. In complete AVSD cases the common atrioventricular valve can be seen with five leaflets. A sequential segmental analysis of the fetal heart could be shown with STIC-TUI in all cases. The both modalities improved visualization of the AV plane and diagnosing the defects at this level, improves also the evaluation of the AV annuli in relation with the major vessels.*

Conclusions: *The volume acquisition of the atrioventricular plane with STIC-rendering and STIC-TUI modalities allows visualization of the images that are not easily accessible with standard 2D sonography, enabling a rapid assessment of the normal and abnormal fetal cardiac structure, respectively AVSD.*

Keywords: *atrioventricular septal defect, congenital heart disease, spatiotemporal image correlation, tomographic ultrasound image*

Introduction

In the last ten years 3D and 4D ultrasound (also called live ultrasound) in the examination of fetal heart evolved rapidly. Perhaps in no other organ system is a recent major progress as evident as in the fetal cardiovascular system. With the advent of a new technique called STIC (spatial and temporal image correlation) it is possible to make the acquisition of a volume data set with information directly to the beating fetal heart[1]. Today, many centres have 3D/4D ultrasound capabilities and a lot of studies in the literature are based on 3D/4D examination of the fetal heart.

A detailed examination of the fetal heart includes visualization of the different cross-sectional planes either in transverse parallel planes, either oblique plane in short and long axis views. The use of colour Doppler completes the examination in confirmation of the blood flow at the level of chambers, vessels and valves of the heart[2,3]. Such planes on 2D or colour Doppler are acquired online during examination but could be generated off-line from a 3D volume data set. The introduction of some virtual planes to fetal echocardiography with the use of the 3D/4D examination has helped us to obtain views of the fetal heart not generally accessible with a standard 2D examination[4].

The fetal atrioventricular (AV) valve junction is formed by the mitral and tricuspid valves. Although both AV valves are usually evaluated in an apical or lateral 4-chamber view of the heart, visualization of the morphology of leaflets and papillary muscles is obtained in a short axis view through the ventricles, which is obtained parallel to and slightly to the left of the fetal sternum. To visualize in this section is rather difficult for most sonographers. Diagnosis of atrioventricular septal defect (AVSD) can be made if the operator skill is combined with knowledge and many years of experience.

Objectives

The aim of our prospective study was to asses the clinical potential of STIC-rendering (surface mode) of the AV junction and to display the morphology of the AV valve junction in normal fetuses and in those with complete AVSD. Also, we assess the role of the 4D echocardiography STIC with TUI (tomographic ultrasound imaging) in the sequential analysis of fetal heart and of the atrioventricular valve planes.

Material and methods

The prospective study consists of 65 fetuses, 5 fetuses with complete AVSD and 60 normal fetuses. The normal fetuses were appropriate in size for the gestational age with normal cardiac and extracardiac anatomy. The fetuses were examined with the five planes technique of fetal echocardiography[3,5,6] and with STIC acquisition of the region of interest-AV annuli[1]. From the 5 fetuses with complete AVSD only for one we could make karyotyping and it was associated with trisomy 21, for the other 4 we cannot make karyotyping (because of the cost of the investigation). The mean gestational age of the patients with AVSD was 23 weeks.

Ultrasound examinations were done using a 4D ultrasound system with STIC capability (Voluson E8, General Electric System, Kretz, Austria) with a 4-8 MHz probe curved array. The scan was done with the fetus in a quiet state as possible, without movement. Volume datasets were obtained with apical or lateral insonation of the fetal heart and using transverse planes of the fetal upper abdomen and mediastinum starting from the 4-chamber view (Figure 1). To obtain a high quality rendered image, the maximum possible duration of acquisition and minimum acquisition sweep angle were used, so that automatic acquisition was performed lasting 10 sec with angles of acquisition between 15° and 30°. Extratime was allowed if necessary for the fetus to move to a more favourable position and for analysis of the volume datasets.

The examiner obtained the classic four-chamber view of the fetal heart in the upper left panel (A) of the multiplanar rendering screen and then defines the rendering box (Figure 2 and 3).

The examiner adjusted the direction of view in order to obtain the most apical four-chamber view and the imaged was also zoomed to 75% of the screen. We used two regions of interest systematically for the AV junction, the render box was placed to include the AV valves, around the AV annuli, the render view direction is placed in the atria at the level of the valves and enables the en face view of both the atrioventricular and semilunar valves, or the render view direction is placed in the ventricles near the AV plane. The view is sometimes adjusted using X-axis rotation to give an anteroposterior plane through the heart. The rendering box can be also adjusted coronal to observe also the great vessels[7].

