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Anomalous drainage of the ductus venosus into the coronary sinus: prenatal ultrasound diagnosis utilizing two-dimensional and three-dimensional imaging techniques and differential diagnosis

Weng-dong Zhang[1†], Bin Ma[1†], Ping-an Qi[1], Gang Wang[1], Xiao Rong Su[1], Xiao Yun Ma[1] and Tian-gang Li[1*]

Abstract

Background Anomalous drainage of the ductus venosus (DV) into the coronary sinus (CS) is a rare fetal vascular anomaly that poses challenges for prenatal diagnosis. This study aimed to investigate the role of two-dimensional (2D) and three-dimensional (3D) ultrasound imaging, specifically spatiotemporal image correlation (STIC) technology, in improving the prenatal diagnosis of this anomaly.

Methods We retrospectively reviewed eight cases of fetuses diagnosed with anomalous DV drainage into the CS at Gansu Provincial Maternal and Child Health Hospital between September 2019 and September 2024. The gestational age of the fetuses ranged from 24 to 30 weeks. Ultrasound examinations, including 2D and Doppler imaging, along with HDlive Flow combined with STIC technology, were used for diagnosis. Differential diagnoses were made based on imaging findings. Descriptive statistics were employed to summarize the results.

Results Eight fetuses with anomalous DV drainage into the CS were identified. Of these, five cases were isolated anomalies, while three had associated malformations, such as aberrant right subclavian artery and right aortic arch. Dilated CS was observed in all cases, with an average inner diameter of 5.7 mm. STIC imaging successfully visualized the abnormal course of the DV, enhancing diagnostic confidence. Postnatal follow-up indicated favorable outcomes for most neonates (except for Case NO.3 and Case NO.7), although persistent CS dilation was observed in these cases, without significant hemodynamic compromise or clinical symptoms.

Conclusions Prenatal diagnosis of anomalous DV drainage into the CS can be effectively achieved using 2D and 3D ultrasound, with STIC technology providing added diagnostic clarity. Early and accurate detection is crucial for ensuring appropriate clinical management and favorable outcomes. Ongoing surveillance of CS dilation in the postnatal period is recommended.

Keywords Ductus Venosus, Coronary Sinus, Spatiotemporal Image Correlation (STIC), Prenatal Diagnosis, Fetal Echocardiography, Anomalous Venous Drainage

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Background

The ductus venosus (DV) is a vessel that connects the umbilical vein to the inferior vena cava near its entrance to the right atrium [1]. It is a unique structure during the fetal period and plays an essential role in fetal circulation. Abnormalities in the DV may be associated with fetal cardiac or extracardiac malformations, chromosomal abnormalities, and congestive heart failure [2, 3]. Doppler ultrasound examination of the DV is an important component of the $11–13^{+6}$ week fetal nuchal translucency (NT) screening. The fetal coronary sinus (CS) is a thin-walled vascular structure with a diameter ranging from 1–3 mm and During weeks 24–30 of pregnancy, the internal diameter of the CS is approximately 1.74 ± 0.15 mm. [4], which drains the majority of the cardiac venous return, including blood from the great cardiac vein, middle cardiac vein, and posterior vein of the left ventricle. Abnormal drainage of the DV into the CS during the fetal period is extremely rare, and prenatal ultrasound diagnosis remains challenging.The pathological and physiological changes of anomalous drainage of the DV into the CS may be related to the connection between the DV and the proximal part of the left vitelline vein (left hepatic common cardinal vein) during embryonic development. After the DV drains abnormally into the CS, the CS expands due to increased blood volume, while the blood flow pathway of the umbilical vein changes, leading to a reduction in oxygenated blood flowing through the foramen ovale into the left atrium. This study retrospectively analyzed the prenatal data of 8 fetuses with anomalous drainage of the DV into the CS, summarized the two-dimensional sonographic features, and employed spatiotemporal image correlation (STIC) technology for diagnosis and differential diagnosis.

Methods

In this retrospective study, the ultrasound and clinical data of eight cases of anomalous drainage of the DV into the CS, diagnosed through prenatal systematic ultrasound or fetal echocardiography at the Gansu Provincial Maternal and Child Health Hospital from September 2019 to September 2024, were analyzed. The gestational age of the fetuses ranged from 24 to 30 weeks, and the age of the pregnant women ranged from 24 to 34 years. All case diagnoses and differential diagnoses were performed by two clinical professors with extensive experience in fetal systemic screening and fetal cardiac examination. The clinical characteristics of the pregnant women are presented in Table 1.

