The Application of an Anatomical Database for Fetal Congenital Heart Disease

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Abstract

Background: Fetal congenital heart anomalies are the most common congenital anomalies in live births. Fetal echocardiography (FECG) is the only prenatal diagnostic approach used to detect fetal congenital heart disease (CHD). FECG is not widely used, and the antenatal diagnosis rate of CHD varies considerably. Thus, mastering the anatomical characteristics of different kinds of CHD is critical for ultrasound physicians to improve FECG technology. The aim of this study is to investigate the applications of a fetal CHD anatomic database in FECG teaching and training program.

Methods: We evaluated 60 transverse section databases including 27 types of fetal CHD built in the Prenatal Diagnosis Center in Peking University People's Hospital. Each original database contained 400–700 cross-sectional digital images with a resolution of 3744 pixels × 5616 pixels. We imported the database into Amira 5.3.1 (Australia Visage Imaging Company, Australia) three-dimensional (3D) software. The database functions use a series of 3D software visual operations. The features of the fetal CHD anatomical database were analyzed to determine its applications in FECG continuing education and training.

Results: The database was rebuilt using the 3D software. The original and rebuilt databases can be displayed dynamically, continuously, and synchronically and can be rotated at arbitrary angles. The sections from the dynamic displays and rotating angles are consistent with the sections in FECG. The database successfully reproduced the anatomic structures and spatial relationship features of different fetal CHDs. We established a fetal CHD anatomy training database and a standardized training database for FECG. Ultrasound physicians and students can learn the anatomical features of fetal CHD and FECG through either centralized training or distance education.

Conclusions: The database of fetal CHD successfully reproduced the anatomic structures and spatial relationship of different kinds of fetal CHD. This database can be widely used in anatomy and FECG teaching and training.

Key words: Anatomic Database; Congenital Heart Disease; Fetal

Introduction

Fetal congenital heart anomalies are the most common congenital anomalies in live births,[1,2] and up to 50% of infant deaths are attributed to congenital heart anomalies.[3,4] The prenatal detection of congenital heart disease (CHD) may improve the outcome of fetuses with specific types of cardiac lesions and reduce the birth rate of seriously complicated CHD.[5-7] Fetal echocardiography (FECG) is the only prenatal diagnostic approach used to detect CHD.[8,9] FECG is more difficult to perform than adult echocardiography because of the variable fetal position and special fetal circulation properties such as intrauterine blood flow in the foramen ovale and ductus arteriosus. Consequently, FECG has not been widely applied, and the antenatal diagnosis rate of CHD varies considerably.[10-13] Our limited understanding of the pathological anatomic features associated with different types CHD is one of the reasons for the low prenatal diagnosis rate.

The development of digital information technology has led to the creation of sectional anatomy databases of adult hearts, which have been used in basic research, education, and clinical research.[14,15] We reported the first normal fetal heart

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anatomical database in 2010.[16] We continued to accumulate information in the database and have established an anatomical database for various types of CHD. This database provides an anatomical foundation to interpret FECG findings. The aim of this study is to investigate the applications of the anatomic database in FECG teaching and training program.

Methods

Study source

We built 60 cross-sectional databases containing 27 types of fetal CHD in the Prenatal Diagnosis Center in Peking University People's Hospital from January 2009 to April 2015. The CHDs included the following types of CHD: Tetralogy of Fallot (TOF), endocardial cushion defect (ECD), pulmonary artery stenosis, pulmonary artery atresia, transposition of the great arteries (TGA), tricuspid atresia, mitral atresia, ventricular septal defect, persistent truncus arteriosus (PTA), coarctation of aorta, double outlet right ventricle, anomalous pulmonary venous drainage (APVD), hypoplastic left heart (HLH), hypoplastic right heart, Ebstein anomaly, noncompaction of ventricular myocardium, persistent left superior vena cava (PSVC), hypertrophic cardiomyopathy, atrial myxoma, single atrium and single ventricle, vascular ring, interruption of aortic arch, interruption of the inferior vena cava (IIVC), dextroaortic arch, rhabdomyoma, anomalous origin of pulmonary artery from the aorta (AOPA), and aortopulmonary collateral arteries.

