Clinical value of ultrasound in diagnosis and classification of common arterial trunk

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Abstract

Objectives: This study aims to explore the clinical value of prenatal ultrasonography in the diagnosis of the common arterial trunk (CAT) classification and associated deformities. **Materials and methods:** The two-dimensional ultrasound images spatiotemporal image correlations (STICs) and clinical data of 108 foetuses diagnosed with CAT malformations were retrospectively analysed, their CAT types were classified, and the correlations between these different types and foetal malformations and pregnancy outcomes were analysed. **Results:** Among the 108 foetuses, there were 47 cases (43.5%) of type A1, 51 cases (47.3%) of type A2, 9 cases (8.3%) of type A3 and 1 case of type A4 (0.9%), of which 22 cases (20.4%) were isolated CAT, 56 cases (51.8%) had complex intra-cardiac structural abnormalities, 30 cases (27.8%) had intra-cardiac or extra-cardiac structural abnormalities, 17 cases had 1 other system abnormality, and 5 cases had 2 other system abnormalities. Four cases were combined with 3 other system abnormalities, while 4 cases were combined with 4 other system abnormalities, among which the facial and physical abnormalities had the highest incidence (40.0%). The STIC images were completely displayed in 88 cases (81.5%). Isolated CAT and CAT combined with other malformations were significantly correlated with foetal pregnancy outcomes ($P < 0.05$). **Conclusions:** Prenatal ultrasonography had a high clinical application value for classifying CAT. Pregnancy outcomes were highly correlated with the classification and combined intra-cardiac and extra-cardiac structural malformations. The early assessment of foetal prognosis before birth has great value for clinical intervention.

Clinical value of ultrasound in diagnosis and classification ofcommon arterial trunk

Short running title: Prenatal diagnosis of the CAT

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Availability of data and materials

The data and material in the current study are available from the corresponding author on reasonable request.

Abstract

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Results: Among the 108 foetuses, there were 47 cases (43.5%) of type A1, 51 cases (47.3%) of type A2, 9 cases (8.3%) of type A3 and 1 case of type A4 (0.9%), of which 22 cases (20.4%) were isolated CAT, 56 cases (51.8%) had complex intra-cardiac structural abnormalities, 30 cases (27.8%) had intra-cardiac or extra-cardiac structural abnormalities, 17 cases had 1 other system abnormality, and 5 cases had 2 other system abnormalities. Four cases were combined with 3 other system abnormalities, while 4 cases were combined with 4 other system abnormalities, among which the facial and physical abnormalities had the highest incidence (40.0%). The STIC images were completely displayed in 88 cases (81.5%). Isolated CAT and CAT combined with other malformations were significantly correlated with foetal pregnancy outcomes ($P < 0.05$).

Conclusions: Prenatal ultrasonography had a high clinical application value for classifying CAT. Pregnancy outcomes were highly correlated with the classification and combined intra-cardiac and extra-cardiac structural malformations. The early assessment of foetal prognosis before birth has great value for clinical intervention.

KEYWORDS: prenatal ultrasound; common arterial trunk; foetus; spatio-temporal image correlation

1 | INtroduction

Common arterial trunk (CAT) is a rare congenital heart defect (CHD), accounting for about 1% of CHD foetuses.[1] CAT represents an early stage of the development of primitive arterial septum during embryonic development. Therefore, only one large artery leading from the bottom of the embryonic heart is preserved, and the ventricular blood is pumped into systemic circulation, pulmonary circulation and coronary circulation through a set of semilunar valves' instead.[2] The prognosis of CAT is extremely poor, as 50% of children die within 1 month of birth due to heart failure and other causes and only 15%–30% survive for more than 1 year.[3] Therefore, an early prenatal diagnosis guides the correct clinical treatment. This study retrospectively analysed CAT prenatal ultrasound images, spatiotemporal image correlation (STIC) images and their associated deformities to improve the understanding of CAT and reduce perinatal mortality.

2 | MATERIALS AND METHODS

This retrospective study analysed two-dimensional ultrasound, colour Doppler and STIC images of CAT diagnosed using prenatal ultrasound at the Gansu Maternal and Child Health Hospital from June 2017 to June 2022. The age of the pregnant women was 17–37 years (average 27.34 ± 4.76 years) and the first detected gestational week was 13–37 weeks (average 23.92 ± 3.38 weeks). The exclusion criteria were incomplete ultrasound or clinical data and lost to follow-up.