Ultrasound images were obtained using an eM6C (2.0–5.0 MHz) transducer from the Voluson E10 ultrasound system (GE Healthcare, Zipf, Austria). Two-dimensional ultrasound was employed to detect structural abnormalities in the fetus. Fetal echocardiography was performed to assess fetal cardiac anomalies. The anomalous course of the DV and dilated CS were observed using two-dimensional ultrasound and HDlive Flow combined with STIC technology, and differential diagnoses were conducted. Freeze the image when a complete CS is visualized in the low four-chamber view. Utilize the cine-loop function to review the last stored image for CS diameter measurement. The CS diameter was measured from inner wall to inner wall at the mid-portion, located between the left atrial wall and the CS orifice.

Acquisition of HDlive Flow combined with STIC images: A volumetric dataset of the fetal heart was obtained using STIC, which utilizes an automated sagittal scan of the fetal anterior chest wall. After the CS and DV were visualized, the image was zoomed in to cover the entire fetal thorax, revealing the CS. The wall motion filter was set to "mid 2," and the pulse repetition frequency was set to 1.3 kHz to ensure maximum

Table 1 Maternal, fetal characteristics, and postnatal outcomes

Case No	MA (years)	GA (weeks)	Fetal Sex	CS Diameter (mm)	Associated Anomalies	Mode of Delivery	Apgar Score (1′/5′)	Postnatal CS Diameter (mm)
1	24	24^{+2}	Male	5.0	ARSA	Cesarean section	9/10	4.7
2	31	24^{+5}	Male	6.2	RAA + ALSA + Subaortic-LBCV	Normal vaginal delivery	8/9	5.3
3	32	26^{+1}	Female	4.6	ARSA	Normal vaginal delivery	9/10	NA
4	31	26^{+2}	Female	6.3	None	Normal vaginal delivery	9/10	5.5
5	28	26^{+3}	Female	4.7	None	Cesarean section	8/9	4.7
6	28	26^{+4}	Female	7.6	None	Normal vaginal delivery	9/10	6.2
7	24	28^{+4}	Male	5.5	ARR	Cesarean section	8/9	NA
8	34	30^{+2}	Female	5.6	None	Normal vaginal delivery	9/10	5.0

MA Maternal Age (years), *GA* Gestational Age (weeks), *CS* Coronary Sinus, *ARR* Arrhythmia, *ARSA* Aberrant Right Subclavian Artery, *RAA* Right Aortic Arch, *ALSA* Aberrant Left Subclavian Artery, *Subaortic-LBCV* Subaortic Left Brachiocephalic Vein, *NA* Not Available

sensitivity. Throughout the fetal heart examination, the following instrument settings were consistently used to maintain optimal STIC image quality: Smoothness (3/4); Dynamics (Balance, 225); Line Density (7); Ensemble (8); Artifact Suppression (On); Power Doppler (1); Power Doppler Line Filter (3); Quality (Normal). A transabdominal volume probe was used for scanning, the STIC mode was activated, the acquisition time was set to 10–12.5 s, and the scanning angle was 25 degrees. Scanning was repeated until satisfactory images were obtained.

Results

This study analyzed eight cases of anomalous drainage of the DV into the CS identified through fetal echocardiography. During cardiac screening in all cases using fetal echocardiography, no significant abnormalities were observed in the standard four-chamber view. However, a dilated CS was detected in the low four-chamber view. No anomalous connections of the left superior vena cava or pulmonary veins were observed during dynamic scanning. Further examination revealed that the umbilical vein followed the normal pathway through the liver, giving rise to the DV, which bypassed the inferior vena cava, left hepatic vein, and diaphragmatic vestibule, draining directly into the coronary sinus. After systematic evaluation, five cases were identified as isolated anomalous drainage of the DV, while three cases were associated with other cardiac structural abnormalities, including two cases of aberrant right subclavian artery, one case of right aortic arch with aberrant left subclavian artery and infra-diaphragmatic course of the brachiocephalic vein. The associated cardiac and extracardiac malformations are summarized in Table 1.

