Original Article

Continuously transverse scanning of fetal heart for comprehensive cardiac evaluation

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Abstract: Objective: To investigate the feasibility of the screening method of continuously transverse scan for comprehensive cardiac evaluation. Case Report: After pretreating, 5 cases of normal fetal heart samples were cut transversely and serially to produce 60 μm thick sections. Then the sections were observed and macroshotted by a digital camera to obtain serial images. The typical anatomical cross-sections that could display steadily and reflect the characteristics of auricular vein connection, atrioventricular connection, ventricular artery connection and vessels of bottom of the heart were chosen from the database. And simultaneously, 105 cases of fetal heart were scanned transversely by fetal echocardiography (FECG) during second trimester. The detection rate of the typical section above was analyzed. In the database of the 5 normal fetal hearts, the typical sections were conformed to the standards mentioned above. The typical sections were the sections of coronary sinus, four-chamber, outflow tract of left ventricle, outflow tract of right ventricle and the transverse-section of ductal arches and aortic arch. During the transverse scan of the 105 cases fetal heart examination, the detection rate of the sections above was 100%, except for the coronary sinus, with the presenting rate of 79%. Conclusion: The anatomical cross-section image database of normal fetal heart provides the anatomical basis to transverse scan of fetal heart. The highly detection rate of the typical sections during the 105 cases fetal heart examination has further proved the feasibility of transversely scanning method.

Keywords: Fetal heart, transverse scan, anatomical cross-section, database

Introduction

The rate of congenital heart deformation (CHD) among the live-born infants and children is 4%-13‰ [1-3] and it is the main reason for the death of infants [4-6]. Examining CHD before giving birth can improve the management in the perinatal period and promote the prognosis of fetus [7-9]. As a result, (the birth rate) the rate of seriously complicated CHD fetus can be reduced [10]. At present, the FECG is the main way to diagnosis fetal CHD prenatally. In second trimester, as the fetal costa ossification is inconspicuous and free from the influence of air in lung, the fetal cardiac anatomical structure from arbitrary angles is continuously observed by getting away from the spinal column [11].

There for the fetal FECG can be much simplified compared with the adult (FECG) [12-14]. In 2001, Israel scholar Yagel et al [15] raised the method of continuously horizontal scan to examine the fetal echocardiography (FECG) by the five short-axis views, which included abdominal transverse section, four-chamber section, five-chamber section (the section of outflow tract of left ventricle), the section of outflow tract of right ventricle and the three vessel and trachea (3VT) plane [15]. In 2008, the fetal ultrasonic cardiogram team of the International Society of Ultrasound in Obstetrics and Gynecology (ISUOG) has already published a consensus [16]. It put forward that fetal ultrasonic cardiogram examination should at least includes the examination of the sections of four-chamber, the outflow tract section of left ventricle, the outflow tract section of right ventricle and the section of the 3VT plane. At the same time, it estimated pulmonary venous connection and held the idea that the method of continuously horizontal scan of fetal heart can accomplish the examination above. During the
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progress of horizontal scan, if the sections mentioned above can be clearly presented and correctly evaluated, it would be no need of examining other special sections [17].

The method of continuously transverse scan of fetal heart is accepted by more and more scholars, however up to now, there has been no any relevant anatomy research [18]. In this research, we established 10 cases cross-sections anatomical databases of the normal fetal heart with the layer of thickness 60 μm in 22-26 weeks from which we chose typical cross-sections of the fetal heart that appeared stably and could reflect the characteristics of auricular vein connection, atrioventricular connection, ventricular artery connection and vessels of bottom of the heart. Simultaneously, we transversely scanned the 105 fetal heart cases and analyzed the detection rate of the sections above and further investigate the feasibility of the method of continuously transverse scan of fetal heart.