After the examination with STIC-rendered acquisition, again we acquire a volume using a reference plane in apical or transversal four-chamber view of the fetal heart, but we prefer when it is possible the apical plane for AV valves. Afterwards we activate the TUI display mode using as a reference the four-chamber view. The number of slices was set to nine and the distance of slices was adjusted finely increasing with 1 mm gradually (Figure 4). The acquisition was performed lasting 10-15 seconds with angles of acquisition between 15⁰ and 30⁰.

Image quality depends on the following factors:

1. fetal spine should be positioned between 3 and 9 o`clock to minimize the shadowing of ribs and spine;
2. minimal maternal and fetal movement;
3. volume acquisition should start from four-chamber view and include the upper mediastinum[8].

Results

The complete AVSD can be classified according to Rastelli system[9], considering the extent of the anteroposterior bridging leaflet to the right ventricle. In type A the anterosuperior bridging leaflet can be attached to the papillary muscle on the crest of the septum. In type B the bridging leaflet is attached to the papillary muscle of the right ventricle and not to the septum. In type C it is attached to papillary muscle that supports the other leaflet of the common valve.

Figure 1. STIC-rendered surface mode acquisition using apical 4CH-view

Figure 2. 4D volume rendering 4CH-view

Figure 3. Positioning of the render box for AV-plane.

The study population of 65 fetuses was taken from pregnant women referred to our clinic for routine sonography. All were singleton pregnancies with the age of pregnancy between 20 and 29 weeks, with the mean gestation 23 weeks. Of the 5 fetuses with AVSD the maternal age was 21, 29, 34, 37 and 38 years old and the parity range between 1 to 3. From the 5 cases of AVSD, in 4 cases it was the single cardiac anomaly (Figure 5) and in 1 case the AVSD was associated with transposition of great vessels.

The volume acquisition and rendering was possible in 61/65 cases (93,8% cases). During the 4D real-time examination the valve appear thin, with movement without restriction and uniform in echogenicity. The medial tissue between the valves correspond to the septum (Figure 6 and 7).

The rendering volume of the left ventricle can show the position of the papillary muscle. This we obtained in 46/60 normal fetuses (76,7%). The muscles are positioned at approximately 3 o`clock and 7 o`clock at the normal fetuses. During the rendering of the right ventricle we visualized the papillary muscles (septal, anterior and posterior muscles) in 43/60 (71,6%) normal fetuses. In the remaining cases it cannot be made an adequate visualization. Limitations of the examinations of the AV annuli and of the papillary muscles were present because of the excessive fatal activity or fetal breathing. In these cases of excessive fetal activity the operator must wait for several minutes for a period of fetal quiescence. In the cases of fetal breathing movements no more then two such movements during acquisition did not have a significant effect on the quality of the image. Also, an important point was that in the cases of failed STIC acquisition of the four-chamber view and of the AV annuli, the maternal body habitus or excesive fetal movement of duration beyond reasonable extension of the time of examination were responsible. Also there are sometimes necessary for the AV annuli plane to make some fine movements with X and Y rotation.

In the cases of complete AVSD in the rendering - STIC image, there is a common orifice and the AV valve has five leaflets (Figure 8). Although it is very difficult to differentiate between each type of complete AVSD (the Rastelli classification) using the rendering - STIC examination of the AV annuli it is possible in some cases to do this and the important point is that we can have a confirmation of the complete AVSD visualized in the 2D examination and of the extension of the defect.

The acquisition of STIC and TUI was possible in all cases and we obtain also a complete sequential segmental analysis of fetal heart. The complete AVSD was diagnosed in all 5 cases (Figure 4). In all cases of AVSD we have anatomopathologic confirmation (Figure 9).

