A Preliminary Comparative Study of Prenatal Screening and Postpartum Anatomy Using a Novel Improved Cardiovascular Model Based on Literature Data

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Research Article

Keywords: Cardiovascular model, Trachea model, Complex Congenital heart disease, IAA, interrupted aortic arch, COA, coarctation of the aorta, PVS, pulmonary valve stenosis, RAA, Right aortic arch, TGA, transposition of the great arteries, RAMI, Right Aortic Arch with Mirror-image Branching, DORV, double-outlet right ventricle

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Abstract

Background: To study the molding method for twenty fetal complex cardiovascular malformation models (CCMM) and its significance in prenatal diagnosis and teaching.

Methods: The modified vascular anatomical molding method was used to cast the micro blood vessels and trachea of twenty specimens diagnosed with complex congenital heart disease. Subsequently, twenty abnormal vascular models of the fetal aorta, pulmonary artery and other branches were analyzed and compared with the prenatal ultrasound to summarize their characteristics and misdiagnosis.

Results: It was observed that all twenty cases of the fetuses were confirmed with complex cardiac malformations. A total of 69 cardiac malformations were recorded, among which 7 cases were misdiagnosed using prenatal echocardiography (including 3 cases of the interrupted aortic arch (IAA) and 3 cases of double outlet right ventricle (DORV) with transposition of the great arteries (TGA) confirmed by CCMM, case 5.12.14.15.16.17.18), and 18 were missed by prenatal echocardiography (including 5 cases of abnormal ductus arteriosus, 1 case of infrahepatic interruption of the inferior vena cava (IIVC), 1 case of the right aortic arch with mirror-image branching (RAMI), and 3 cases of aberrant subclavian artery (ASA), All cases except 5.8).

Conclusion: There are many different kinds of abnormalities in the fetal aorta, pulmonary artery and other branches, which are often complicated with intracardiac malformation and arterial/venous branch variation. Prenatal echocardiography has important diagnostic value; a vascular model can directly show its characteristic changes, which is helpful to improve the differential diagnosis of complex congenital heart disease. Our findings prove that CCMM can play an important role in the clinics, scientific research, teaching, and popular cardiovascular science. Furthermore, it can promote the development of fetal cardiac surgery and the diagnosis with medical imaging and the teaching of medical theory.

Background

The incidence of congenital heart disease in Asia is about 8~12‰, which is significantly higher than that in other parts of the world and is on the persistent rise due to the accelerated process of industrialization, food safety and environmental pollution (1.2). Complex congenital heart disease can lead to a high disability rate and mortality and various postnatal complications, thereby requiring complex perinatal detection and postpartum treatment. It is one of the most common congenital diseases with a poor prognosis. Early prenatal diagnosis and early postnatal treatment are particularly important. Fetal echocardiography has become the first choice for screening fetal congenital heart disease during pregnancy, but the display of small-micro blood vessels is not good and accurate. Additionally, the complex congenital heart disease has various vascular variations and is limited by the small volume of the fetal heart, thereby making the teaching of prenatal echocardiography very difficult (3.4.5.6). Fortunately, the improved cardiovascular molding method has brought an opportunity to fully observe the circuit of vascular branches in the state of the fetal physiological circulation and better reflect the three-

dimensional structure of fetal cardiac microvessels. In this pursuit, our team conducted microvessel models on 20 cases of fetal cardiac malformations and compared them with prenatal fetal echocardiography, to analyze the characteristics of fetal vascular malformations and the causes of missed and misdiagnosis in fetal echocardiography, and further improve the application value of the fetal echocardiography in the diagnosis of fetal complex cardiac malformations. In addition, the article deals with a very complex topic. Accurate prenatal diagnosis of congenital heart disease is not simple and has many implications that are not limited to surgical correction alone. They also concern the possibility of terminating pregnancy and the psychological impact on future parents. In recent years, with the opening of China's "two-child policy" in 2016, a large number of elder and high-risk pregnant women have gradually increased, while the domestic medical environment and doctor-patient relationship is very poor. Thousands of malignant criminal cases of medical injuries caused by the wrong diagnosis break out every year, as mentioned in our team's previous article (2.7.8), and a misdiagnosis of prenatal diagnosis can lead to a huge financial medical compensation to the hospital. This has cast a "black veil" on the development of prenatal diagnosis in China. At present, our technology has been extended to many provinces and has been highly praised. Therefore, the improved vascular trachea molding technology is not only conducive to the prenatal echocardiography diagnosis teaching, but also reduces unnecessary medical disputes and provides a strong support for the medical insurance system for children with congenital heart disease.