Material and methods

For the induced labor CHD fetal heart samples, along the left sternal border, the skin and the subcutaneous tissue to the pleura were incised. According to different size of the fetus, the length of the cut was about 3 cm to 4 cm, than they were fixed with 4% formaldehyde for 4 to 8 weeks. Along with the original cut, the chest from xiphoid to suprasternal fossa was opened and the thoracic viscera was taken out, then they were fixed with formaldehyde for 2 to 4 weeks. According to the biggest size that the freezing microtome could cut, 0.5 cm outside the margin of the left and right lateral heart, the two sides of lung tissue were cut. Then the remained samples were put into the organic glass cases (4×4.5×4.5 cm or 5×5.5×5.5 cm) vertically and poured into OCT to submerge the samples. After four hours in the refrigerator at -25 c, the content was removed and fixed it in the freezing microtome. From the apex to the bottom, the samples were cut serially with a freezing microtome to produce 60 μm thick sections. The slices were then macroshot with a digital camera (Canon EOS 5D; camera lens, SIGMA 70 mm 1:2.8 DG MACRO) to obtain serial images of the section planes. And the 5 anatomical image databases of normal fetal heart cross-section were established. In these 5 database images, the typical anatomical cross-sections were chose, which could stably and at least show the auricular vein connection, atrioventricular connection, atrioventricular septum, ventricular artery connection, and vessels of bottom of the heart.

105 fetuses of 22-26 weeks were randomly chosen. The GE VOLUSON four-dimensional Doppler ultrasound instrument was applied and the ultrasound instrument whose frequency of volume transducer was 4~8 MHz. Then the obstetric procedures was started with power less than <100 Mw/cm². Letting the pregnant woman take supine or lateral position, verify fetal age by observing the biparietal diameter, head circumference, abdomen circumference and femur length. From (the transverse view of the upper abdomen) the cross-section of enterocoelia, except for successively presenting the typical sections above, the section of enterocoelia was added as the section to be observed with the method of continuously horizontal scan of fetal heart. At the same time, the sections of the 3VT were obtained when the section of ductal arches is horizontal and the probe leans slightly to the fetal right shoulder. Then every typical section was saved.

By comparing the detection rate of the typical cross-sections that established in the anatomical image database of normal fetal heart cross-section when the 105 fetal heart cases were horizontally scanned, the feasibility of the method of continuously horizontal scan of fetal heart was investigated.

Results

In this research, 5 cases anatomical image databases of normal fetal heart cross-section were built. The thickness of section was 60 μm, the pixel of image was 3888×2592 and the format of anatomical image databases was JPEG. The capacity of anatomical image databases was respectively 2.21, 2.72, 1.94, 2.89, 2.56 GB and the anatomical image databases included respectively 793, 803, 898, 769 and 751 cross-sections. The 5 image databases could show the typical anatomical sections and could reflect the auricular vein connection, atrioventricular connection, atrioventricular septum, ventricular artery connection, the sections of four-chamber, the outflow tract section of left ventricle, the outflow tract section of right ventricle, cross section of aortic arch and ductus arch. The vessels of bottom of the heart
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Figure 1. Typical anatomical sections of normal fetal heart. A. Coronary sinus section; B. Four-chamber view; C. Left ventricular outflow tract section; D. Right ventricular outflow tract section; E. The three-vessel section; F. The ductal arch cross-section; G. The aortic arch section.
During the continuous horizontally scanning of the 105 fetal heart cases, the presenting rate of the sections above was 100%, except for the coronary sinus, with the presenting rate of 79%. The echocardiography was showed in Figure 2.

Discussion

In this research, the fetal samples were fixed in the formaldehyde and the heart specimens were cut serially with part of thoracic cavity, to maintain the natural state of the heart as far as possible. Meanwhile, the database with the layer of thick 60 μm was proved to be the thinnest heart section database at present. It not only could present the atrioventricular cavity and large vascular structures, but also could present the valve, chordae tendineae and other tiny structures, that could be applied into the anatomical research of fetal heart as well as FECG.

The five cases anatomical image database of normal fetal heart cross-section, From the apex to the bottom, The typical anatomical cross-sections showing the auricular vein connection, atrioventricular connection, ventricular artery connection, vessels of bottom of the heart was coronary sinus section, the sections of four-chamber, the outflow tract section of left ventricle, the outflow tract section of right ventricle, the cross section of ductus arch and aortic arch. They include all the short axis view that was put forward by Yagels except for the 3VT plane.