In all eight cases, no significant abnormalities were observed in the atrial and ventricular proportions in the standard four-chamber view. No special findings were noted in the left and right ventricular outflow tract views. In all cases, a dilated CS was detected in the low four-chamber view (Fig. 1A), with an inner diameter ranging from 4.6 to 7.6 mm, and an average inner diameter of 5.7 mm. Tracing the scan centered on the coronary sinus, it was observed in the para-median sagittal

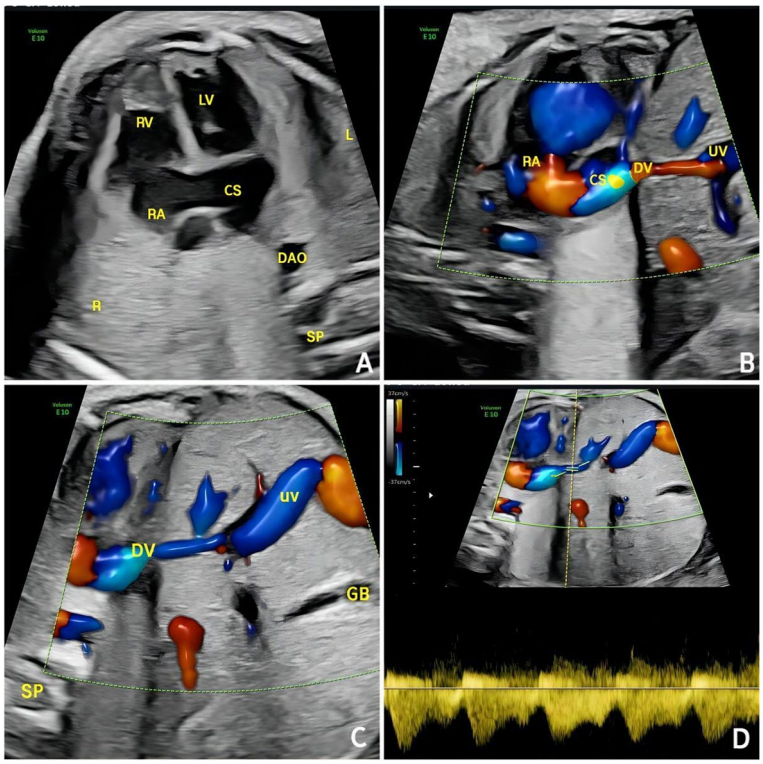

Fig. 1 Two-Dimensional Ultrasound, Color Doppler, and Spectral Doppler Features of Anomalous Drainage of the Ductus Venosus into the Coronary Sinus. (1**A**) Sonograms reveal a dilated coronary sinus in the low four-chamber view. (1**B**) Parasagittal sonograms demonstrate the aberrant course of the ductus venosus (DV). Near the insertion of the inferior vena cava into the right atrium, an anomalous vessel is visualized draining into the coronary sinus. The vessel's connection to the umbilical vein (UV) confirms its identification as the ductus venosus (DV). (1**C**) Abdominal transverse sections show the abnormal trajectory of the ductus venosus from different angles. (1**D**) Pulsed Doppler flow at the ostium of the coronary sinus displays the characteristic ductus venosus waveform. RV: Right Ventricle; LV: Left Ventricle; RA: Right Atrium; CS: Coronary Sinus; DAO: Descending Aorta; SP: Spine; DV: Ductus Venosus; UV: Umbilical Vein; GB: Gall Bladder; L: Left; R: Right

plane that the DV did not connect to the inferior vena cava but instead traveled towards the fetal head and drained directly into the coronary sinus (Fig. 1B-1C; Mov.1). Color Doppler imaging showed that blood flow from the umbilical vein passed through the DV and drained directly into the CS (Mov.2). Spectral Doppler displayed a typical DV waveform, characterized by a double-peak and single-valley unidirectional blood flow throughout the cardiac cycle (Fig. 1D;Mov.3). STIC imaging was performed on the abnormally coursing DV (Fig. 2A-2D), when the fetal position allowed, yielding good results and providing additional imaging views for differential diagnosis (Fig. 3).

