Published in final edited form as:

Congenit Heart Dis. 2014 ; 9(3): 187–193. doi:10.1111/chd.12120.

Mid-Gestation Fetal Pulmonary Annulus Size is Predictive of Outcome in Tetralogy of Fallot

Kevin Friedman, MD, Sowmya Balasubramanian, MD, and Wayne Tworetzky, MD

Departments of Pediatric Cardiology, Boston Children's Hospital and Pediatrics, Harvard Medical School

Abstract

Background—Surgical management of tetralogy of Fallot (TOF) is increasingly moving towards valve-sparing approaches rather than transannular patch (TAP). We evaluate if fetal pulmonary valve (PV) size is predictive of postnatal course and surgical approach in TOF.

Methods—In this retrospective study, fetal and postnatal demographic, clinical and echocardiographic data on 66 patients diagnosed prenatally with TOF were collected. We compared those with mid-gestation PV z-score >-3.5 to those ≤ -3.5 . We analyzed fetal and postnatal PV size and growth and outcomes between groups

Results—Gestational age at 1st fetal echo was 23 weeks (range 18-28). PV diameter and z-score on mid-gestation echo were 3.5 mm (1.3 to 6.0) and -2.8 (-0.5 to -6.0) respectively. Patients with PV z-score ≤ -3.5 on 1st fetal echo had smaller PV diameter (4.5 vs. 5.0 mm, $p=0.047$) and PV z-score (-3.8 vs. -2.8 $p<0.001$) in late gestation and at time of surgery (6.0 mm vs. 7.0 mm, $p=0.01$; z-score $= -2.9$ vs. -1.7 , $p=0.007$). Similarly, those with smaller fetal PV z-score had smaller main and branch pulmonary arteries at time of surgery. PV growth rate over gestation was similar between groups, while after birth PV growth rate was lower in those with smaller PV (0 mm/month vs. 0.6 mm/month, $p=0.002$).

Those with smaller pulmonary valve were more likely to be cyanotic ($p=0.05$), to undergo surgery at < 1 month ($p<0.01$) and to have a TAP repair ($p=0.01$). Among patients undergoing valve-sparing repair, those with smaller PV had underwent more re-interventions for residual valvar PS ($p<0.01$).

Conclusion—Mid-gestation fetal PV size is predictive of postnatal PV and PA size in TOF. Mid-gestation PV size has implications for timing and type of surgical management as well as for need for re-intervention in valve-sparing repair patients and is therefore important to consider in prenatal counseling for TOF fetuses.

Address for Correspondence: Kevin Friedman, MD, Boston Children's Hospital, Department of Cardiology - Bader 2, 300 Longwood Avenue, Boston, MA 02115, Kevin.Friedman@cardio.chboston.org.

Author contributions:

Dr. Friedman had substantial contribution to research design, data acquisition and analysis and drafting the manuscript as well as approving and submitting the final manuscript.

Dr. Balasubramanian had substantial contribution to research design, data acquisition and analysis and reviewing and approving the final manuscript.

Dr. Tworetzky had substantial contribution to research design as well as editing and revised the final manuscript

No disclosures.

Background

Tetralogy of Fallot (TOF) is the most common form of cyanotic congenital heart disease occurring in ~ 3 of every 10,000 newborns and accounting for 7-10 % of congenital heart disease¹. Outcomes after TOF repair are excellent with surgical mortality < 2 % and 15-year survival rates > 95%¹⁻³. Despite excellent outcomes over the first several decades of life, the late deleterious effects of pulmonary regurgitation and subsequent right ventricular (RV) volume overload have been well established⁴⁻⁷. Due to known sequelae of RV volume overload and dilation, including heart failure, arrhythmia and sudden death⁴⁻⁸, surgical management of TOF has increasingly moved towards pulmonary valve-sparing approaches rather than transannular patch (TAP) repair⁹⁻¹⁴.

TOF is now commonly diagnosed in utero, typically in mid-gestation¹⁵⁻¹⁸. Only a few previous studies have evaluated the association between fetal echocardiographic (echo) parameters and postnatal outcomes in TOF¹⁹⁻²¹, thus limiting the data available for prenatal counseling. In a small cohort of fetuses with TOF, mid-gestation pulmonary valve size has been shown to correlate with postnatal pulmonary valve diameter (PV) and pulmonary artery (PA) size¹⁹. Prenatal counseling for parents of fetuses with TOF should ideally include progression of disease through the remainder of gestation, recommendation for location of delivery, likelihood of cyanosis prior to repair, timing and type of surgical repair, and likelihood of need for re-intervention after repair. This study aims to evaluate the association between mid-gestation echocardiogram findings in TOF and postnatal echo findings and outcomes in order to improve the data available for prenatal counseling.

