Pulmonary atresia and ventricular septal defect: How accurate is the fetal echocardiography, and do the major aortopulmonary collateral arteries matter?

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Abstract

Objective: To assess the accuracy of prenatal echocardiography in defining pulmonary vasculature in pulmonary atresia with VSD (PAVSD). The second aim is to compare the perinatal and postnatal outcomes of different pulmonary blood supply types. Design:The cases prenatally diagnosed with PAVSD between January 2017- October 2022 in a single tertiary fetal medicine center were identified on the electronic database. Fetal echocardiography reports and images were reviewed retrospectively. Postnatal outcomes and images were acquired from the hospital records of relevant pediatric cardiology and cardiovascular surgery clinics. Fetal echocardiography results were compared with postnatal results. Perinatal and postnatal outcomes were compared between the pulmonary vascular supply types. Results: Among the 24 PAVSD cases, six were diagnosed with major aortopulmonary collateral arteries (MAPCA) dependent, eleven were diagnosed with ductus arteriosus (DA) dependent pulmonary vascular supply, and seven were diagnosed with double pulmonary supply (MAPCA + DA) on prenatal echocardiography. Seventeen cases were live-born and have undergone postnatal investigations. Fetal echocardiography was 88.2% accurate about the type of pulmonary vascular supply. The accuracy of fetal echocardiography regarding pulmonary vascular anatomy was 82.3%. Four cases were demised before surgical interventions. Postoperative survival was 69.2%. Mortality and postoperative survival did not differ between pulmonary supply groups. Survival was disrupted with extracardiac anomalies. The need for early surgical interventions was significantly higher in the DA group. Conclusion:The anatomy of pulmonary vascularization in PAVSD can be defined precisely on fetal echocardiography. The source of pulmonary blood supply does not impact postnatal short-term outcomes significantly; however, it affects the postnatal management. The associated anomalies highly contribute to postnatal mortality. Therefore, MAPCAs, the anatomy of the pulmonary arteries, and accompanying abnormalities should be intensely searched on fetal ultrasonography.

INTRODUCTION

PAVSD is a rare congenital cardiac defect with an incidence of 0.4:10000 live births[1]. It is characterized by a large perimembranous septal defect with an overriding aorta and an atretic pulmonary valve leading to the absence of antegrade flow from the right ventricle to the pulmonary artery (Figure 1). The infundibulum of the pulmonary artery (PA) is often poorly formed along with the atretic valve. The pulmonary trunk may be severely hypoplasic; confluent or non-confluent branches of the pulmonary arteries may present as hypoplasic vasculature. In this case, their blood supply and size depend on either DA or the systemic arterial collateral connections, or both (double supply). The pulmonary trunk may completely be atretic in severe cases. In this case, the alternate source of pulmonary blood supply is only major aortopulmonary collateral arteries (MAPCAs). MAPCAs are the non-regressed embryological connections between pulmonary vasculature and the aorta or the main branches of the aorta. They usually originate from the descending aorta and communicate with the branches of the pulmonary or bronchial arteries. Rarely, they can arise from the

branches of the aortic arch- brachiocephalic trunk, subclavian arteries- or even from coronary arteries[2,3]. The patency of DA and the presence of MAPCAs have important impacts on postnatal management, survival, and prognosis of the cases with PAVSD. Therefore, a detailed and accurate description of pulmonary vasculature provides precise counseling for the parents and directs early postnatal management.

This study aims to investigate the accuracy of fetal echocardiography in the vascular anatomic assessment of PAVSD. The second aim is to compare the postnatal prognosis in different pulmonary vascularization types.

METHODS:

This was a retrospective study conducted in a single tertiary fetal medicine center. The cases diagnosed with PAVSD between January 2017 and December 2022 were identified on the electronic database of our fetal echocardiography clinic. All prenatal echocardiographies were performed using Voluson E6 (GE Healthcare Ultrasound, Milwaukee, Wisconsin) equipped with a curved transabdominal probe by the same expert fetal medicine consultant (OD) in a systematic manner, usually twice a month for each pregnancy. The cases with additional complex cardiac defects were not included. Long and short-axis views were used to assess pulmonary vasculature and comprehensive cardiac anatomy. Axial, sagittal, and coronal views of the aorta were used to detect MAPCAs. The vessels which supply blood to the pulmonary parenchyma were also identified, beginning from the parenchymal tissue and following towards the systemic origin on color Doppler. Vascular blood flow was evaluated using high-definition (HD) Doppler, applying a pulse repetition frequency of 0.3–0.6 kHz. As a routine clinical protocol, an informed consent was taken from each patient approving the publication of the ultrasound images and clinical data in case of a clinical research, provided that their identities and personal information were kept confidential. The study protocol was approved by the institutional ethical committee (22.03.2023, No. 46), and it was carried out following the principles of the Declaration of Helsinki.