Materials And Methods

Twenty cases of complex cardiovascular malformation diagnosed by fetal echocardiography and final autopsy and microvascular casting from March 2014 to December 2020 in the Jiangsu Hospital Group (includes Jiangsu Maternal and Child Health Hospital, Xiangyang first hospital, Suzhou Hospital Maternal and Fetal Medical Consultation Centre, and Jiangsu fetal heart disease database and specimen bank) were collected into this study, that included 12 males and 8 females. The pregnant women were 21-42 (31.3 ± 4.3) years old; the gestational weeks were 24-33 (25.2 ± 2.1) weeks. This study was approved by Jiangsu Hospital Group Ethics Committee (approval No.: 2013016x) and signed informed consent from the parents.

We followed the methods of Saravi B et al (7,9,15). GE Voluson E8 and Mindray Resona7 colour Doppler ultrasound machines were used with convex array transducers and a frequency of 3.0 - 5.5 MHz. The diagnostic standards by the International Society of Ultrasound in Obstetrics and Gynecology (ISUOG) and the British Journal of Obstetrics and Gynaecology (BJOG) were adopted with a close check on the structure of the cardiovascular system, valve morphology, and complex cardiovascular systemic circulation path (10.11.12). For suspected cases of the abnormal aortic arch and its branches, the three vessels-trachea view (3V+ T view), bilateral subclavian artery view and tracheal coronal view were combined, along with observing the specific circuit of the left ventricular outflow tract, ascending aorta, aortic branches and ductus arteriosus. All 20 complex congenital heart disease (CCHD) fetuses underwent systemic ultrasound screening at the gestational age of 24 - 33 weeks. All resulting CCHD views/section images were stored in the Neusoft ultrasound system workstation and screened, analyzed

by two CCHD diagnostic qualified physicians with 20 years of work experience, who reached a final diagnosis with the agreement.

Pathoanatomical examination: In the fetus diagnosed with complex cardiovascular malformations using the fetal echocardiography, the family decided to terminate the pregnancy after multidisciplinary consultation, and autopsy and microvascular casting were implemented with the approval of the Science and Technology Ethics Committee of the hospital. Fetal microvascular casting process: It was operated by a pathologist with the qualification of Deputy Chief Physician or above. The abdominal wall was cut, and the umbilical vein and abdominal aorta were separated. They were perfused with a cleaning agent, until the fluid flowing out of the heart and microvessels was clear, and there was no blood clot. The abdominal aorta was ligated, the fixing agent was perfused into the umbilical vein at a uniform speed, fixed and corroded, and then washed until there was no residual tissue. Details of improved casting method: ¶ The chest wall was opened to expose the heart and lungs, retain the pericardium, the abdominal wall was opened and disconnected one side of the common iliac artery; the umbilical vein was separated and punctured (a 1.0-1.5 mm scalp needle catheter was used for cannulation) and fixed, and the blood vessels were flushed with normal saline until the clear fluid flowed out of the common iliac artery; ¶ Epoxy resin, polyamide resin curing agent and ethyl acetate were used as the main raw materials, and an appropriate amount of bright red pigment was added. After stirring and standing, the bubble-free mould agent was absorbed in the lower layer for use; ¶ The 20 ml syringe was manually injected with a casting agent to make the heart and vascular cavity full and the pressure was maintained for 30 s, and then the umbilical vein was ligated; ¶ After the perfusion specimen was fixed, the thoracic and abdominal organs were removed and put into potassium hydroxide solution for corrosion. After 48 hours, the alkaline solution was washed with running water and bleached with chlorine disinfectant; ¶ The specimen was properly trimmed and the casting results were recorded; ¶ Fetuses with CHD are often diagnosed with small for gestational age (particularly the head is small) and present higher risk of prematurity(13,14); It is difficult to cast a small fetus model. At this time, we will use small intubation and small pressure or micropump for perfusion to complete the casting as perfectly as possible. ¶ It should be noted that this method will not completely hinder the routine autopsy, because our perfusion is mainly carried out through arteriovenous and trachea, we will roughly check the cardiovascular structure and record some data after opening the chest, but the extremely detailed autopsy cannot be done. ¶ The examination, inspection and diagnosis of cast model need to be completed by pathologists, obstetricians, ultrasound doctors, radiologists and cardiac surgeons together to reduce bias.