Methods

Patients

All patients diagnosed in mid-gestation (18-28 weeks) with TOF and pulmonary stenosis (PS) between 2006 and 2011 at our institution were reviewed. Patients followed longitudinally at our institution both pre- and postnatally with a minimum of 2 fetal echos were included. Exclusion criteria included TOF with pulmonary atresia, fetuses with TOF who were not liveborn (in utero fetal demise or termination), diagnosis after 28 weeks gestation, and gestational age < 34 weeks at birth.

Data Collection

All fetal and postnatal echocardiograms prior to surgical repair were included in the data analysis. The following variables were retrospectively re-measured on all fetal echocardiograms by a single pediatric cardiologist specializing in fetal cardiology (KF) from images stored at the time of the study: pulmonary valve annulus diameter (PV), main pulmonary artery (PA) diameter, right and left PA diameter, and aortic annulus diameter (AoV). AoV to PV ratio (AoV:PV) was calculated for the initial and final fetal echocardiograms. Z-scores for all fetal measurements were calculated using normative data adjusted to gestational age²². Cardiac dimensions were measured at their maximal size. The great vessels and semilunar valves were measured in systole. Three measurements were taken for each value and the mean value was used for analysis. Functional assessment

included peak systolic velocity across the PV and direction of flow across the ductus arteriosus. Longitudinal assessment of PV growth during gestation was performed using the initial fetal echocardiogram and the last fetal echocardiogram for each patient. Change in PV diameter and PV z-score over gestation were calculated using the difference between first fetal and last fetal echocardiogram. The change in PV diameter was divided by the difference in gestational age between echocardiograms to obtain a rate of change in millimeters/week of gestation. Fetal weight was estimated using Hadlock formula²³. Postnatal echocardiographic data was collected from reports produced at the time of the study and included the following measurements and z-scores: PV diameter, main PA diameter, right and left PA diameter. Change in PV diameter and z-score were calculated using the difference between first postnatal echocardiogram (within the first week of life in all patients) and the pre-surgical echocardiogram (3 days to 5.2 months of age) and the rate of postnatal PV growth (mm/month) was calculated.

Fetal and postnatal clinical and demographic data were collected. Surgical data, including age at surgery, indication for repair (elective vs. cyanosis) as documented in operative and/or cardiology clinic notes, type of surgery (valve-sparing vs. TAP), and number and type of postoperative re-interventions were collected

Statistical Analysis

A subset of mid-gestation PV measurements (n=20) were measured independently by two pediatric cardiologists (KF, SB) to assess interobserver variability using interclass correlation. Interclass correlation indicated high agreement between observers ($r=0.986$, R^2 for analysis of variance =0.97). Patients with mid-gestation PV z-score ≤ -3.5 were compared to those with z-score > -3.5 . A z-score of -3.5 was chosen for two reasons: a. -3.5 (or -4) is a commonly accepted cutoff between moderately and severely hypoplastic PV b. our current institutional practice is that the cardiac surgeons will consider a valve-sparing repair in patients with PV z-score of > -3.5 on preoperative echo, while those with z-score < -3.5 undergo a transannular patch. Chi-square exact test and Wilcoxon rank sum test were used to compare variables between study groups for binary and continuous variables respectively. Pearson correlation coefficient was used to calculation association between mid-gestation echo parameters and postnatal echo parameters. All statistical analysis were 2-sided and type I error was controlled at a level of 0.05. Analyses were performed with SPSS (version 16.0, SPSS Inc, Chicago, Ill).

Results

The cohort consisted of 66 fetuses diagnosed in mid-gestation with TOF/PS. Demographic data for the cohort is summarized in Table 1. Patients with mid-gestation PV z-score ≤ -3.5 were diagnosed later in gestation than those with larger PV. Genetic syndromes included 4 patients with trisomy 21, 2 with VACTERL, 1 with DiGeorge Syndrome, and 1 with Turner's syndrome. The most common associated cardiac anomalies were right aortic arch in 9 patients and left superior vena cava to coronary sinus in 5 patients. Two patients had major aortopulmonary collaterals both of whom had fetal PV z-score ≤ -3.5 .