Application of the databases

Each database contained 400–700 cross-sectional digital images with a resolution of 3744 pixels × 5616 pixels. The images were originally saved in JPEG format. We imported the database into three-dimensional (3D) software Amira 5.3.1 (Australia Visage Imaging Company, Australia) after registering and format conversion. The database was manipulated through a series of visual 3D software functions. The features of the anatomical database of fetal CHD were analyzed to determine its applications in FECG continuing education and training.

Results

Based on the original database of transverse sections, a database of 400 sagittal and 700 coronal section images was rebuilt

The image resolution was 3744 pixels × 5616 pixels and the database images distinctly showed the atrium and ventricle, great vessels, cardiac valves, chordae tendineae, and musculi papillares. As shown in Figure 1, the fetus was an induced labor because of trisomy 21. The heart was otherwise normal except for the presence of PSVC. The cross section of the original database [Figure 1a] contained 612 images. The sagittal reconstruction image database [Figure 1b] contained 423 images, and the coronal image database [Figure 1c] contained 556 reconstruction images.

The original and rebuilt database can be displayed dynamically and continuously

The user can scroll through the database using the slider bar in the workspace and pictures from both the original and rebuilt databases can be displayed dynamically and continuously. Figure 2 shows the parts of a typical image made from the rebuilt coronal sections in the database [Figure 1b] of PSVC with continuous and dynamic display.

Original and rebuilt database can be displayed synchronically

The lesion structure or region of interest can be synchronically displayed in cross, sagittal, and coronal sections. These sections demonstrated the spatial relationship of the pathological changes in different types of fetal CHD [Figure 3]. The common venous cavity was presented in different directions synchronously in the original [Figure 3a], rebuilt coronal [Figure 3b], and sagittal [Figure 3c] section databases.

The original and rebuilt database can be rotated at arbitrary angles

After rotation at an arbitrary angle, the sections reflecting the pathological features can be obtained. Figure 4 shows the long axis section of the common vein cavity obtained after arbitrary angle rotation of the rebuilt sagittal section database of APVD. This section clearly displayed the left superior pulmonary vein and right superior pulmonary vein entering into the common vein cavity and then into the abdominal cavity.

Sections from dynamic display and rotation are consistent with fetal echocardiography sections

The sections of the original and rebuilt database were consistent with the sections in FECG after rotation at an arbitrary angle in the dynamic display. Figure 5 shows the typical images from

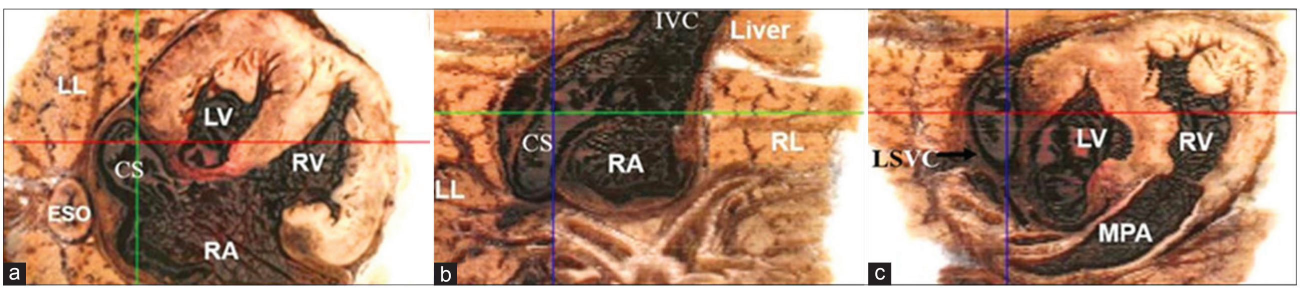

Figure 1: Original and rebuilt database of persistent left superior vena cava. (a) Original transverse sections database; (b) rebuilt coronal sections database; (c) rebuilt sagittal sections database. LV: Left ventricle; RV: Right ventricle; RA: Right atrium; MPA: Main pulmonary artery; LSVC: Left superior vena cava; IVC: Inferior vena cava; CS: Coronary sinus; RL: Right lung; LL: Left lung; ESO: Esophagus.