If there was filling material for the second part, acrylonitrile-butadiene-styrene (ABS) was used: The casting medium was a mixture of 60 g of ABS (Shanghai Chemical Plant Co. Ltd., China), 70 ml of acetone and dye. High-quality azo pigments such as permanent orange (RN C.I.5), bronze-red (C.I.21), benzidine yellow (GC.I.12), emerald green (XC.I.11), etc. were used. If the above pigments were not available, water-soluble painting pigments were employed. After the desired color was achieved by mixing multi-colors, it was added into ABS at a ratio of 1/120(15.16.17).

Results

According to the complex cardiovascular malformation casts (CCMCs), all 20 cases of fetuses were confirmed with complex cardiac malformations, and no false-positive results were observed. In the 69 cardiac malformations recorded, 7 cases were misdiagnosed by prenatal echocardiography (including 3 cases of the interrupted aortic arch (IAA) and 3 cases of double outlet right ventricle (DORV) with transposition of the great arteries confirmed (TGA) by CCMC, case 5.12.14.15.16.17.18), and 18 were missed by the prenatal echocardiography (including 5 cases of abnormal ductus arteriosus, 1 case of infrahepatic interruption of the inferior vena cava (IIVC), 1 case of the right aortic arch with mirror-image branching (RAMI), and 3 cases of aberrant subclavian artery (ASA), All cases except 5.8); 20 cases of complex congenital heart disease with various malformations were accurately diagnosed based on combination with the prenatal echocardiography, casting and anatomy.

Among the 20 fetuses with cardiac malformation, 14 cases were complicated with extracardiac malformations. The main combined malformations were: 1 case of polysplenia, 1 case of persistent right umbilical vein (PRUV), 1 case of diaphragmatic hernia, 1 case of malrotation of the intestine, 1 case of heterotaxy syndrome, 1 case of intestinal atresia, 1 case of oesophageal atresia; 4 cases of the single umbilical artery, 1 case of meconium peritonitis, and 1 case of bilateral ureterectasis, and 1 case of left renal dysplasia (Table 1).

Table 1

Twenty cases with prenatal misdiagnosis or missed diagnosis corrected by postnatal cardiovascular casting

Case	Maternal age (year)	Gestational age (week)	Prenatal ultrasonic findings confirmed by postnatal casting	Prenatal misdiagnosis corrected by postnatal casting	Prenatal missed diagnosis detected by postnatal casting	Extracardiac anomalies
1	32	28+5	LAI; ASD;		TAPVC,	Polysplenia
2	29	25+3	DORV; VSD; PAS;	RAA with ALSA	JRAA	PRUV
3	34	25+2	Right AVA; PVS; PAS		Abnormal connection of DA (connecting LPA to LSA)	
4	27	27+3	RAI; PVA; PAS ;	AHVC	TAPVC, Double IVC	Diaphragmatic hernia;
5	25	24+3	VSD; PAS; TOF	RAA with mirror-image branching corrected to RAA with ALSA; PLSVC corrected to LIV		Malrotation of intestine
6	25	24+2	LAI; Left AVA; hypoplastic LV; DORV; IAA; interrupted IVC; PLSVC		RAA with ALSA	Heterotaxy syndrome (midline liver, right-sided spleen, bilateral left-sided lungs)
7	38	26+3	VSD; HLHS		IAA	Intestinal atresia
8	21	32+2	PAS	absence of DA corrected to slim DA		Esophageal atresia; single umbilical artery;
9	33	29+2	VSD; PVA; PAS		Common origin of RBA and LCCA;	single umbilical artery