PV z-score on initial fetal echocardiogram ranged from -0.5 to -6.0 with 50 patients (74%) having z-score ≤ -2 and 18 patients (26%) having z-score ≤ -3.5 at diagnosis (Table 2). Those with mid-gestation PV z-score ≤ -3.5 had higher mid-gestation Ao:PV and were more likely to have flow reversal (left to right) in the ductus arteriosus reversal than those with larger PV z-score (28% vs. 4%, $p=0.02$). Absence of an identifiable ductus arteriosus was common (29% of entire cohort) and did not differ between groups. Peak right ventricular outflow tract systolic velocity at mid-gestation was similar between groups. At last fetal echocardiogram in late gestation, those with mid-gestation PV z-score ≤ -3.5 had smaller PV score and higher Ao:PV than those with mid-gestation PV z-score > -3.5 . Fetal pulmonary valve growth rate as measured by change in PV annulus diameter over gestation (mm/month) was similar between groups. Only 4 patients (6%) had a significant decrease in PV z-score during gestation (decrease ≥ 1 z-score unit) and no fetuses had progression from PS to pulmonary atresia.

Postnatal PV diameter, PV z-score, and main and branch PA z-scores were lower in those with mid-gestation PV z-score ≤ -3.5 compared to those with higher mid-gestation PV z-score (Table 3). Mid-gestation fetal PV z-score correlated with pre-surgical PV score ($r=0.57$, $p=0.002$). In contrast to PV growth during gestation, PV growth measured in mm/month change from newborn echocardiogram to presurgical echocardiogram was lower in those with smaller mid-gestation PV.

Patients with mid-gestation PV annulus z-score ≤ -3.5 were more likely to undergo non-elective repair due to cyanosis than those with z-score > -3.5 (56% vs. 19%, $p=0.05$) (Figure 1) and had lower median pre-operative oxygen saturations (92% (77-99) vs. 98% (75-100), $p=0.03$). No patients in this cohort required prostaglandins. Mid-gestation PV z-score ≤ -3.5 was associated with increased likelihood of undergoing surgery at < 1 month of age (50% vs. 3%, $p<0.01$). Ten patients (15%) underwent surgery at ≤ 1 month of age, 9 of whom had mid-gestation PV z-score ≤ -3.5 and 5 of whom had TAP repair. There was an overall trend towards earlier repair in patients with PV z-score ≤ -3.5 (median age at repair 2.4 months (range: 0.1-6.2)) compared to those with large mid-gestation PV (3.1 months (0.1-7.4)) ($p=0.06$). Lower mid-gestation z-score was also associated with increased likelihood of TAP (32% vs. 3%, $p=0.01$) and smaller balloon size used for intraoperative PV dilation in patients undergoing valve-sparing repair (median of 9 mm (range: 7-14) vs. 7 mm (5-10), $p<0.01$).

No pre or post-operative deaths have occurred in this cohort. Eleven patients, all in the valve-sparing surgical group, have undergone re-intervention for right ventricular outflow tract obstruction over a median follow-up duration of 10 months (range 2-67 months). Re-interventions have consisted of 8 repeat surgeries and 7 catheterizations. Among those undergoing valve-sparing repair, post-operative intervention for residual PS was more common in patients with mid-gestation PV z-score ≤ -3.5 . Re-intervention rate for patients with mid-gestation PV z-score < -3.5 was 50% compared to only 9% in those with larger mid-gestation PV z-score.

Discussion

In this study we find that mid-gestation PV annulus can be reliably measured and that lower mid-gestation PV z-score is associated with smaller PV and pulmonary artery size, both in late gestation and in infancy through the time of surgery, and a lower PV growth velocity postnatally. Additionally, we found that lower mid-gestation PV z-score is associated with the following clinical outcomes: cyanosis prior to surgical repair, surgical repair at < 1 month of age, higher likelihood of undergoing TAP repair, increased risk of post-operative intervention due to residual PS in patients undergoing valve-sparing surgery.