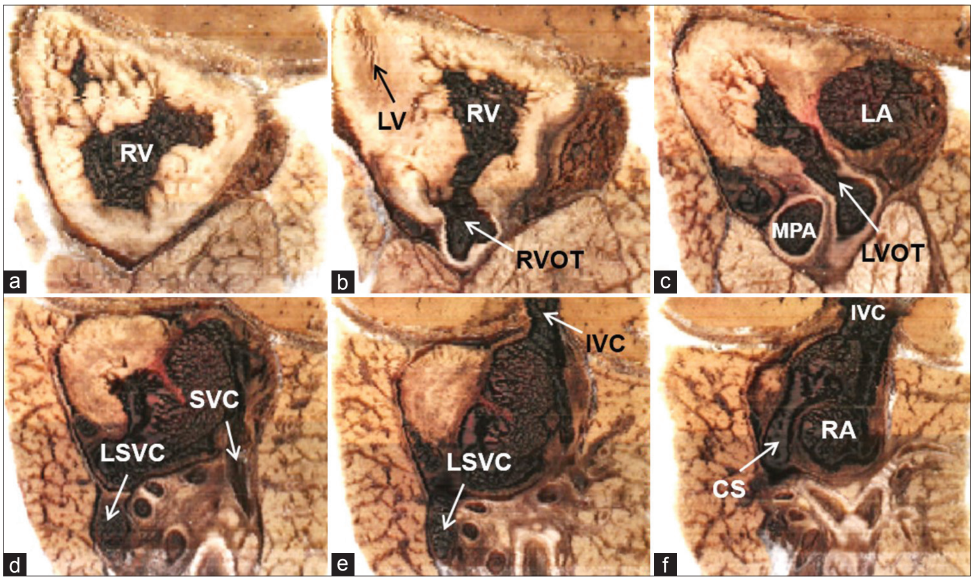

Figure 2: Parts of typical images of rebuilt coronal sections database of persistent left superior vena cava (a-f). LV: Left ventricle; RV: Right ventricle; LA: Left atrium; RA: Right atrium; RVOT: Outflow tract of right ventricle; MPA: Main pulmonary artery; LVOT: Outflow tract of left ventricle; SVC: Superior vena cava; LSVC: Left superior vena cava; IVC: Inferior vena cava; CS: Coronary sinus.

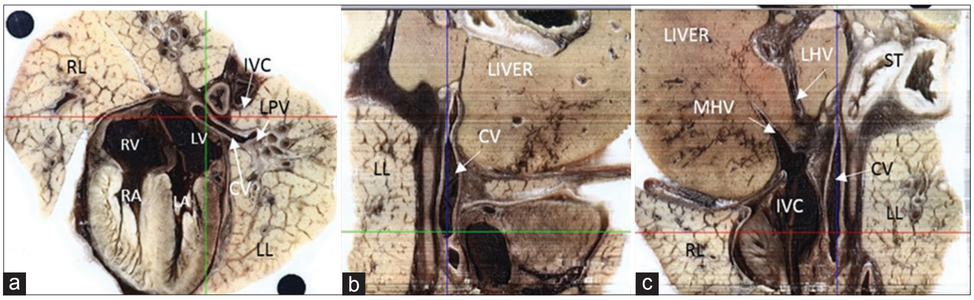

Figure 3: The common venous cavity presented at different direction synchronously of anomalous pulmonary venous drainage. (a) Original transverse sections database; (b) rebuilt coronal sections database; (c) rebuilt sagittal sections database; LL: Left lung; RL: Right lung; LV: Left ventricle; RV: Right ventricle; LA: Left atrium; RA: Right atrium; CV: Common vein cavity; MHV: Middle hepatic vein; LHV: Left hepatic vein; IVC: Inferior vena cava; ST stomach; LPV: Left pulmonary vein.