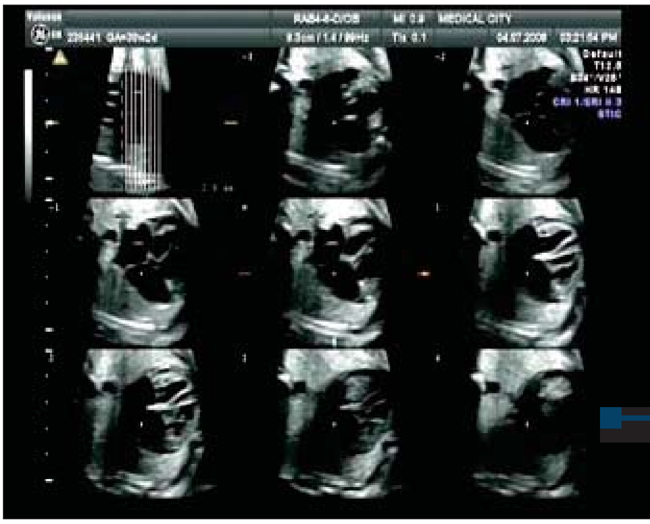

Figure 4. STIC-TUI acquisition of complete AVSD

Figure 5. Complete AVSD - 2D view

Discussion

Congenital heart disease are one of the most common congenital anomalies and most cases occur in low-risk women[10]. Fetal echocardiography remains the main method used for diagnosis of these anomalies, but to be an effective tool it must be reliable and feasible. So it must be accessible to the doctors and acceptable by the patients. Also for a technique to be effective it is necessary to be easily learnt by many doctors that were able to establish the nature and the prognosis of the cardiac anomaly[11].

The main goal of prenatal echocardiography is to visualize the anomalies of the fetal heart and of the great vessels, to establish the precise diagnosis and to provide images that will be able to make parents and other doctors to understand the cardiac anomalies. Using 4D-rendering examination of the fetal heart is improved the visualization of both normal and abnormal fetal heart[12].

Diagnosis of atrioventricular septal defect can be made if we combined operator skill, knowledge and experience. The Euroscan group presents a detection rate for isolated AVSD of 56%[11], and other systematic reviews reported a detection rate of 42% for complete AVSD[13].

Atrioventricular septal defect can be present in 2 forms[14]:

- **complete AVSD** - which can be diagnosed with 2D ultrasound better in diastole with the following elements: dominant atrium (septum primum absence), common atrioventricular valve (because of a fusion of the two atrioventricular orifices), absence of the cardiac crux, VSD (ventricular septal defects)
- **partial AVSD** - which can be very difficult to diagnose with 2D ultrasound with the following elements: dominant atrium (septum primum absence), the atrioventricular valves are separate but we did not find the normal plane of the insertion of the atrioventricular valves, so the atrioventricular valves are in the same plane.

The components of the AV valve junction can be reconstructed from the volumes obtain with the STIC acquisition with rendering capabilities from an apical or transversal four-chamber view, preferably from apical four-chamber view . Also the association of STIC with TUI acquisition give us information regarding the anatomy of the heart from the four-chambers view to arterial outflow connection.

There are some postnatal studies that describes the characteristics of the papillary muscles of both ventricles and the morphology of complete AVSD[15,16,17]. Type A complete AVSD commonly occurs alone or in association with Down syndrome, while type C is encountered with other cardiac anomalies like complete transposition of great vessels[18]. Complete balanced AVSD is the single anomaly most commonly associated with

Figure 6.
4D volume rendering of normal AV plane (systole)

Figure 7.
4D volume rendering of normal AV plane (dyastole)

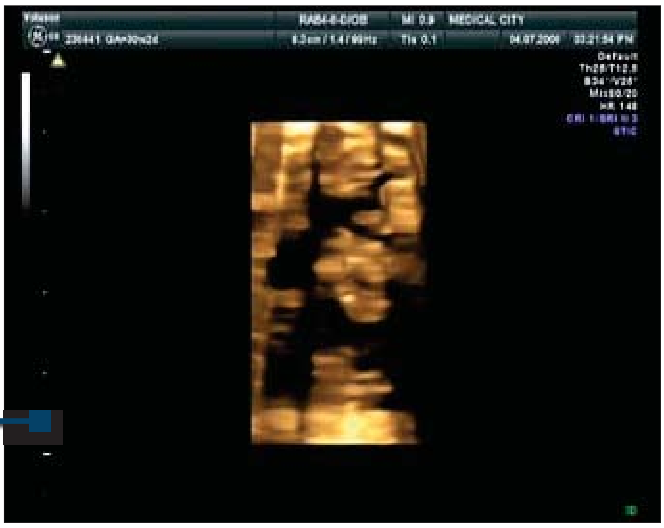

Figure 8.
4D volume rendering of complete AVSD

Down syndrome in the fetus. Much more rarely common AVSD is associated with other autosomal trisomies, 13 and 18[19,20,21].