Details of ultrasonographic findings such as the presence or absence of DA, pulmonary arteries, and the confluence of the pulmonary arteries, the diameters of the right pulmonary artery (RPA) and left pulmonary artery (LPA), the source of blood supply to the lungs (DA, MAPCAs or double supply), the origin of the MAPCAs were obtained from the fetal echocardiography reports and archived sonographic images. The pulmonary blood supply was assumed as 'ductus arteriosus" if retrograde flow was displayed in DA adjacent to the aortic isthmus in 3VT plane or from the undersurface of the aortic arch, distal to the left subclavian artery towards the pulmonary artery without any intervening branches in sagittal plane. The vascular supply was assumed as MAPCAs when collaterals that fed the pulmonary parenchyma were detected to originate from the main branches of the aortic arch, coronary arteries, or descending aorta. Confirmation of the fetal echocardiographies was sought from neonatal echocardiography and angiography with cardiac catheterization performed in collaborated pediatric cardiology clinic for all live-born neonates. Postnatal confirmation of the fetal echocardiographies of the babies who had undergone surgery was made by operation reports. TOP cases could not be confirmed due to the families' refusal of an autopsy. Measures of association for categorical variables were analyzed with Pearson Chi-square test. All analyses were performed using SPSS version 22 (IBM Corp., Armonk, NY, USA). The Mann-Whitney U test was used for comparing the surgical intervention time between groups. A p-value of <0.05 was considered statistically significant.

RESULTS:

We diagnosed 28 cases of PAVSD during five years in our fetal diagnosis and therapy center. Four were excluded due to lacking postnatal data or being lost to follow-ups. The mean maternal age was 30 $\pm$5 years (range: 23-49 y). The mean gestational age at diagnosis was 22.4 $\pm$ 4.3 weeks (range: 13-31 w). 45.8% of the cases were isolated. On prenatal ultrasound, 37.5% of the cases (9 cases) were found to have extracardiac anomalies other than thymus hypoplasia/ aplasia (Table 1). Genetic studies could be employed for 17 cases. Chromosomal abnormalities were detected in 41.1% of these cases. 22q11.2 microdeletion syndrome constituted 71.4% (5 cases) of the chromosomal abnormalities (Table 1). All those cases with thymus hypoplasia were found to have chromosomal abnormalities.

On prenatal ultrasound examinations, the four-chamber view was normal except for left axis deviation in all

patients. Overriding aorta, hypoplastic or atretic pulmonary arteries, and absent antegrade flow through the right ventricle outflow tract (RVOT) were the shared characteristics of the cases. Right aortic arch (RAA) was detected in five fetuses (20.8%). Confluent pulmonary arteries were identified in 15 (62.5%) fetuses when the pulmonary vasculature was assessed. The Z-score of the dimensions of LPA and RPA were below -2 in all of the fetuses[4]. The antegrade ductal flow was seen in none, and retrograde ductal flow was displayed in 18 (75%) cases. Six of the fetuses had MAPCA-dependent pulmonary vascular supply. Seven (30.4%) cases had pulmonary vascular supply originating both from the ductus arteriosus and MAPCAs (double supply), according to the fetal echocardiographies. (Table 1)

TOP was performed in 29.1% of the pregnancies (7 cases). Additional chromosomal or structural anomalies corroborated the decision of TOP in all of the terminated cases. The remaining 17 fetuses were born alive. Overall survival was 52.9% for the live-born fetuses. Two infants were demised after the early first-stage shunt procedures. Four cases (including three with mortal extracardiac anomalies) were demised without surgical interventions. Nine infants survived after the cardiac operations. Among those, seven had complete cardiac repair, and two have been scheduled for complete repairment surgery after the palliative Blalock Taussig (BT) shunt (Figure 2). Follow-up time since the completion of total repairment is 1-4 years. Two infants were demised after the cardiac surgeries. 62.5% of the babies who died before or after surgery had major extracardiac anomalies.

There was no significant difference between the groups when we evaluated the postoperative outcomes of our cases within the different pulmonary blood supply groups based on postnatal diagnoses. However, the median surgical intervention time was earlier in the DA group than in MAPCA dependent group (Table 2). The DA-dependent group included eight live-born babies. Four of these cases had serious extracardiac anomalies leading to mortality (Table 1). Four cases in this group could undergo surgery. Postoperative survival was 66.6% for this group. MAPCA dependent group had seven live-born babies. Two cases were demised before surgery, and five infants in this group could undergo total cardiac repair surgery. Postoperative survival was 60%. The double supply group had two cases, both surviving after surgeries. One of them had a coronary artery-originated collateral, feeding the RPA. She underwent surgery, which included the closure of the DA and collateral, unifocalization of central PAs, and a modified BT shunt. She is currently scheduled for total repair.