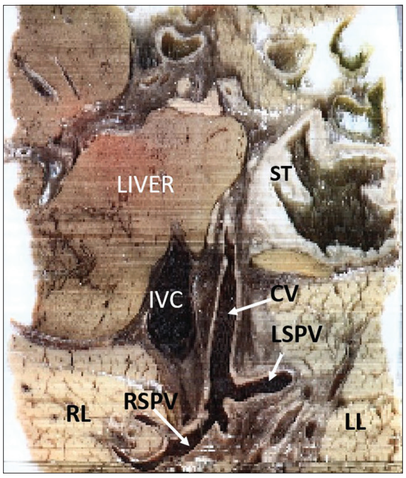

Figure 4: RSPV and LSPV into CV after arbitrary angle rotation of the rebuilt sagittal section database of anomalous pulmonary venous drainage. ST: Stomach; RSPV: Right superior pulmonary vein; LSPV: Left superior pulmonary vein; CV: Common vein cavity; IVC: Inferior vena cava; LL: Left lung; RL: Right lung.

the cross section database after dynamic display and rotation. This database contained an anomalous origin of the right pulmonary artery from the aorta combined with ectopic blood vessels, ECD, HLH, and pulmonary stenosis. The database sections were consistent with FECG [Figure 6].

Discussion

These database functions recreated the anatomic structure and spatial relationship features of different fetal CHDs. Ultrasound physicians and students can learn the anatomical features of fetal CHD and FECG through centralized training or distance education. In contrast to traditional anatomical specimens, the digital database can be used repeatedly and reserved permanently. The database contained 60 cases involving 27 types of fetal CHDs. In addition to TOF, TGA, ECD, and PTA, there were also rare types of CHD such as AOPA, BPCC, and IIVC. This tool can alleviate the shortage of anatomical specimens in medical colleges and hospitals.

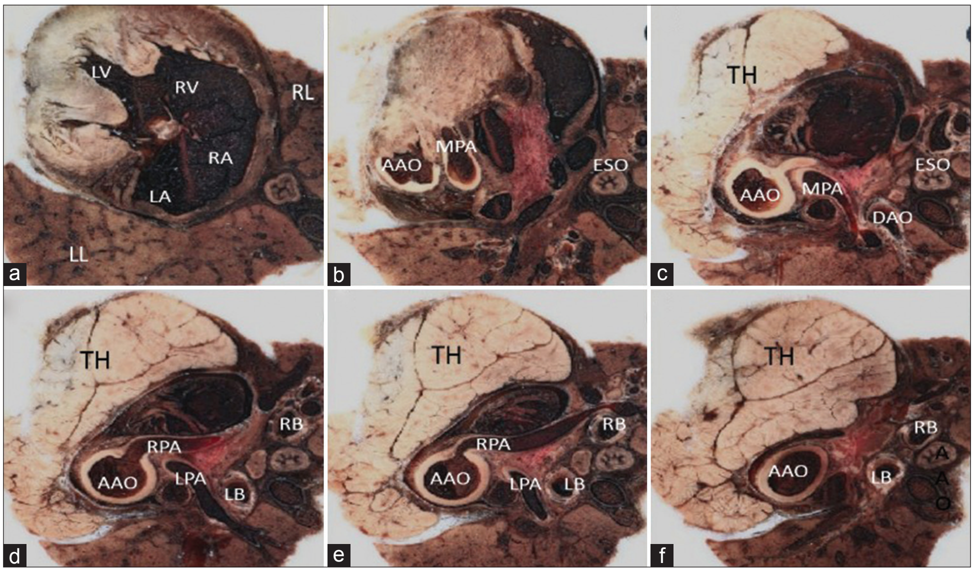

Figure 5: Sections of database from dynamic displaying and rotating of AORPA (a-f). AORPA: Anomalous origin of right pulmonary artery from the aorta; LL: Left lung; RL: Right lung; LV: Left ventricle; RV: Right ventricle; LA: Left atrium; RA: Right atrium; MPA: Main pulmonary artery; RPA: Right pulmonary artery; LPA: Left pulmonary artery; ROVT: Outflow tract of right ventricle; AO: Aorta; AAO: Ascending aorta; DAO: Descending aorta; ESO: Esophagus; TH: Thymus gland; LB: Left bronchus; RB: Right bronchus.