In our study, The neonates exhibited good postnatal outcomes, as reflected by their Apgar scores, which were within normal limits. Follow-up assessments performed at 3 days and 50 days post-delivery showed that the infants had normal growth parameters, including height and weight. None of the neonates exhibited signs of cyanosis or other symptoms typically associated with congenital heart disease.

However, during the postnatal period, we noted that the CS remained dilated in all cases (Table 1). Neonatal echocardiography performed at both 3 days and 50 days of age confirmed that the CS continued to be dilated (Fig. 4; Mov.4–6), even though there was no evidence of hemodynamic compromise or clinical symptoms suggesting heart failure.

Discussion

Dilated CS was observed in all eight cases of anomalous drainage of the DV into the CS in this study. Based on our study group and previous literature [1–3], it can be inferred that the anomalous drainage of the DV into the CS does not significantly impact fetal development and newborn health. This is because anomalous drainage of the DV into the CS differs from the absence of the DV with direct connection of the umbilical vein to the CS [5–7]. In the former case, fetal hemodynamics are not significantly disturbed, and the development of the umbilical vein, systemic veins, and portal veins proceeds normally. Furthermore, the DV typically closes after birth, which prevents additional load on the CS.

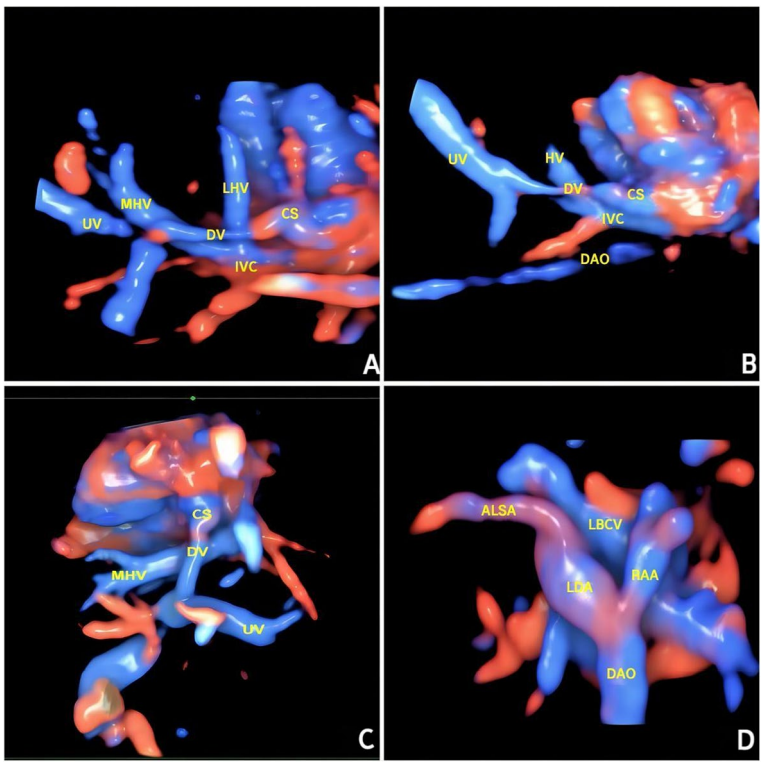

Fig. 2 STIC Imaging of Anomalous Ductus Venosus and Vagal Right Subclavian Artery in a Fetal Case. (2**A**, 2**B**, and 2**C**) STIC imaging showing the course and connections of the ductus venosus in three-dimensional space, with results from different cases. (2**D**) A case showing anomalous drainage of the ductus venosus into the coronary sinus, associated with a right-sided aortic arch, a vagal left subclavian artery, and a brachiocephalic vein running beneath the aortic arch. UV: Umbilical Vein; MHV: Middle Hepatic Vein; LHV: Left Hepatic Vein; DV: Ductus Venosus; IVC: Inferior Vena Cava; CS: Coronary Sinus; HV: Hepatic Vein; DAO: Descending Aorta; ALSA: Aberrant Left Subclavian Artery; LBCV: Left Brachiocephalic Vein; RAA: Right Aortic Arch; LDA: Left Diagonal Artery