All of the live-born fetuses were confirmed to have PAVSD on postnatal echocardiography. Pulmonary vascular supply type was defined precisely on fetal echocardiography in 88.2% of the cases, according to postnatal echocardiography, angiography, or surgery. The existence or absence of MAPCA was accurately detected in 100% of the cases. There were only two misdiagnosed cases who were considered to have a double supply on fetal echocardiography, but were found to have only MAPCA-dependent pulmonary flow in the catheter angiography (Table 3). The sources of MAPCAs were mainly descending aorta except for one case with the prenatal diagnosis of coronary artery-originated MAPCA (Figure 3) and two cases with MAPCAs from both descending aorta and aortic arch (Figure 4). Fetal echocardiography was 94.1%, 82.3%, and 88.2% accurate in defining the confluence of the PAs, RPA/LPA, and main pulmonary trunk, respectively (Table 3).

DISCUSSION

Our study shows that fetal echocardiography can accurately identify the origin of pulmonary vascular supply. Accuracy in defining the anatomy of the pulmonary vasculature and the source of pulmonary blood supply was 82.3% and 88.2%, respectively. Previously published studies report lower rates[5,6]. Zhoi J et al. and Naimi I et al. reported similar rates with us in recent studies[7,8]. The improvement seems to be related to the advanced ultrasound technology. Besides, we have been intensely searching for MAPCAs and the origin of pulmonary blood supply since the beginning of the study period. We have no false negative MAPCA-dependent PAVSDs in our study. Therefore, we suggest that cases with MAPCAs can be diagnosed with 100% sensitivity with a meticulous search, including sagittal and coronary planes of the aortic arch and descendent aorta. MAPCAs mostly originate from the descending aorta (Figure 4b,4c, Figure 5c). They can also arise from the aortic arch (Figure 4a, Figure 5a), subclavian arteries, brachiocephalic trunk, internal

mammarian artery, and left coronary artery[9].

We detected MAPCA originating from the coronary artery in one of the cases (Figure 3a). MPA and the confluence of central PAs were absent on fetal echocardiography. Postnatal angiography (Figure 3c,3d) and surgery (Figure 3e,3f) confirmed the prenatal diagnosis. According to the intraoperative assessment, MPA was absent. The LPA originated from patent DA. The RPA was supplied by a collateral from the left main coronary artery (LMCA) (Figure 3e,3f). There was no confluence of PAs. Coronary to pulmonary collaterals are rare and can be detected in 1.3%-10% of the cases with PAVSD[10,11]. To our knowledge, this was the first case in the literature diagnosed prenatally and confirmed surgically. It was expected that cardiac ischemia could have occurred due to increased coronary to pulmonary steal secondary to decreased pulmonary vascular resistance after birth. Thanks to the prenatal diagnosis, the newborn was immediately referred to the collaborated cardiovascular clinic on prostaglandin infusion and underwent early surgery to avoid coronary stealing. Therefore, we suggest that the aortic root should also be carefully searched in axial and longitudinal planes in PAVSD cases to detect any collaterals arising from coronary arteries. These newborns may not present cyanosis due to the high flow from coronary arteries to the lungs; however, they may develop acute cardiac failure based on cardiac ischemia.

The impact of MAPCAs on perinatal and postnatal outcomes is debatable in the literature[3,7]. MAPCA-dependent newborns can present cyanosis in case of narrow collaterals, or those with adequate collaterals may be acyanotic with subtle symptoms for months until stenosis of the collaterals occurs. Multiple, dilated collaterals may lead to pulmonary hypertension, congestive heart failure, or pulmonary parenchymal bleeding. MAPCA-dependent cases usually have non-confluent PAs with arborization abnormalities or no central PAs at all, while DA-supplied cases usually have confluent PAs with complete intrapulmonary arborization[8]. Consistently, in our study, except the one with DA arising from the 1stbranch of the aortic arch (Figure 6a, 6b), all DA-dependent cases had unifocal, confluent PAs. On the other hand, only 28.5 % of the MAPCA group had confluent PAs. The presence or absence of confluent PAs transforms the method of surgery. Non-confluent PAs have narrow RPA, LPA, and larger MAPCAs which may lead to pulmonary parenchymal disease secondary to incomplete intrapulmonary arborization[7]. Therefore, assessment of the confluence of PAs and the size and anatomy of PAs on fetal echocardiography is as necessary as identifying the origin of pulmonary blood supply for proper prenatal counseling. Considering the smaller PAs and impaired PA arborization, worse outcomes could have been expected in the MAPCA group compared with the DA group. However, we found that the existence of MAPCAs did not significantly impact postnatal survival. This may be related to the relatively higher accompanying anomalies in the DA group in our study. Moreover, DA-dependent cases needed surgical intervention to prevent desaturation secondary to the stenosis of DA within the first two weeks of life. In contrast, MAPCAs were operated on in later weeks as the stenosis occurred later.