Case	Maternal age (year)	Gestational age (week)	Prenatal ultrasonic findings confirmed by postnatal casting	Prenatal misdiagnosis corrected by postnatal casting	Prenatal missed diagnosis detected by postnatal casting	Extracardiac anomalies
10	28	24+3	DORV; VSD; PAS; curved DA	RAA with ALSA	Abnormal connection of DA (connecting LPA to LCCA); anomalous aortic origin of LVA	
11	24	28+2	TGA; hypoplastic RV; VSD		RAA with ALSA	Meconium peritonitis
12	28	24+5	VSD; PAS	TOF corrected to DORV	Common origin of RBA and LCCA; subaortic LIV	
13	26	26+2	DORV		TGA, ductus arteriosus abnormal connections (LCCA-DA-PA)	single umbilical artery
14	27	27+1	COA, DSVC	IAA with descending aorta originated from the pulmonary artery, DSVC	abnormal connection of DA (PA- DA- LCCA)	single umbilical artery
15	28	25+1	DORV; VSD; PAS; curved DA	RAA with ALSA, DORV with TGA	Abnormal connection of DA (connecting LPA to LSA); Right Aortic Arch with Mirror-image Branching	Left renal dysplasia
16	33	25+4		IAA with descending aorta originated from the pulmonary artery	PA to DA to LCCA, ALSA originating from the DAO	

Case	Maternal age (year)	Gestational age (week)	Prenatal ultrasonic findings confirmed by postnatal casting	Prenatal misdiagnosis corrected by postnatal casting	Prenatal missed diagnosis detected by postnatal casting	Extracardiac anomalies
17	41	26+1	DORV; VSD	LAI, DORV with TGA	Infrahepatic interruption of the inferior vena cava(IIVC)	
18	28	27+2	DORV		TGA	single umbilical artery
19	26	29+1	LAI; ASD;		PAPVC	
20	24	25+3	COA with descending aorta originated from the right ventricle	IAA with descending aorta originated from the pulmonary artery	PA to DA to LCCA, ALSA from DAO	bilateral ureterectasis

Notes: The above CHD or Non-CHD deformities are not China's TOP (Termination Of Pregnancy) indicators. The above cases are voluntarily TOP by parents. Any doctors can't make any TOP suggestions and can't interfere TOP. In China's legal level, TOP other than the non six fatal deformities (Anencephaly, severe encephalocele, severe spina bifida, severe thoracoabdominal wall defect with viscera bareness, single chamber heart, fatal dyschondroplasia) is not allowed, but in fact, TOP management is not generally strict. Parents can choose to voluntarily TOP in public or private hospitals at any time.

Discussion

CHD is the most common congenital malformation in China. Due to the increased number of pregnant women with an advanced maternal age, since the announcement of the two-child policy in 2016, there were about 360,000 children with CHD born in China in 2018. Fetal echocardiography is a reliable means to diagnose the fetal heart malformation. Identification of severely fatal CCHDs by fetal echocardiography is helpful for timely intrauterine interventions, postpartum cardiac surgery, and saving lives. However, the cardiovascular malformations in the fetuses with CCHD are quite complicated. At present, the observation of the fetal cardiovascular system is still limited, especially the abnormal circuit of blood vessels and their branches are difficult to be fully displayed, which affects the quality of diagnosis. Limited by the experience and spatial imagination, especially by the knowledge of the anatomical structure of various types of CCHD, various diagnostic medical sonographers have different understandings and screening skills of CCHD. The detailed, accurate diagnosis of CCHD by prenatal echocardiography remains a huge challenge. In addition, the prenatal diagnostic legal disputes caused by

CCHD in China are rising year by year, reaching 20%, which greatly hinders the development of prenatal ultrasound. Theoretically, the solidified filler can fill the fetal heart cavity, micro blood vessels and main branches, fully display the integrity and three-dimensional structure of the fetal blood vessels, comprehensively observe the circuit, shape and position of the blood vessels, and directly display the relationship between the local and overall. Therefore, it is especially suitable for the complex congenital heart diseases with abnormal vascular routing, and can be used as a control index to analyze the causes of missed and misdiagnosis of fetal echocardiography (7.8.18.19). Our team obtained 20 perfect models through an improved casting method, which played an important role in feeding-back prenatal ultrasound details and guiding clinical teaching.