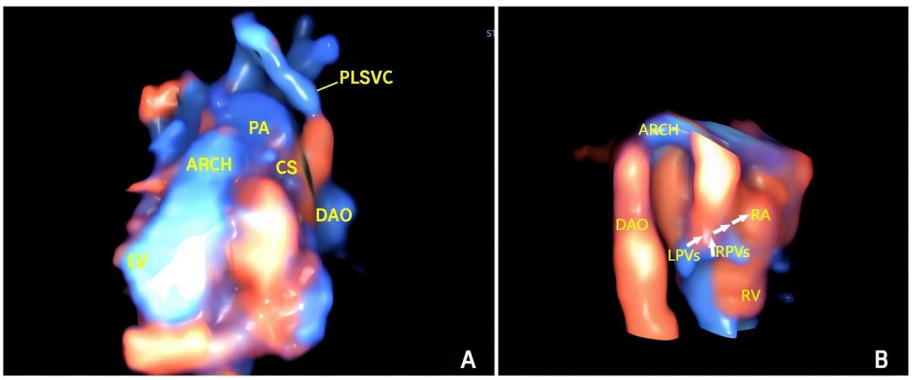

Fig. 3 Differential Diagnosis of Dilated Coronary Sinus: Persistent Left Superior Vena Cava and Intracardiac Pulmonary Venous Drainage. (3**A**) STIC imaging of a persistent left superior vena cava (PLSVC), showing a vessel draining from the left pulmonary artery into the coronary sinus. (3**B**) STIC imaging of intracardiac pulmonary venous connection (APVC), demonstrating the anomalous connection to the coronary sinus. The drainage path of the pulmonary veins is indicated by the white arrows. PA: Pulmonary Artery; CS: Coronary Sinus; DAO: Descending Aorta; ARCH: Aortic Arch; LV: Left Ventricle; RA: Right Atrium; RV: Right Ventricle; LPVs: Left Pulmonary Veins; RPVs: Right Pulmonary Veins

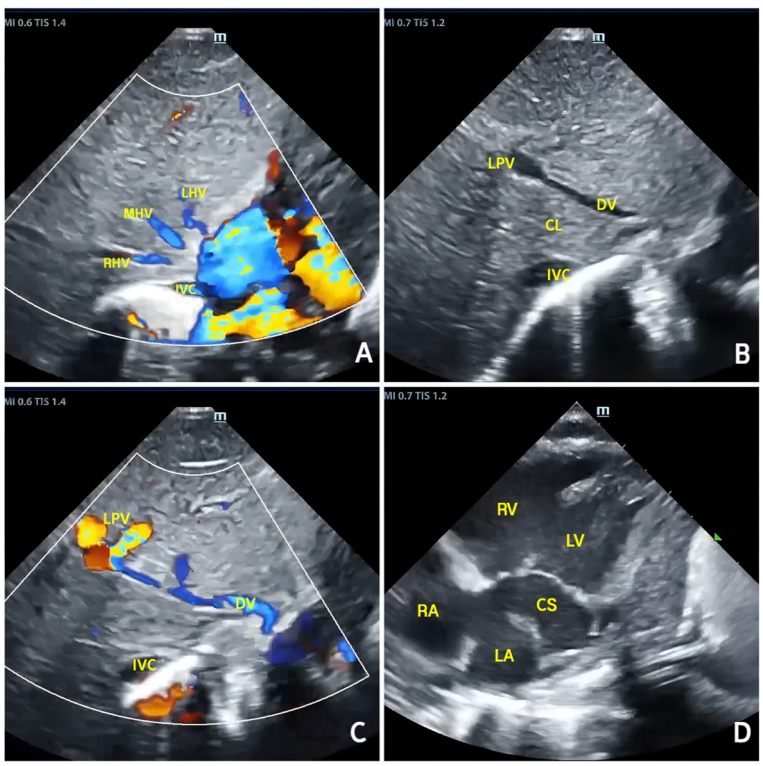

Fig. 4 Ductus Venosus Draining into the Coronary Sinus on Postnatal Day 3 Ultrasound. (4**A**) Color Doppler Flow Imaging at the First Hepatic Portal in a Neonate. (4**B**) Two-dimensional Ultrasound Demonstrating a Non-occluded DV. (4**C**) CDFI Showing the Course of the DV Without Drainage into the IVC. (4**D**) Subxiphoid Non-standard Four-chamber Heart View: Depicting Drainage into a Dilated CS. LPV: Left Portal Vein; CL: Caudate Lobe; DV: Ductus Venosus; LHV: Left Hepatic Vein; MHV: Middle Hepatic Vein; RHV: Right Hepatic Vein; IVC: Inferior Vena Cava; LA: Left Atrium; LV: Left Ventricle; RA: Right Atrium; RV: Right Ventricle

Since the DV and CS are not part of the prenatal ultrasound screening in the second and third trimesters, anomalies involving these structures may be overlooked unless other abnormalities are present. A retrospective analysis of our data from 122,542 pregnant women showed an incidence of approximately 0.65‰ for this condition.