The overall survival was too low compared with the other studies in the literature[3,7]. Survival was highly disrupted by extracardiac anomalies, particularly in the DA group. Among the babies who survived until the operation, postoperative survival rates for MAPCA and DA groups were 60% and 66.6%, respectively. These rates are also lower than the other studies[3,9]. Both postoperative deaths were related to extracardiac anomalies in the DA group. Therefore, while counseling the parents, it should be emphasized that extracardiac malformations may prohibit surgery or lead to postoperative mortality. Postnatal surgical series report rather promising outcomes[12,13]. However, many newborns like the ones in our study do not survive until the operation.

One of the weaknesses of our study is the small sample size. We restricted the study period to the last five years as we have had a dedicated fetal echocardiography clinic since 2017. Another consequence of this short study period is that we could not compare the long-term prognosis between the groups. The strength of the study is that it was conducted in a single center, and the fetal echocardiographies were performed by the same operator. All of the angiographies and the majority of the surgeries were performed by the associate cardiovascular surgery clinic.

CONCLUSION

Accurate assessment of pulmonary vascular anatomy on fetal echocardiography is possible and crucial in the ultrasound examination of PAVSD. Despite the origin of the pulmonary blood supply having no impact on postnatal prognosis and postoperative survival, prenatal identification of the pulmonary vascular anatomy may lead to decisions about early postnatal management strategies.

Conflict of Interest : None declared.

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Figure legends:

Figure 1: Images of Fallot tetralogy with PAVSD case. Figure 1a: Color Doppler image of overriding aorta receiving blood from the right and left ventricles, axial planes. Figure 1b: Atretic pulmonary valve (arrow). Figure 1c: Confluence of hypoplastic pulmonary arteries (arrow) Hypoplastic central pulmonary arteries on grayscale(asterisks). Figure 1d: Retrograde flow of main pulmonary artery. Figure 1e: Postnatal image of RPA and LPA (asterisks) supplied by PDA (arrow) via selective ductus arteriosus angiogram. Pulmonary blood supply is solely through a vertically oriented PDA (arrow) with confluent pulmonary arteries. When the arterial duct presents, it originates from the undersurface of the aorta in most patients.

Figure 2: Flow diagram of prenatally diagnosed PAVSD in 28 cases

Figure 3: Case 4 presented double supply and MAPCA arising from the coronary artery. Figure 3a: Grayscale image of origin of the left coronary artery (asterisk) from the aortic root in supra valvular level (double-headed arrow) in longitudinal view. The left main coronary artery (LMCA) gives rise both to the left anterior descending artery (double-headed, dashed arrow) and a collateral (thick arrow) towards the RPA (thin arrow). RV: Right ventricule, LV: Left ventricule. Figure 3b: Color Doppler image of the coronary artery (asterisk), which gives rise to the left anterior descending coronary (thick arrow) and MAPCA (thin arrow) supplying the RPA. Figure 3c: Axial view of the aortic root, the origin of coronary artery (thin arrow), which gave MAPCA supplying the RPA (thick arrows) and left anterior descending artery (dashed arrow). Figure 3d: Color Doppler image of overriding aorta and ductus arteriosus (arrow) supplying left pulmonary artery (asterisk) in longitudinal view. Figure 3e: Angiographic images of the aortic root and the collateral between the left main coronary artery (LMCA) and right pulmonary artery (RPA). Figure 3f: Operation image displaying the insertion of coronary to pulmonary collateral (CA-Pac) into the lumen of RPA. The collateral arose from the left main coronary artery (LMCA).

Figure 4a: Sagittal plane, MAPCAs from descending aorta (arrow), and the end of the aortic arch (asterisk) of case 1. The collateral arising from the end of the aortic arch (asterisk) was considered as ductus arteriosus on fetal echocardiography. However, since the pulmonary trunk was completely atretic, it was diagnosed as MAPCA from the aortic arch in the postnatal transcatheter angiography. Figure 4b: MAPCAs originating from descending aorta at 35th gestational weeks, coronal view of the aorta. They became dilated and visible even on grayscale (arrows). Figure 4c: Color Doppler of MAPCAs (arrow) on the coronal plane in case 1. Figure 4d: Angiographic images of MAPCAs in various sizes and morphology. Desendan aortogram shows that large collateral vessels are the sole source of pulmonary blood flow. No native central pulmonary arteries were seen.