The microvessel tracheal casting technique can stereoscopically display the abnormalities of cardiovascular and tracheal branches of the CCHD fetuses, especially the mutual positional relationship and the complex spatial structure of the large-micro vessel malformations. Therefore, the detailed information provided by the casting technique can help to improve the accuracy of an echocardiography diagnosis of CCHD, thereby providing a virtual reality tool to conduct the simulated CCHD cognitive training for diagnostic medical sonographers. At the same time, the correctly restored CCHD cardiovascular models can also be used to establish a permanently stored database by computerized tomography technology for future 3D printing restorations and replications. Therefore, the rare CCHDs can be infinitely copied for various cardiac surgeons and obstetricians and gynecologists for future study. The authors successfully prepared 20 CCHD casts and found a total of 69 abnormalities, of which 7 cases were missed, and 18 cases were misdiagnosed by prenatal echocardiography, resulting in an accurate ultrasound diagnosis rate of 52.18%. Furthermore, these diagnostic results were found amongst the senior physicians/experts, which can be unimaginably low, if conducted by general medical sonographers. The detailed information of the casts perfectly explained some of the doubts in prenatal ultrasound images (17.20.21). CCMM can clearly exhibit the shape, size, location and orientation of the atria and ventricles, and it can also show the abnormal connections between the atria and ventricles. In addition, the cast can clearly display the atrial appendage morphology, trachea-bronchial branch structures, anomalous pulmonary venous return (APVR), abnormal superior and inferior vena cava, hepatic veins, and the double outlet of the right ventricle with transposition of great arteries, which are difficult to find with the prenatal ultrasound.

A traditional autopsy has always been regarded as the gold standard for verifying the prenatal diagnosis. However, from our 20 years extensive research and experience, there are many defects in the diagnosis of complex congenital heart disease in regional anatomy. For example, CCHD specimens are usually small and weigh less than 2 kg, which is easy to destroy the thoracic structure, and the variation of microvessels cannot be observed in detail. Each CCHD specimen is extremely precious. The traditional formalin immersion cannot perfectly reflect the cardiovascular morphology, which often leads to the shrinkage of the heart and eventually leads to damage. Our modified CCMM could more clearly, completely, and permanently display the spatial relationship of the aorta and its branches (including abnormal arteriovenous, trachea, and oesophagus). Therefore, this technology can improve the clinician's and sonographer's understanding of the spatial location of complex cardiovascular malformations and

further reveal some “rare” vascular malformation paths. Additionally, it can also help develop and evaluate the more complicated 3D mathematical models of the fetal cardiovascular systems (22,23).

Abnormal ductus arteriosus: Our study suggests that the highest rate of prenatal misdiagnosis is abnormal ductus arteriosus, including abnormal ductus arteriosus connection, abnormal morphology with stenosis and absence of ductus arteriosus. In severe right heart system obstructive congenital heart disease, the reverse blood flow in the arterial duct occurs due to the need of perfusion of the pulmonary artery from the aorta to support the growth and development of the lung. The changes in blood flow direction and flow volume cause the ductus arteriosus to be distorted and narrow. When the ductus arteriosus is distorted, the winding blood flow signal from the aorta to a pulmonary artery can be displayed. Still, when it is too narrow, the blood flow is difficult to be displayed, so it is easy to be misdiagnosed as an absence. For example, ¶ In Case 20, the prenatal ultrasound was misdiagnosed as coarctation of the aorta (CoA) with descending aorta originated from the right ventricle, while the cast confirmed it was an interrupted aortic arch (IAA) with a descending aorta originated from the pulmonary artery, the abnormal connection of ductus arteriosus (pulmonary artery - ductus arteriosus - left common carotid artery), and aberrant left subclavian artery (Fig. 1 & Video 1.2.3). ¶ In Case 13, only the aortic coarctation was diagnosed by prenatal ultrasound, while the ductus arteriosus abnormal connections (LCCA-DA-PA) was confirmed by cast (Fig. 2).

Aberrant subclavian artery: Aberrant left subclavian artery is an abnormal branch of the aortic arch, which is common in the left aortic arch with aberrant right subclavian artery or right aortic arch with aberrant left subclavian artery. The diameter of the aortic branches in the fetal period is small, and the examiner is easy to miss the accurate diagnosis. Therefore, when the left ductus arteriosus with the right aortic arch appears in the examination, we should consider, whether there is an aberrant left subclavian artery, for example: In Case 10, the prenatal ultrasound only diagnosed DORV and PAS. Later, DORV with TGA, RAA with ALSA were confirmed by vascular casting. When the left ductus arteriosus with the left arch appeared, attention should be paid to, whether there is an aberrant right subclavian artery. The examiner should pay attention to the scanning of the three vessels-trachea (3V+ T view) view, and increase the use of Spatio-temporal image correlation to evaluate the spatial position relationship of micro blood vessels, which is helpful to clearly and stereoscopically display the aortic branches and their circuit that are difficult to be clearly displayed on the two-dimensional image view.