Prenatal ultrasound of the fetal abdominal parasagittal and transverse sections reveals the DV draining into the CS as a direct sign of anomalous drainage. The blood flow spectrum of the DV further aids in diagnosis. When scanning the fetal four-chamber view, especially the posterior four-chamber view, attention should be focused on the dilated CS. The probe should then be rotated to perform parasagittal scans to actively search for the cause of CS dilation. Additionally, the characteristic blood flow spectrum of the DV can help confirm the diagnosis [8, 9].

When prenatal ultrasound detects a dilated CS in the fetus, it is essential to determine the cause to assess prognosis. Several factors may contribute to fetal CS enlargement, with persistent left superior vena cava (PLSVC) being the most common, followed by intracardiac anomalous pulmonary venous connection (APVC). Other possible causes include increased right heart pressure (such as severe pulmonary stenosis or premature closure of the ductus arteriosus), excessive right heart volume load (such as severe Ebstein's anomaly or significant tricuspid regurgitation), and heart failure. It is also crucial to consider the possibility of multiple contributing factors [10].

When CS dilation is caused by a PLSVC, there is often no significant hemodynamic change, and prognosis is generally favorable. PLSVC can typically be visualized as an abnormal vessel on the left side of the pulmonary artery in the three-vessel tracheal view, connecting downward to the dilated CS in the sagittal view (Fig. 3A). Prenatal ultrasound diagnosis of PLSVC can be made using four key views: the four-chamber view, the low four-chamber view, the three-vessel tracheal view, and the left parasternal view.

Another rare condition is intracardiac anomalous pulmonary venous connection (APVC), where multiple pulmonary veins connect directly or through a common venous trunk to the coronary sinus (Fig. 3B). In such cases, if there is no persistent left superior vena cava, a dilated CS should raise suspicion for intracardiac anomalous pulmonary venous connection. Given the significant hemodynamic abnormalities, these fetuses require delivery in a facility equipped to provide specialized care, and the newborn should undergo surgical correction promptly after birth.

If CS dilation is caused by severe conditions such as tricuspid valve dysplasia or heart failure, a comprehensive prognostic assessment of the fetus is necessary to guide subsequent pregnancy management.

STIC technology offers significant advantages in the diagnosis of fetal heart abnormalities, particularly in visualizing vascular and blood flow pathways. It provides a three-dimensional spatial view, which allows for clearer presentation of complex structures such as the coronary sinus and its abnormal connections. However, for the diagnosis of APVC, the performance of STIC is relatively limited. Therefore, in diagnosing intracardiac APVC, it is essential to combine STIC technology with other imaging techniques, such as two-dimensional ultrasound, dynamic blood flow evaluation, and other relevant imaging methods. This multi-modality approach ensures greater diagnostic accuracy and comprehensiveness [11].

In our study, prenatal ultrasound detected CS dilation in seven cases via the low four-chamber view, followed by comprehensive scanning that revealed the DV draining into the CS. In one case (Number 2), a right aortic arch was initially detected, and subsequent low four-chamber scanning revealed CS dilation. Further examination revealed that the DV was draining into the CS. STIC technology effectively helped identify these structures in three-dimensional space, thereby offering additional diagnostic views for both definitive diagnosis and differential diagnosis.

In the process of diagnosing and differentially diagnosing anomalous drainage of the DV into the CS, it may be quite challenging for general examiners who lack specialized training and experience; therefore, professional knowledge and technical experience are crucial. Nevertheless, personnel conducting routine ultrasound examinations can perform preliminary screening by identifying the dilation of the CS and refer these pregnant women to fetal cardiology specialists for further consultation. More detailed diagnostics should be carried out by experts with extensive experience in fetal cardiac examinations. The detection of fetal CS dilation during the 2nd trimester may serve as the initial clue, and under permissible conditions, a complete fetal echocardiographic examination, including both standard and supplementary planes, should be performed, along with further screening of fetal abdominal vasculature [12]. The four-chamber view, low four-chamber view (displaying the coronary sinus), and the three-vessel series views should be prioritized for meticulous examination.