Figure 2. Typical echocardiography of the fetal heart cases. A. The abdominal cross-section; B. The coronary sinus section; C. The four-chamber view; D. The left ventricular outflow tract section; E. The right ventricular outflow tract section; F. The three vessel view; G. The ductus arteriosus arch cross-section or three-vessel trachea view; H. The aortic arch cross-section.
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 second one is the section of ductal arches. As they cannot appear in the same section, the cross section of the fetal database cannot show the 3VT plane. However, during the progress of continuous horizontally scan of the 105 fetal hearts, when the cross-section of ductal arch appears, the probe slightly leans to the right shoulder of the fetus and we can see the 3VT plane. The detection rate is 100%. The 3VT plane shows the section of ductus arch and aortic arch. Compared with, it is much easier to observe the inner diameter ratio and the positional relationship, and also helpful to diagnose the transverse coarctation of Aorta and the malformation of arterioles ring. As a result, this research also suggests to use the 3VT plane to instead of the independent sections of ductus arch and aortic arch [19, 20]. Being one section of the continuously scanned sections of fetal heart, it can help to observe the great vessels structure of fetal heart. 

The database of anatomical cross-section images of the normal fatal hearts doesn’t include upper abdomen transverse view. However, during the continuously scanning of 100 fetuses, upper abdomen transverse view appears stably. Compared with other sections, it is much easier to be obtained and recognized. Its normal presenting excludes the atrial trans, inferior vena cava interruption, Azygos vein ectopic drainage and other kinds of CHD. Besides, this kind of malformation is with poor prognosis and always companied with serious malformation in other system. For example, asplenia syndrome and so on. And its ultrasonicic appearance lacks of specialty. As a result, it is very easy to omit it. The unshow of inferior vena cava and the abnormal expending of azygos vein can provide information to this kind of malformation [21].

During the continuous horizontally scanning of the 105 fetal hearts, we can see upper abdomen transverse view, the sections of four-chamber, the outflow tract section of left ventricle, the outflow tract section of right ventricle and the 3VT plane as well as the cross-sections of the ductus arch and the aortic arch. The detection rate of the sections above is 100% while the detection rate of coronary sinus is 79%, which is lower than the former ones.

Though the detection rate of coronary sinus section is low, it doesn’t fail to be the observing section of continuously horizontal scan. Normally, when the fetal coronary sinus is narrow, the section of coronary sinus is very hard to be seen. However, when the venous return is abnormal, for example, in the case of intracardiac type drainage pulmonary vein abnormalities, forever left cavity malformation, the coronary sinus would be expended abnormally. As a result, the ultrasound examination is much easier [22]. Thus, during the continuous scan of fetal heart, its unshow is normal in the coronary sinus section.

The database of cross-sectional anatomical images of normal fetal heart provides the anatomical basis to the method of continuously transverse scan of fetal heart. During the horizontally scan of 105 fetal hearts, the high presenting rate of the sections above further proves the feasibility of the method of continuously horizontal scan of fetal heart.

In the western developed countries, some of the antenatal diagnosis centers have already regarded the continuously scan of fetal heart as a kind of fetal ultrasonic cardiogram and applied into the antenatal diagnosis [18]. Among them, the sections of four-chamber, the outflow tract section of left ventricle, the outflow tract section of right ventricle, the 3VT plane are greatly applied. Sydney royal hospital, British medical Mr Willy and children and some other hospitals also regard the section of enterocoelia as a common examining section when they examine the sections of four-chamber, the outflow tract section of left ventricle, the outflow tract section of right ventricle, the 3VT plane [23]. However, no scholar has regarded the coronary sinus section as one of the common examining section yet.

The method of continuous scan of fetal heart greatly simplifies the fetal ultrasonic cardiogram technology and is very easy to be popularized. The difficulty of fetal ultrasonic cardiogram is not the obtaining of sections; instead, it is the standardization and accurate evaluation of the sections. During the continuous scan, the obtaining of standard sectional images can not only help to analyze, but also can help to remote diagnose.

In conclusion, the anatomical image database of normal fetal heart cross-section has provided anatomical foundation for the continuous scan of fetal heart. During the horizontally scan
of 105 fetal hearts, the high presenting rate of the sections above further proves the feasibility of the method of continuously horizontal scan of fetal heart. The method of continuous scan of fetal heart not only simplifies the fetal ultrasonic cardiogram technology, but also helps to standardize the images. Besides, it also makes the remote diagnosis more convenient.

Disclosure of conflict of interest
None.

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