Figure 5: Multiple MAPCAs of a case with severe hypoplastic pulmonary trunk (case 19). The pregnancy was terminated based on the genetic diagnosis of Di George syndrome. Figure 5a: MAPCAs arising from the aortic arch (arrows) in the sagittal plane. Figure 5b: MAPCAs arising from descending aorta, sagittal plane. Figure 5c: Multiple and dilated MAPCAs arising from descending aorta, sagittal plane

Figure 6a: Continuity of the first main branch of the aorta (thin arrow) and the supplying vessel (dashed arrow) feeding the non-communicant right pulmonary artery (thick arrow) in sagittal view. The supplying vessel could have been considered as MAPCA originated from aortic arch branches; however, the short, non-tortuous, unbranched course and the narrowing at the attachment site to the right pulmonary artery (asterisk) directed the diagnosis towards ductus arteriosus arising from the 1st branch of a left aortic arch.

Figure 6b: The probe was slightly turned following the supplying vessel of the non-communicant right pulmonary artery (dashed arrow), and a coronal view was obtained displaying the common origin of the right subclavian artery (arrow) and the ductus arteriosus (dashed arrow). Tr: trachea.

Table 1: Prenatal sonographic findings and outcomes of PAVSD cases

Case	GA at first appeal	Prenatal defined source of pulmonary blood supply	MPA	Confluence of PAs	Genetic studies (kary-otype/ CMA)	Extracardiac anomalies	Outcome
1.	28	Double	-	non-confluent	normal/normal	-	Postoperative survival
2.	23	Double	+	confluent	normal/normal	-	Postoperative survival
3.	30	MAPCAs	+	confluent	normal/normal	-	Postoperative survival
4.	31	Double	-	non-confluent	normal/normal	-	Postoperative survival, SCR
5.	19	DA	+	confluent	Tr13	Multiple anomalies, thymus hypoplasia	Neonatal death
6.	26	DA	+	confluent	normal/normal	-	Postoperative survival
7.	18	MAPCAs	-	non-confluent	Tr18	MCDK, anhydramnios	Neonatal death
8.	20	Double	-		normal/normal	-	Postoperative death
9.	22	MAPCAs	-	non-confluent	Not performed	-	Postoperative survival
10.	20	MAPCAs	-	non-confluent	Not performed	-	Postoperative death
11.	21	DA	+		Di George	Thymus hypoplasia	Postoperative death
12.	24	MAPCAs	-	non-confluent	Not performed	-	Infant death before surgery/interv
13.	13	DA	+	confluent	normal/normal	Omphalocele	Neonatal death
14.	26	DA	+	confluent	Not performed	Anal atresia with urinary fistula	Postoperative survival
15.	24	DA	+	confluent	Not performed	DWM	Postoperative death
16.	22	DA	-	confluent	Not performed	-	Postoperative survival
17.	22	DA	+	confluent	normal/normal	-	Postoperative survival, SCR
18.	32	Double	+	confluent	Di George	Thymus hypoplasia	TOP

Case	GA at first appeal	Prenatal defined source of pulmonary blood supply	MPA	Confluence of PAs	Genetic studies (kary-otype/ CMA)	Extracardiac anomalies	Outcome
19.	21	MAPCAs (from aortic arch and descendent aorta)	+	confluent	Di George	Thymus hypoplasia	TOP
20.	22	Double	+	confluent	Di George	Thymus hypoplasia	TOP
21.	20	Double	-	non-confluent	normal/normal	Cerebellar hypopla-sia, FGR	TOP
22.	18	DA	+/	confluent	normal/normal	CH, CDH, PEV	TOP
23.	16	DA	NPI/NPI		Not performed	MCDK, anhydramnios	TOP
24.	21	DA	-	non-confluent	Di George	Cleft palate, thymus hypoplasia	TOP