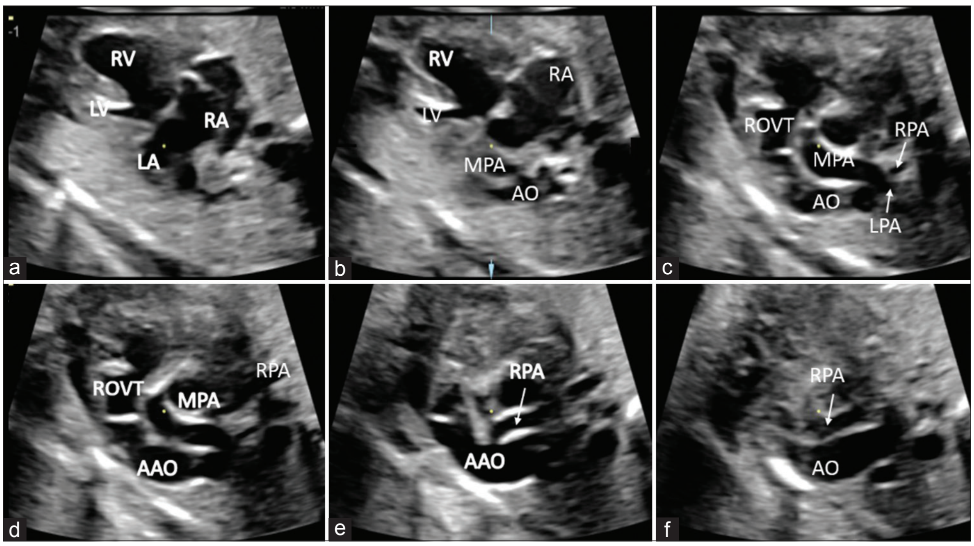

Figure 6: Parts of typical images of fetal echocardiography showed AORPA (a-f). AORPA: Anomalous origin of right pulmonary artery from the aorta; LV: Left ventricle; RV: Right ventricle; LA: Left atrium; RA: Right atrium; MPA: Main pulmonary artery; RPA: Right pulmonary artery; LPA: Left pulmonary artery; ROVT: Outflow tract of right ventricle; AO: Aorta; AAO: Ascending aorta.

The transverse sweep technique has become popular and is increasingly accepted by ultrasound physicians. In 2013, the International Society of Ultrasound in Obstetrics and Gynecology published practice guidelines (updated)[17] and further highlighted the transverse sweep technique. The most difficult aspect of FECG is not section acquisition, but rather cognitive view. The cross section database established in this study contains more than 90% of the different types of CHD and the corresponding continuous transverse scanning FECG images. Therefore, ultrasound doctors can master both the characteristics of anatomical and transverse sonograms in various types of CHD quickly and can improve continuous transverse scanning technology of the fetal heart by centralized training.

The databases established in this study provide a digital teaching platform. Related units can share the database through the network. In addition, in remote districts, distance education can be completed through digital teaching CD-ROMs. Thus, the range of FECG training will be expanded and will promote and popularize this technology. In the future, we will create a more specialized digital teaching platform. In addition, cloud technology will allow the anatomical database of fetal CHD to reach more users.

The limitation of this study was that the database of fetal CHD is in a starting process, so it needs to prove its effect during practical application and improve in time basing on its feedback.

In conclusions, the database of fetal CHD successfully reproduced the anatomic structures and spatial relationship of different kinds of fetal CHD. This database can be widely used in anatomy and FECG teaching and training.

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Conflicts of interest

There are no conflicts of interest.

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