The view of atrioventricular plane in 2D ultrasound has some limitation especially the difficulty in obtaining the coronal views. The major limitation of the methodology - STIC rendered - is that the coronal views are reconstructed and usually have a worst quality of the 3 multiplanar views, but still are better than 2D coronal images. The images that are obtained by STIC rendered acquisition in our study have diagnostic quality for the assessment of normal and abnormal AV plane. The images obtained with STIC –TUI acquisition are much easier to obtain, more rapid and gives information concerning the AV plane but also make an analysis of the other important segments of fetal heart. The plane of the AV valves obtained with STIC-rendered acquisition gives us images that are not formerly obtained and the characteristics of the connections of the vessels with heart chambers and AV valves. The contribution of the AV plane in the analysis of the anatomy of the heart lies also in the evaluation of the relative positions of the great vessels.

The improvements in 3D-4D acquisition allowed us to obtain satisfactory images for analysing the AV valve complex, in normal cases to evaluate the position of the papillary muscle in each ventricle and in cases of complete AVSD the commissure and the common AV valve junction could be displayed. Also, the pathologic anatomy of the AV valves diagnosed prenatally has an important role in the pre-surgical evaluation.

Although this study encompasses a few pathological cases to show the clinical impact of the described STIC acquisition technique for the abnormal AV planes, we suggest that STIC-rendering and STIC-TUI acquisition of the fetal AV junction have an important role in obtaining views that are not easily obtained with 2D ultrasonography and the application in a large systematic study with sufficient numbers of cases may demonstrate the practical benefit of these acquisitions. Also, this technique allows rapid assessment of the cases that are abnormal or suspicious for the complete AVSD diagnosis.

Conclusions

In the last five years 3D and 4D examination of the fetal heart, especially with the use of STIC technique, allows imaging of the fetal heart beating during an entire cardiac cycle.

Spatiotemporal - image correlation with rendered and STIC with TUI acquisition of the AV plane are useful to clarify our understanding of normal and abnormal of the fetal cardiac anatomy. Also with these techniques we can store volume data sets of the anomalies of AV plane for review or for a second opinion, but also to improve communication with the family and the management team.

This kind of approach for the examination of the AV plane can also be used with a lot of advantages for the diagnosis of other complex fetal cardiac defects. ■

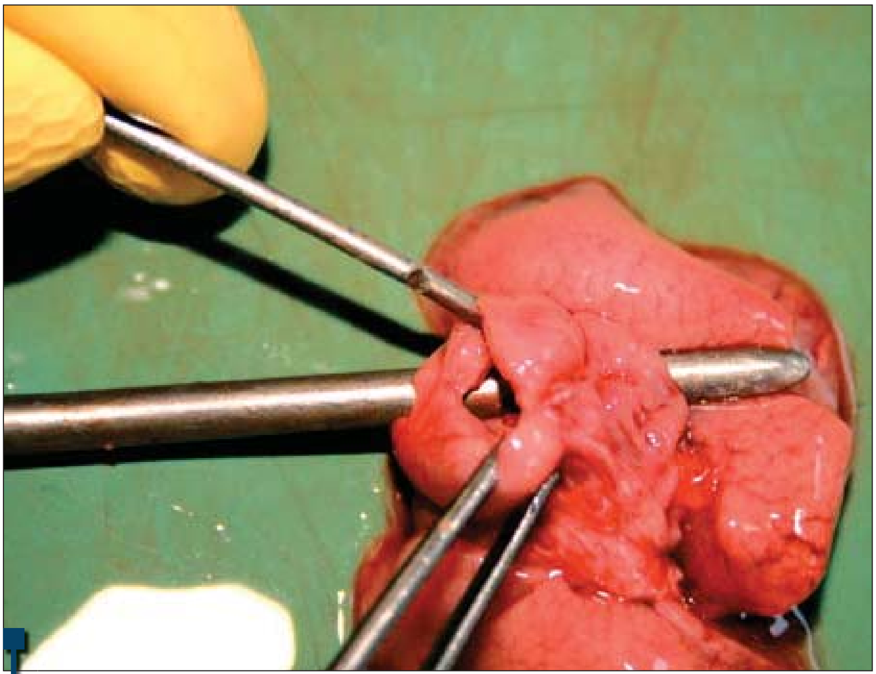

Figure 9. Complete AVSD-anatomopathologic specimen (22 weeks of gestation)

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