The Voluson E8, E10 colour Doppler ultrasound diagnostic instrument (General Electric Co., Boston, MA, USA) and an abdominal volume probe at a frequency of 2.0–5.0 MHz were used for the ultrasound. Pregnant women were placed in the supine position, the main structures of the foetuses were examined, and related

growth and development assessments were performed. Visceral locations were determined, beginning with the transverse section of the abdomen. The foetal heart mode was selected, and reserved sections were checked according to cardiac standards, including two-dimensional ultrasonography, colour Doppler and STIC volume images. The ventricular outflow tract section and the three-vessel tracheal section were mainly observed. A CAT was considered if the ventricular outflow tract view showed only one set of semilunar valves, only one thick arterial trunk emerged from the left or right ventricles, the normal order of the great arteries disappeared on the three-vessel tracheal view, or only a single arterial trunk and the superior vena cava were displayed. The woman was instructed to hold her breath, and the STIC condition was selected for volume data acquisition when the foetus was in a quiet state, and the connection between the left and right pulmonary arteries and the common arterial trunk was determined on the stereoscopic STIC images. The diagnosis was confirmed by two deputy chief physicians with prenatal diagnosis qualifications. The pregnancy outcomes were followed up in all cases.

The common arterial trunk was divided into 4 types using the Van Praagh classification based on the origin of the pulmonary artery:[4] A1 type: the common pulmonary artery originated from the left wall of the PTA (Figures 1a, 1b); A2 type: the left and right pulmonary arteries originated from the posterior or both lateral walls of the PTA, respectively (Figures 2a, 2b); A3 type: pulmonary artery originated from a single trunk and the ductus arteriosus, or collaterals supplied the other lung (Figures 3a, 3b); type A4: persistent trunk with severed interrupted aortic arch (IAA).

SPSS 25.0 statistical software (SPSS Inc., Chicago, IL, USA) was used to analyse the data. Maternal age and the detected gestational age were normally distributed and expressed as mean ± standard deviation. The count data are expressed as frequencies and percentages, and the chi-square or Fisher's exact test was used to compare the groups. All results are two-tailed, and P <0.05 was considered significant.

3 | RESULTS

A total of 108 CAT cases were identified by prenatal echocardiography, of which 10 were detected before 20 weeks of pregnancy, 3 in the third trimester, and the remaining 95 in the second trimester between 20 and 28 weeks. Forty-seven cases were the A1 type (43.5%, 47/108), 51 cases were the A2 type (47.3%, 51/108), 9 cases were the A3 type (8.3%, 9/108), and 1 case was the A4 type (0.9%, 1/108). The A1 and A2 prenatal types were the most common, accounting for 90.7% (98/108) of this cohort, but only 1 case of the A4 type was associated with an aberrant right subclavian artery (Figures 4a, 4b). Among them, 22 cases (20.4%) were isolated CAT, 56 cases (51.8%) were complicated with complex intra-cardiac structural abnormalities, including total endocardial cushion defects, single atrial-single ventricle, hypoplastic left heart syndrome, persistent superior vena cava, atrial isomerism syndrome, total anomalous pulmonary venous collection, left aortic arch with aberrant right subclavian artery and left ductus arteriosus, right aortic arch with aberrant left subclavian artery and left ductus arteriosus, mirror image right aortic arch and left brachiocephalic vein, etc (Table 1). 30 cases (27.8%) were complicated with intra-cardiac and extra-cardiac structural abnormalities. A total of 55 systemic malformations were detected in 30 foetuses with abnormal extra-cardiac structures, of which 17 were combined with 1 abnormality in another system, 5 were combined with 2 other system abnormalities, 4 were combined with 3 other system abnormalities, and 4 cases were combined with 4 other system abnormalities. The extra-cardiac system, particularly the facial and physical abnormalities, had the highest incidence (40.0%), followed by the urinary system (14.5%) and the nervous system (14.5%) (Table 2). The STIC images were completely displayed in 88 cases (81.5%), but satisfactory STIC volume images were not obtained in the other 20 cases.

The pregnancy outcomes of all 108 foetuses were followed up. Among the 22 foetuses with isolated CAT, 1 case died in utero, 7 of the 16 foetuses died after birth, and 5 pregnant women and their families terminated their pregnancies after antenatal consultation. Of the 86 cases of PTA complicated with other malformed foetuses, 7 cases chose to continue the pregnancy and received timely surgical treatment after delivery. Among them, 2 cases were in good health. The remainder were combined with various complications. Eight intrauterine deaths, 10 postnatal deaths and 61 cases of pregnancy termination due to complicated intra-cardiac and extra-cardiac malformations were encountered. The incidence of combined other malformations

was higher than that of isolated PTA, resulting in an adverse pregnancy outcome (20.37% vs 79.63%, $P < 0.05$; Table 3).