Case	GA at first appeal	Prenatal defined source of pulmonary blood supply	MPA	Confluence of PAs	Genetic studies (karyotype/ CMA)	Extracardiac anomalies	Outcome
GA: gestational age, MAPCAs: major aortopulmonary collaterals, DA: ductus arteriosus, MPA: main pulmonary artery, NPI: not possible to identify, CMA: chromosomal microarray, MCDK: multicystic dysplastic kidneys, DWM: Dandy-Walker malformation, FGR: fetal growth restriction, CH: cystic hygroma, CDH: congenital diaphragmatic hernia, PEV: pes equinovarus, SCR: scheduled for total cardiac repair, TOP: termination of pregnancy	GA: gestational age, MAPCAs: major aortopulmonary collaterals, DA: ductus arteriosus, MPA: main pulmonary artery, NPI: not possible to identify, CMA: chromosomal microarray, MCDK: multicystic dysplastic kidneys, DWM: Dandy-Walker malformation, FGR: fetal growth restriction, CH: cystic hygroma, CDH: congenital diaphragmatic hernia, PEV: pes equinovarus, SCR: scheduled for total cardiac repair, TOP: termination of pregnancy	GA: gestational age, MAPCAs: major aortopulmonary collaterals, DA: ductus arteriosus, MPA: main pulmonary artery, NPI: not possible to identify, CMA: chromosomal microarray, MCDK: multicystic dysplastic kidneys, DWM: Dandy-Walker malformation, FGR: fetal growth restriction, CH: cystic hygroma, CDH: congenital diaphragmatic hernia, PEV: pes equinovarus, SCR: scheduled for total cardiac repair, TOP: termination of pregnancy	GA: gestational age, MAPCAs: major aortopulmonary collaterals, DA: ductus arteriosus, MPA: main pulmonary artery, NPI: not possible to identify, CMA: chromosomal microarray, MCDK: multicystic dysplastic kidneys, DWM: Dandy-Walker malformation, FGR: fetal growth restriction, CH: cystic hygroma, CDH: congenital diaphragmatic hernia, PEV: pes equinovarus, SCR: scheduled for total cardiac repair, TOP: termination of pregnancy	GA: gestational age, MAPCAs: major aortopulmonary collaterals, DA: ductus arteriosus, MPA: main pulmonary artery, NPI: not possible to identify, CMA: chromosomal microarray, MCDK: multicystic dysplastic kidneys, DWM: Dandy-Walker malformation, FGR: fetal growth restriction, CH: cystic hygroma, CDH: congenital diaphragmatic hernia, PEV: pes equinovarus, SCR: scheduled for total cardiac repair, TOP: termination of pregnancy	GA: gestational age, MAPCAs: major aortopulmonary collaterals, DA: ductus arteriosus, MPA: main pulmonary artery, NPI: not possible to identify, CMA: chromosomal microarray, MCDK: multicystic dysplastic kidneys, DWM: Dandy-Walker malformation, FGR: fetal growth restriction, CH: cystic hygroma, CDH: congenital diaphragmatic hernia, PEV: pes equinovarus, SCR: scheduled for total cardiac repair, TOP: termination of pregnancy	GA: gestational age, MAPCAs: major aortopulmonary collaterals, DA: ductus arteriosus, MPA: main pulmonary artery, NPI: not possible to identify, CMA: chromosomal microarray, MCDK: multicystic dysplastic kidneys, DWM: Dandy-Walker malformation, FGR: fetal growth restriction, CH: cystic hygroma, CDH: congenital diaphragmatic hernia, PEV: pes equinovarus, SCR: scheduled for total cardiac repair, TOP: termination of pregnancy	GA: gestational age, MAPCAs: major aortopulmonary collaterals, DA: ductus arteriosus, MPA: main pulmonary artery, NPI: not possible to identify, CMA: chromosomal microarray, MCDK: multicystic dysplastic kidneys, DWM: Dandy-Walker malformation, FGR: fetal growth restriction, CH: cystic hygroma, CDH: congenital diaphragmatic hernia, PEV: pes equinovarus, SCR: scheduled for total cardiac repair, TOP: termination of pregnancy

Case	GA at first appeal	Prenatal defined source of pulmonary blood supply	MPA	Confluence of PAs	Genetic studies (kary-otype/ CMA)	Extracardiac anomalies	Outcome

Table 2 Postnatal outcomes based on the type of pulmonary vascular supply

Pulmonary vascular supply (based on postnatal diagnosis)	DA (n=8)	MAPCA (n=7)	Double supply (n=2)	p-value (DA/MAPCA)
Neonatal/infant death without surgery	2/8	2/7	0	0.66
Surgical intervention time (days)	7.75 (±2,76) 7.5 (4-12)	179 (±60) 150 (120-270)	12 (11-13)	<0.05
Postoperative mortality	2/8	2/7	0	0.55
Survival*	4/8	3/7	2 /2	0.59
Survival excluding extracardiac abnormalities	4/5	3/6	2/2	0.18
Including two cases that are scheduled for complete repair, one case from DA, one case from the double supply group	*Including two cases that are scheduled for complete repair, one case from DA, one case from the double supply group	*Including two cases that are scheduled for complete repair, one case from DA, one case from the double supply group	*Including two cases that are scheduled for complete repair, one case from DA, one case from the double supply group	*Including two cases that are scheduled for complete repair, one case from DA, one case from the double supply group

Table 3: Comparison of fetal echocardiographic findings and postnatal catheter angiography/ operation findings for the live-born cases

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PN: postnatal, DA: ductus arteriosus, RPA: right pulmonary artery, LPA: left pulmonary artery, MCDK: multicystic dyspla