RAA increases the risk of associated cardiac defects regardless of laterality of the ductal arch. Concomitance of right ductus and right aortic arch was object of a recent meta-analysis(24). Since there are cases of RAA and ALSA in table 1, We believe that left ductal arch in RAA often occurs in cases with interrupted aortic arch with TGA or coarctation of the aorta wiht TGA after cast model re-analysis. The casting technique directly shows the ductal path, which is obviously very easy to assist in the diagnosis of ductal laterality. For example, Figure 1 and Figure 2, they all belong to LDA. The experimental materials of this study only include ABS or denture base powder , pigment, syringe, catheter, sodium hydroxide solution and sulfuric acid, which are all from clinical departments, pathology departments, stomatology departments in our hospital and affiliated University anatomy rooms. The cost of a mold is about 200

yuan(\$ 31.4). Because it does not involve commercial use, the hospital provides material support, so the casting procedure is basically free, Casting cannot replace standard anatomy because some details cannot be reached. In recent years, We learned that postmortem MRI (25,26) and micro CT (27,28) or as an alternative to the autopsy confirm the fetal diagnosis post-mortem and obtain more detail benefits. It is undeniable that this is much more advanced than the cast mold to some extent (Fig. 4-5). However, our team (especially Cardiologist and junior residents) believes that the casting technology still has advantages. After all, the MRI and micro CT images are too professional and not easy to understand. The casting model can directly show the detailed path of large blood vessels and their branches, which is more convenient for medical teaching. A complex CHD deformity model can bring a deep visual impression to medical students. Moreover, we can also carry out the casting process after postmortem MRI or micro CT.

With the continuous development of prenatal diagnosis techniques, the opening of “the second child policy”, and the increase in the pregnant women with advanced maternal age, the medical disputes of prenatal diagnosis in China are increasing by 15-20% every year, and the medical disputes due to the diagnostic defects lead to the deterioration of the doctor-patient relationship. In addition, based on China’s special social medical insurance model, if pregnant women do not buy expensive congenital disability insurance before neonatal delivery, once newborns are diagnosed with congenital malformations, huge treatment costs are needed to be borne by the families. They have to claim huge compensation from the hospital, which is very different from the advanced medical insurance system in Europe and America. Therefore, many families have to abandon these children with congenital diseases after childbirth (Fig. 3). Some children were subsequently adopted by foreigners, the same situation also prevails in India and other extensive Southeast Asian regions. Thus, the accuracy of prenatal diagnosis is very important in China, which can not only provide anatomical details for the postpartum surgery, but also reduce the burden on the families and society, and reduce unnecessary medical disputes. Of course, it is more important to deepen the reformation of the domestic medical system by learning the advanced medical insurance system in Europe and America (8,21).

Limitations

The casting of fetal cardiovascular model is indeed a novel and futuristic technology, but it is difficult to perfect the casting model and widely used in clinical practice. In addition, it must be considered that above all the pathologies of the arch and the obstructive ones are also evolutionary so it is not excluded that the ultrasound diagnoses may be late. Prenatal ultrasound has well-known limitations so it seems exaggerated to pretend that diagnoses can be made as the isolation of the epiaortic trunks. They are, in fact, diagnoses that are notoriously performed after birth. In fact, the best weeks at which heart disease can be seen by ultrasound are between the 18th and 22nd internationally; but it is limited to China's prenatal diagnosis regulations and special medical insurance system. Pregnant women usually carry out fetal malformation screening at 24-28 weeks or above, so I'm sorry that my medical institution can only carry out screening at 24-28 weeks, the diagnosis would not be so timely for intrauterine treatment. The method can be used to confirm prenatal diagnosis or to diagnose missed cases in poly-malformed cases

undergoing TOP for other reasons, but cannot be done as a gold standard in livebirths, obviously. This is the major limitation to be presented.

Conclusions

In conclusion, though echocardiography plays a significant role in the diagnosis of CCHD, the anatomy and position relationship displayed by CCMM is more conducive for promoting the perceptual knowledge of CCHD to the diagnostic medical sonographers and giving feedbacks on prenatal ultrasound diagnosis information. This can assist in improving the accuracy of the type and extents of the fetal heart malformations diagnosed by the sonographers and clinicians, and provide broad information in the field of clinical teaching.