4 | DISCUSSION

This study was a larger-scale study of prenatal CAT diagnosis, with a particular focus on the diagnostic accuracy of two-dimensional ultrasonography compared with STIC images for anatomical subtypes and to assess the effect of intra-cardiac and extra-cardiac structural abnormalities associated with CAT on pregnancy outcomes. According to the anatomical classification proposed by Van Praagh, CAT is classified following the anatomical origin of the pulmonary artery and the spatial relationship between the vessels. Among the 108 foetuses with CAT in this study, the incidence of the A1 and A2 types was higher (90.7%), which was consistent with a previous study[2]. Among them, 22 cases (20.4%) were isolated CAT, and the remainder were combined with complex intra-cardiac and extra-cardiac structural deformities.

As an accurate prenatal assessment of CAT is extremely challenging, many cases may be misdiagnosed during prenatal ultrasonography screening.[5] A large proportion of foetuses in this study had complex intra-cardiac and extra-cardiac malformations, with prevalence rates of 51.8% and 27.8%, respectively, and only 20.4% of the foetuses were isolated. In contrast, the incidence of CAT complicated with intra-cardiac malformations was higher (51.8%), and the incidence of extra-cardiac malformations was consistent with that reported by Gomez et al.[6] However, Abel et al. reported that the incidence of extra-cardiac malformations was 58.8%.[7] This difference may be because most of the studies focused on examining the foetal cardiac structure and ignored the extra-cardiac structural malformations. A total of 55 systemic abnormalities were found in 30 cases of combined extra-cardiac structural malformations, of which facial and physical abnormalities were the most common (40.0%), followed by the urinary and nervous systems. Previous studies only reported the incidence of combined extra-cardiac malformations, and the incidence in each system was not specified. Thus, detailed facial and body scans should be routinely performed after a CAT diagnosis.

The prognosis of CAT is closely related to the type of combined deformity. Complex intra-cardiac structural abnormalities complicate the surgery, leading to higher postpartum mortality and morbidity and may affect the decision of the parents to continue or terminate the pregnancy.[3] In previous studies, the incidence of pregnancy termination varied widely at 24%,[8]40%[9] and 75%,[10] respectively. In our study, 61.1% of pregnant women and their families chose to terminate the pregnancy after consulting a prenatal diagnostician. Duke et al. reported a lower incidence of pregnancy termination,[8] possibly due to the first detection during the third trimester. In contrast, up to 75% of foetal terminations in Gomez's cohort may have included only 8 cases, and the accuracy of prenatal diagnosis was only 67%.[10]

Previous studies have shown that foetal echocardiography and STIC images are useful in improving the differential diagnosis of CAT.[6, 11] In our series, 61.1% of the parents chose to terminate the pregnancy due to complicated intra-cardiac and extra-cardiac malformations. We retrospectively analysed 108 cases of traditional two-dimensional echocardiography and STIC images.[12] STIC images can be used to evaluate the anatomical structure of the CAT and pulmonary artery stereoscopically and intuitively, which is of great value in determining the CAT classification and differential diagnosis.[13] STIC completely displays the aortic arch, which is a better display rate than IAA.[14] In our study, prenatal STIC images were obtained for 88 cases, of which 1 case of A4 type STIC image intuitively showed IAA. The prenatal diagnosis was consistent with the autopsy results. The STIC image quality of the other 20 cases was poor, so satisfactory STIC volume images could not be obtained, possibly due to shorter or longer gestational age, along with other influencing factors such as maternal obesity. Therefore, STIC can be used as an auxiliary diagnostic method to increase the accuracy of CAT diagnosis.

The prenatal diagnosis of CAT has been mainly differentiated from other malformations of the conus arteriosus, such as tetralogy of Fallot (TOF) and pulmonary atresia with ventricular septal defect (PA-VSD). In the case of TOF, the finer branches of the pulmonary artery arise from the right ventricular outflow tract with two sets of semilunar valves.[15] In PA-VSD, the pulmonary artery is not connected to the ventricle or the ascending aorta. The majority of the aortopulmonary collateral arteries or retrograde ductus arteriosus sup-

ply blood, and most of them are associated with the right aortic arch (RAA).[16] Only 22 foetuses (20.4%) had an RAA in our study. This study shows that the STIC images were more accurate for differential diagnosis and with the types between PTA, TOF and PA-VSD.

In summary, prenatal echocardiography combined with STIC images was useful for accurately diagnosing CAT and identifying its subtypes. This study included intra-cardiac and extra-cardiac anomalies associated with CAT; therefore, it can be used as an important basis for clinical decisions.