Our findings have important implications for prenatal counseling in this patient population. Smaller mid-gestation PV z-score was associated with increased likelihood of undergoing TAP repair and high-risk for re-intervention in those undergoing valve-sparing surgery. Over short to medium-term follow-up duration in this study, there was a 50% re-intervention rate in patients with PV z-score ≤ -3.5 who underwent valve-sparing repair. Families of fetuses with TOF and smaller PV z-score should be counseled on the likely need for multiple procedures whether it is TAP and later PV replacement or valve-sparing repair and later catheterization for surgery for residual pulmonary stenosis. Smaller mid-gestation PV z-score was also associated with increased risk of cyanosis prior to surgery and increased likelihood of undergoing early surgery (≤ 1 month of age) due to development of cyanosis. Counseling for families of fetuses with TOF and smaller PV z-score should include planning delivery at a center that is prepared to care for a cyanotic neonate and potential need for more frequent postnatal follow-up as these patients are more likely develop cyanosis; while fetuses with larger PV z-score can be counseled that they are unlikely to develop early cyanosis and have to undergo early repair.

Similar to previous studies, we found that mid-gestation PV z-score was predictive of PV size and pulmonary artery size at the time of surgery. Hirji et al. report on fetal echo results from 29-32 weeks and show that smaller PV and lower PV:AoV are associated with need for prostaglandin and increased likelihood of TAP repair¹⁹. In a study of 23 TOF patients followed pre- and postnatally, Escribano et al. report that two functional parameters reversed patent ductus arteriosus flow and higher peak systolic velocity across the PV were associated with need for intervention at < 3 months of age²⁰. In our cohort reversed ductus arteriosus flow in mid-gestation was associated with smaller PV z-score, smaller branch pulmonary arteries and increased likelihood of TAP. We did not find peak systolic PV velocity to be associated with any clinical outcomes.

Although serial evaluation of fetuses with TOF and PS for progression of RV outflow tract obstruction is commonly performed, PV z-score and AoV:PV were stable in the vast majority of patients with few patients having significant changes over fetal life and no patients having progression from PS to pulmonary atresia or critical PS. This is in contrast to a previous report by Horneberger et al. which described progression of PS to pulmonary atresia in 2 of 16 TOF followed prenatally²¹. Larger, prospective studies are needed to determine the true frequency of significant progression in severity of PS during fetal life in TOF.

A primary limitation of this study is non-standardized surgical decision-making. Timing and type of surgery varies by center and surgeon, which may limit the generalizability of our data for predicting surgical timing and outcomes. We had a smaller number of patients with severe PS than expected, which may be due to difficulty in distinguishing most severe forms of PS for pulmonary atresia in utero. This study only included patients who were liveborn. We excluded pregnancies that experienced in utero demise or were terminated. Additionally, we excluded patients who were seen for only a single fetal echocardiogram at our institution and therefore did not have longitudinal fetal data.

In conclusion, mid-gestation fetal PV size is predictive of PV size at surgery and postnatal PV growth rate in TOF. Mid-gestation PV size has implications for prenatal counseling regarding timing and type of surgical repair and need for re-intervention in those undergoing valve-sparing repair.

Acknowledgments

Dr. Friedman is supported by a NIH training grant (T32 HL 007572-28). Neither author received an honorarium, grant or other payment for this manuscript