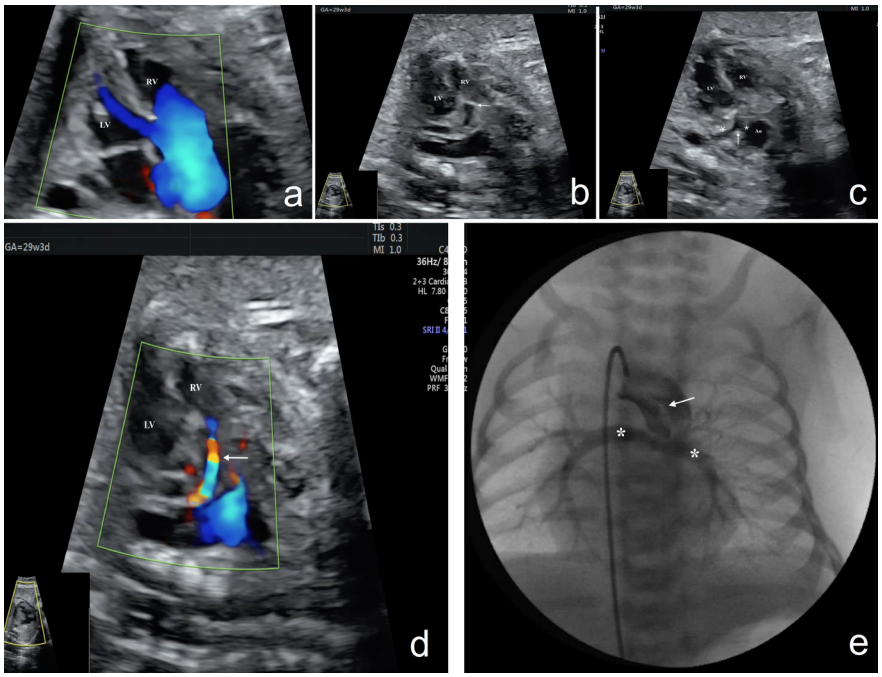

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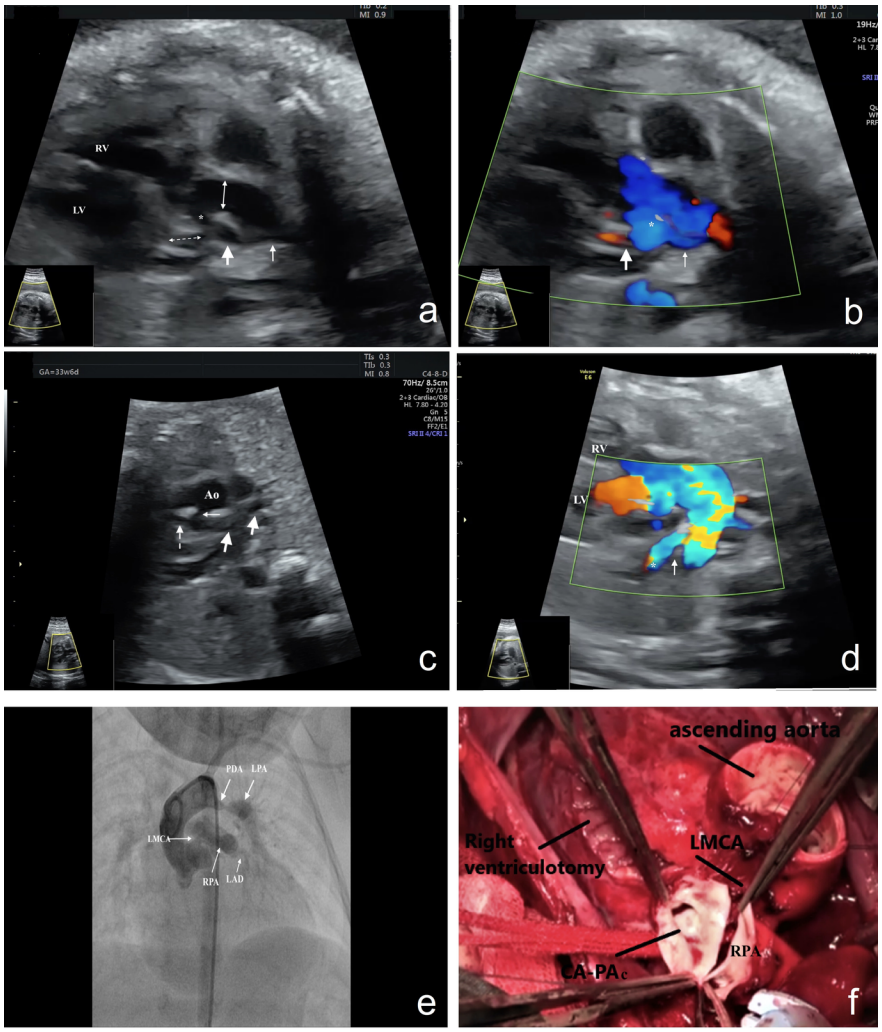
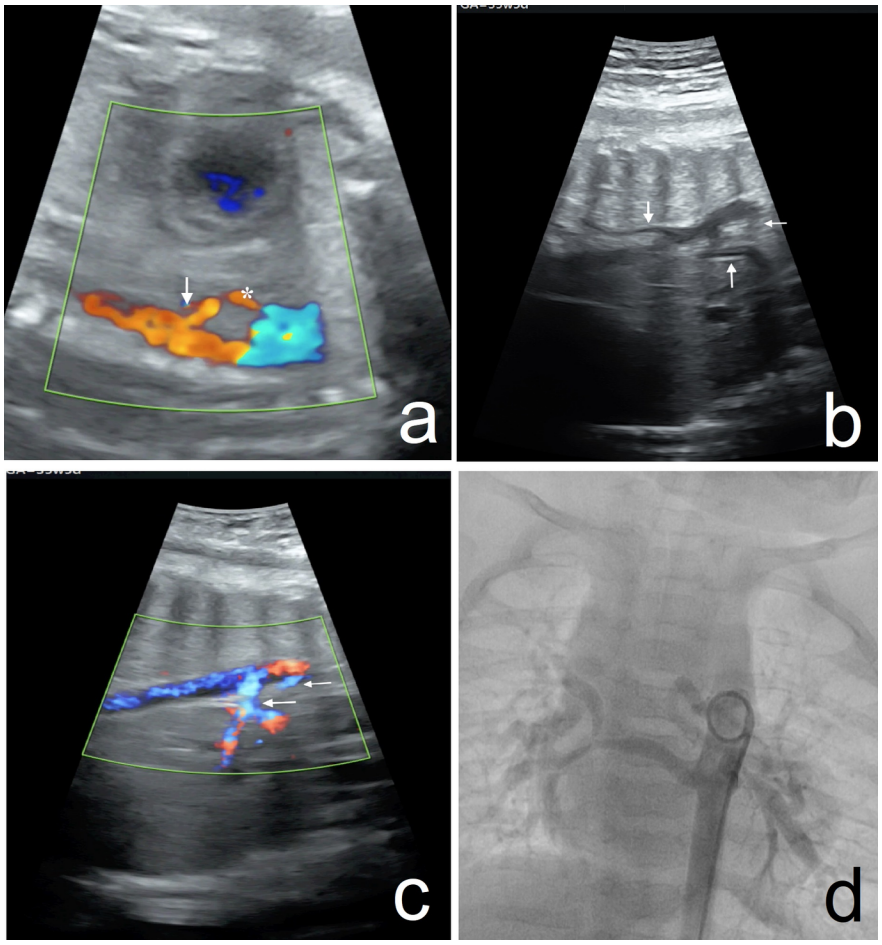
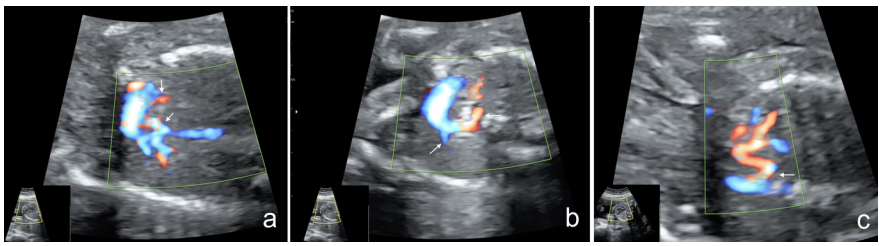
Figure 2.docx available at https://authorea.com/users/630274/articles/650078-pulmonary-atresia-and-ventricular-septal-defect-how-accurate-is-the-fetal-echocardiography-and-do-the-major-aortopulmonary-collateral-arteries-matter