Based on our case follow-up results, isolated cases of anomalous drainage of the DV into the CS have shown satisfactory perinatal outcomes. For fetuses with additional cardiac or extracardiac anomalies, monitoring from the 2nd trimester to the 3rd trimester should follow the advice of fetal medicine specialists, despite potential constraints on fetal cardiac assessments in the third trimester due to factors such as fetal positioning and amniotic fluid volume. During prenatal follow-up of this group of cases, no delays in fetal growth and development were observed; however, the potential impact of such vascular anomalies on the growth and development of the fetus should not be overlooked [13]. In the 3rd trimester, a surveillance assessment at 36 weeks of gestation is warranted to evaluate fetal growth and development [14].

While STIC technology enhances three-dimensional visualization for characterizing anomalous DV drainage into the CS, its clinical application in assessing such anomalies remains inherently constrained by some technical limitations: gestational age dependency, suboptimal fetal positioning, fetal motion interference during volume acquisition. In addition to the factors previously mentioned, due to the low incidence rate of this DV anomaly, the number of cases included in this study is limited. Moreover, there is a lack of data from ECG, chest X-rays, CT scans, and long-term follow-up. In future studies, attention should be paid to collecting such data, provided that it is done with the informed consent of the participants.

Conclusions

A dilated CS can be caused by anomalous drainage of DV into CS, among other abnormalities. Traditional two-dimensional echocardiography can clearly demonstrate the anomalous course of the DV draining into the CS. STIC technology provides additional three-dimensional views for diagnosis and differential diagnosis, and has certain clinical application value in diagnosing abnormalities of this type of DV. Continuous tracking of the blood flow in the dilated CS also helps with diagnosis.

Abbreviations

DV	Ductus Venosus
CS	Coronary Sinus
2D	Two-Dimensional
3D	Three-Dimensional
STIC	Spatiotemporal Image Correlation
HDlive Flow	High Definition Live Flow
NT	Nuchal Translucency
PLSVC	Persistent Left Superior Vena Cava
APVC	Anomalous Pulmonary Venous Connection

Supplementary Information

The online version contains supplementary material available at https://doi.org/10.1186/s12884-025-07560-w.

Supplementary Material 1: Mov.1: Fetal echocardiography reveals a dilated CS, with the DV originating from the umbilical vein and draining into the CS.

Supplementary Material 2: Mov.2: CDFI demonstrates the drainage pathway of the DV.

Supplementary Material 3: Mov.3: Spectral Doppler captures the characteristic triphasic waveform of the DV.

Supplementary Material 4: Mov.4: Postnatal 2D ultrasound at 3 days reveals a patent DV.

Supplementary Material 5: Mov.5: CDFI confirms the absence of connection between the DV and the IVC.

Supplementary Material 6: Mov.6: Subxiphoid non-standard four-chamber view in the neonate shows a dilated CS.

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Authors' contributions
WZ drafted the manuscript. BM and TL reviewed and provided constructive revisions to the manuscript. PQ, GW, XS, and XM collected prenatal ultrasound images and clinical data. All authors read and approved the final manuscript.

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Data availability
Data sharing is not applicable to this article as no datasets were generated or analysed during the current study.

Declarations

Ethics approval and consent to participate
All procedures performed in this study were in accordance with the ethical standards of the Medical Ethics Committee of Gansu Provincial Maternity and Child-Care Hospital and with the Helsinki Declaration (as revised in 2013). Written informed consent was obtained from the patient's next of kin for publication of this article and any accompanying images. A copy of the written consent is available for review by the editorial office of this journal.

Consent for publication
The clinical data and imaging used in this study were obtained with the written informed consent of the legal guardians of the fetuses involved in the research. The consent covers the use of these materials for scientific research and publication purposes. All materials will be made freely available in accordance with the relevant Creative Commons license.

Competing interests
The authors declare no competing interests.

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