Reference List

1. Bailliard F, Anderson RH. Tetralogy of Fallot. *Orphanet J Rare Dis*. 2009; 4:2. [PubMed: 19144126]
2. Kantorova A, Zbieranek K, Sauer H, Lilje C, Haun C, Hraska V. Primary early correction of tetralogy of Fallot irrespective of age. *Cardiol Young*. 2008 Apr; 18(2):153–157. [PubMed: 18252030]
3. Tamesberger MI, Lechner E, Mair R, Hofer A, Sames-Dolzer E, Tulzer G. Early primary repair of tetralogy of fallot in neonates and infants less than four months of age. *Ann Thorac Surg*. 2008 Dec; 86(6):1928–1935. [PubMed: 19022010]
4. Gregg D, Foster E. Pulmonary insufficiency is the nexus of late complications in tetralogy of Fallot. *Curr Cardiol Rep*. 2007 Jul; 9(4):315–322. [PubMed: 17601398]
5. Redington AN. Physiopathology of right ventricular failure. *Semin Thorac Cardiovasc Surg Pediatr Card Surg Annu*. 2006:3–10. [PubMed: 16638541]
6. Oosterhof T, Tulevski II, Vliegen HW, Spijkerboer AM, Mulder BJ. Effects of volume and/or pressure overload secondary to congenital heart disease (tetralogy of fallot or pulmonary stenosis) on right ventricular function using cardiovascular magnetic resonance and B-type natriuretic peptide levels. *Am J Cardiol*. 2006 Apr 1; 97(7):1051–1055. [PubMed: 16563914]
7. Zeltser I, Gaynor JW, Petko M, Myung RJ, Birbach M, Waibel R, Ittenbach RF, Tanel RE, Vetter VL, Rhodes LA. The roles of chronic pressure and volume overload states in induction of arrhythmias: an animal model of physiologic sequelae after repair of tetralogy of Fallot. *J Thorac Cardiovasc Surg*. 2005 Dec; 130(6):1542–1548. [PubMed: 16307996]
8. Gatzoulis MA, Balaji S, Webber SA, Siu SC, Hokanson JS, Poile C, Rosenthal M, Nakazawa M, Moller JH, Gillette PC, Webb GD, Redington AN. Risk factors for arrhythmia and sudden cardiac death late after repair of tetralogy of Fallot: a multicentre study. *Lancet*. 2000 Sep 16; 356(9234):975–981. [PubMed: 11041398]
9. Robinson JD, Rathod RH, Brown DW, Del Nido PJ, Lock JE, McElhinney DB, Bacha EA, Marshall AC. The evolving role of intraoperative balloon pulmonary valvuloplasty in valve-sparing repair of tetralogy of Fallot. *J Thorac Cardiovasc Surg*. 2011 Dec; 142(6):1367–1373. [PubMed: 21703641]
10. Stewart RD, Backer CL, Young L, Mavroudis C. Tetralogy of Fallot: results of a pulmonary valve-sparing strategy. *Ann Thorac Surg*. 2005 Oct; 80(4):1431–1438. [PubMed: 16181883]
11. Bacha E. Valve-sparing options in tetralogy of Fallot surgery. *Semin Thorac Cardiovasc Surg Pediatr Card Surg Annu*. 2012; 15(1):24–26. [PubMed: 22424504]

12. Graham TP Jr, Bernard Y, Arbogast P, Thapa S, Cetta F, Child J, Chugh R, Davidson W, Hurwitz R, Kay J, Sanders S, Schaufelberger M. Outcome of pulmonary valve replacements in adults after tetralogy repair: a multi-institutional study. *Congenit Heart Dis.* 2008 May; 3(3):162–167. [PubMed: 18557878]
13. Harrild DM, Berul CI, Cecchin F, Geva T, Gauvreau K, Pigula F, Walsh EP. Pulmonary valve replacement in tetralogy of Fallot: impact on survival and ventricular tachycardia. *Circulation.* 2009 Jan 27; 119(3):445–451. [PubMed: 19139389]
14. Knauth AL, Gauvreau K, Powell AJ, Landzberg MJ, Walsh EP, Lock JE, Del Nido PJ, Geva T. Ventricular size and function assessed by cardiac MRI predict major adverse clinical outcomes late after tetralogy of Fallot repair. *Heart.* 2008 Feb; 94(2):211–216. [PubMed: 17135219]
15. Khoo NS, Van EP, Richardson M, Robertson T. Effectiveness of prenatal diagnosis of congenital heart defects in South Australia: a population analysis 1999–2003. *Aust N Z J Obstet Gynaecol.* 2008 Dec; 48(6):559–563. [PubMed: 19133043]
16. Tometzki AJ, Suda K, Kohl T, Kovalchin JP, Silverman NH. Accuracy of prenatal echocardiographic diagnosis and prognosis of fetuses with conotruncal anomalies. *J Am Coll Cardiol.* 1999 May; 33(6):1696–1701. [PubMed: 10334445]
17. Apitz C, Webb GD, Redington AN. Tetralogy of Fallot. *Lancet.* 2009 Oct 24; 374(9699):1462–1471. [PubMed: 19683809]
18. Ozkutlu S, Ayabakan C, Karagoz T, Onderoglu L, Deren O, Caglar M, Gucer S. Prenatal echocardiographic diagnosis of congenital heart disease: comparison of past and current results. *Turk J Pediatr.* 2005 Jul; 47(3):232–238. [PubMed: 16250307]
19. Hirji A, Bernasconi A, McCrindle BW, Dunn E, Gurofsky R, Manlhiot C, Miner SE, Kingdom JC, Jaeggi ET, Van AG, Nield LE. Outcomes of prenatally diagnosed tetralogy of Fallot: Implications for valve-sparing repair versus transannular patch. *Can J Cardiol.* 2010 Jan; 26(1):e1–e6. [PubMed: 20101358]
20. Escribano D, Herraiz I, Granados M, Arbues J, Mendoza A, Galindo A. Tetralogy of Fallot; prediction of outcome in the mid-second trimester of pregnancy. *Prenat Diagn.* Dec; 2011 21(12):1126–1133.
21. Hornberger LK, Sanders SP, Sahn DJ, Rice MJ, Spevak PJ, Benacerraf BR, McDonald RW, Colan SD. In utero pulmonary artery and aortic growth and potential for progression of pulmonary outflow tract obstruction in tetralogy of Fallot. *J Am Coll Cardiol.* 1995 Mar 1; 25(3):739–745. [PubMed: 7860923]
22. Schneider C, McCrindle BW, Carvalho JS, Hornberger LK, McCarthy KP, Daubeney PE. Development of Z-scores for fetal cardiac dimensions from echocardiography. *Ultrasound Obstet Gynecol.* 2005 Nov; 26(6):599–605. [PubMed: 16254878]
23. Hadlock FP, Harrist RB, Carpenter RJ, Deter RL, Park SK. Sonographic estimation of fetal weight. The value of femur length in addition to head and abdomen measurements. *Radiology.* 1984 Feb; 150(2):535–540. [PubMed: 6691115]