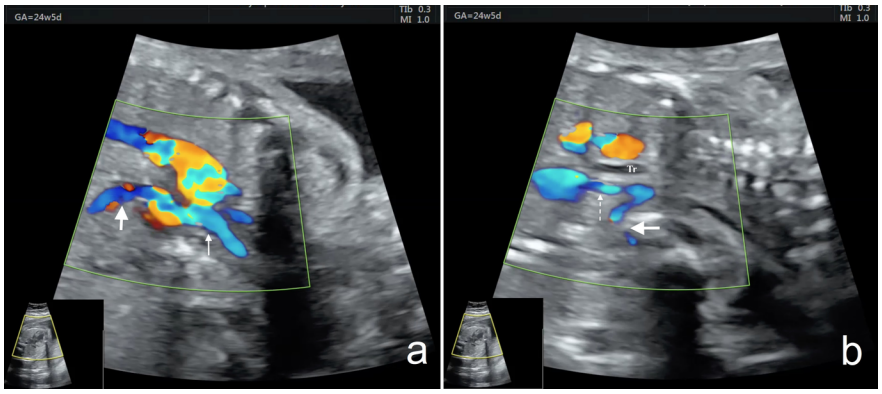


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Table 3-PAVSD.docx available at https://authorea.com/users/630274/articles/650078-pulmonary-atresia-and-ventricular-septal-defect-how-accurate-is-the-fetal-echocardiography-and-do-the-major-aortopulmonary-collateral-arteries-matter