Abbreviations

AO: Aortic arch, **AVA,** atrioventricular valve atresia; **AHVC,** anomalous hepatic venous connection; **ALSA,** aberrant left subclavian artery; **ASD,** atrial septal defect. **CHD** Congenital heart disease **CCHD** Complex congenital heart disease **COA:** coarctation of the aorta ; **DA:** ductus arteriosus, **DORV,** double-outlet right ventricle; **DAO,** descending aorta; **DSVC,** Double superior vena cava. **DA** ductus arteriosus. **HLHS,** hypoplastic left heart syndrome; **IVC,** inferior vena cava; **IIVC** Infrahepatic interruption of the inferior vena cava **IAA,** interrupted aortic arch; **JRAA,** juxtaposition of right atrial appendage; **LCCA:** Left common carotid artery, **LSA:** Left subclavian artery, **LIA:** Left innominate artery, **LPA:** left pulmonary artery, **LV,** left ventricle; **LVA,** left vertebral artery; **LAI,** left atrial isomerism; **LHV,** left hepatic vein; **LIV,** left innominate vein; **LPA,** left pulmonary artery; **LCCA,** left common carotid artery; **LBA,** left brachiocephalic artery; **PAS,** pulmonary artery stenosis; **PRUV,** persistent right umbilical vein; **PVS,** pulmonary valve stenosis; **PAPVC,** partial anomalous pulmonary venous connection; **PLSVC,** persistent left superior vena cava; **PA:** pulmonary artery, **PVA,** pulmonary valve atresia; **RSA:** Right subclavian artery, **RCCA:** Right common carotid artery, **RV:** Right ventricle, **RV,** right ventricle; **RAI,** right atrial isomerism; **RAA** Right aortic arch; **RPA,** right pulmonary artery; **RBA,** right brachiocephalic artery **RAMI** Right Aortic Arch with Mirror-image Branching; **RHV,** right hepatic vein **RAA,** right aortic arch; **TAPVC,** total anomalous pulmonary venous connection; **TGA,** transposition of the great arteries; **TOF,** Tetralogy of Fallot; **VSD,** ventricular septal defect.

Declarations

-Ethics approval and consent to participate:

This study ethics has been approved by the Human Ethics Committee of Jiangsu Hospital Group Ethics Committee (approval No.: 2013016x). Our present medical research medical research was conducted according to the principles expressed in the Declaration of Helsinki. We also obtained, written consent from the patient's family.

-Consent for publication:

Written informed consent was obtained from the patient's family for publication of this case and any accompanying images.

-Availability of data and material:

All relevant data supporting the conclusions of this article are included within the article.

-Competing interests:

The authors declare that they have no competing interests

-Authors' contributions:

PA conceived and drafted the manuscript. All of the authors contributed to the literature review, revised the manuscript critically for important intellectual content, WZQ approved the final version to be published and agreed to act as guarantors of the work.

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Figures

1A ↑

1B ↑

Figure 1

In Case 20, the coarctation of the aorta (CoA) with descending aorta originated from the right ventricle was misdiagnosed by the prenatal ultrasound (1A), while the cast confirmed it was interruption Aortic arch (IAA) with descending aorta (DAO) originated from the pulmonary artery (PA), the abnormal connection of ductus arteriosus (pulmonary artery - ductus arteriosus - left common carotid artery), and aberrant left subclavian artery (originated from the descending aorta)(1B)

Figure 2

In Case 13, only the coarctation of the aorta was diagnosed using the prenatal ultrasound, and then abnormal ductus arteriosus connections (Left common carotid artery (LCCA) - ductus arteriosus (DA) - pulmonary artery (PA)) was confirmed by the cast.

Figure 3

Many children with albinism and congenital heart disease are abandoned every year. Similar situations happen every day (a picture taken at a remote rural market).

Figure 4

Axial and coronal view of the heart of a fetus of 32-week gestational age terminated for Tetralogy of Fallot and microdeletion 22q11 using 3-T postmortem magnetic resonance imaging (A, C) and ultrasound (B, D) showing thymus agenesis in which a blood clot related to termination (open arrow), pulmonary artery atresia (arrow), and right-sided aorta crossing ventricular septal defect are seen(*) (25).

Figure 5

Sequential slice in a volume obtained using microfocus computed tomography in a fetus of 13-week gestational age terminated for trisomy 18(25,27).

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