Ethical approval

This study was granted an exemption from the Medical Ethics Committee of Gansu Provincial Maternity and Child-care Hospital. The participants provided their written informed consent to publish their cases (including publication of images).

CONFLICTS OF INTEREST

The authors declare no conflict of interest.

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Figure legends CAT

FIGURE 1: (a) Two-dimensional image showes that the main pulmonary artery originated from the left side of the arterial trunk.**(b)** STIC image showing the main pulmonary artery originating from the left side of the arterial trunk. CAT: common arterial trunk, PA: pulmonary artery, MPA: main pulmonary artery, LPA: left pulmonary artery, RPA: right pulmonary artery.

FIGURE 2: (a) Two-dimensional image shows that the left and right pulmonary arteries originate behind the arterial trunk, respectively. **(b)** STIC image showing the left and right pulmonary arteries originate behind the arterial trunk, respectively. AO: aorta, TA: arterial trunk, RPA: right pulmonary artery, LPA: left pulmonary artery.

FIGURE 3: (a) Two-dimensional ultrasound shows that the left pulmonary artery originates from the arterial trunk and the right pulmonary artery is supplied by the ductus arteriosus.**(b)** STIC image showing the left pulmonary artery originates from the arterial trunk and the right pulmonary artery is supplied by the ductus arteriosus. LV: left ventricle, RV: right ventricle, Tr: trunk, LPA: left pulmonary artery, RPA: right pulmonary artery, DA: ductus arteriosus.

FIGURE 4: (a) Two-dimensional ultrasonography and CDFI of the three-vessel tracheal section showed that the left subclavian artery was interrupted in the distal aortic arch, and the right subclavian artery originated from the origin of the descending aorta.**(b)** STIC shows that the arterial trunk divides into the pulmonary artery and the ascending aorta, and the right subclavian artery arises from the origin of the descending aorta. AAO: ascending aorta, PA: pulmonary artery, Tr: trunk, DA: ductus arteriosus, DAO: descending aorta, ARSA: aberrant right subclavian artery.

TABLE 1 Intra-cardiac structural malformations combined with the CAT subtypes

Type	Total	A1	A2	A3	A4
TECD	26	12	12	2	0
SA-SV	31	13	16	2	0
HLHS	8	4	4	0	0
PLSVC	10	4	4	2	0
LAIS	2	1	1	0	0
RAIS	2	2	0	0	0
TAPVC heart type intra-cardiac sub-cardiac	4 1 3	0 1 2	4 0 1	0 0 0	0 0 0
LAA-ARSA-LDA	4	2	0	1	1

Type	Total	A1	A2	A3	A4
RAA-ALSA-LDA	9	4	5	0	0
MRAA	2	0	1	1	0
LBCV abnormality LBCV intrathymic course LBCV behind the oesophagus	1 1	0 1	1 0	0 0	0 0
Left axis deviation	3	2	0	1	0
left ventricular bright spot	5	1	2	2	0

Abbreviations: TECD, total endocardial cushion defects; SA-SV, single atrial-single ventricle; HLHS, hypoplastic left heart syndrome; PLSVC, persistent superior vena cava; LAIS, left atrial isomerism syndrome; RAIS, right atrial isomerism syndrome; TAPVC, total anomalous pulmonary venous collection; LAA-ARSA-LDA, left aortic arch with aberrant right subclavian artery and left ductus arteriosus; RAA-ALSA-LDA, right aortic arch with aberrant left subclavian artery and left ductus arteriosus; MRAA, mirror image right aortic arch; LBCV, left brachiocephalic vein

TABLE 2 Extra-cardiac structural malformations associated with CAT

	One abnormal organ system (n = 17)	Two abnormal organ systems (n = 5)	Three abnormal organ sys
Urinary	2	1	1
Digestive	2	2	0
Nervous	0	2	3
Skeletal	0	0	1
Face and body	11	4	4
Other	2	1	3
Total	17	10	12

TABLE 3 Comparison of pregnancy outcomes between isolated CAT and CAT combined with other malformed foetuses

	Total	Isolated CAT	CAT with anomalies	χ-value	p-value
Live birth	16 (14.81%)	9 (40.91%)	7 (8.14%)	24.372	0.000
Intrauterine death	9 (8.33%)	1 (4.55%)	8 (9.30%)		
Death after birth	17 (15.74%)	7 (31.82%)	10 (11.63%)		
Termination	66 (61.12%)	5 (22.72%)	61 (70.93%)		
Total	108	22	86