Figure 1.

Comparison of Clinical Characteristics Based on Mid-Gestation Pulmonary Valve Z-score

Table 1
Demographic and Clinical Data

	Fetal PV z-score >-3.5 n=48	Fetal PV z-score -3.5 n=18	<i>p</i> value
Gestational age at diagnosis (weeks)	21 (18-30)	27 (19-30)	0.005
Number of fetal echocardiograms (n, range)	2 (1-5)	1 (1-5)	0.29
Male (n,%)	30 (65%)	5 (28%)	0.014
Associated cardiac anomalies	11 (23%)	7 (39%)	0.44
Left SVC to coronary sinus	3 (6%)	2 (11%)	0.61
Right aortic arch	7 (15%)	2 (11%)	0.97
Major aortopulmonary collaterals	0 (0%)	2 (11%)	0.02
Other	1 (2%)	1 (6%)	0.48
Genetic Syndromes	7 (15%)	2 (11%)	0.69
Major non-cardiac anomalies	10 (21%)	1 (6%)	0.13
Trachoesophageal fistula	4 (8%)	0 (0%)	0.57
Congenital diaphragmatic hernia	2 (4%)	0 (0%)	0.37
Other	4 (8%)	1 (6%)	0.69
Gestational Age at Birth	39 (32-41)	39 (31-40)	0.90
Birth weight (kg)	3.0 (2.2-3.9)	2.9 (2.1-3.7)	0.86

Values represent median (range) or count (%)

PV, pulmonary valve; TOF, Tetralogy of Fallot; PS, pulmonary stenosis

Table 2
Fetal Echocardiographic Data

	Fetal PV z-score >-3.5 n=48	Fetal PV z-score -3.5 n=18	p value
Data from 1st fetal echocardiogram			
Gestational age (weeks)	22 (18-30)	27 (19-30)	0.005
Estimated fetal weight (kg)	0.75 (0.24-2.1)	.81 (0.30-2.6)	0.16
PV diameter (mm)	3.3 (2.1-6.1)	3.0 (2.6--4.1)	0.80
PV z-score	-2.4 (-0.5 to -3.4)	-3.9 (-3.5 to -6.0)	<0.001
Aortic valve: pulmonary valve	0.7 (0.5-1.3)	0.6 (0.4-1.0)	0.045
Absent ductus arteriosus, (n,%)	13 (27%)	7 (39%)	0.39
Ductus arteriosus flow reversal	2 (4%)	5 (28%)	0.02
Peak RVOT systolic velocity (cm/s)	0.8 (0.7-0.9)	0.9 (0.8-1.3)	0.34
Data from last fetal echocardiogram			
Gestational age (weeks)	32 (27-36)	33 (28-36)	0.73
Estimated fetal weight (kg)	1.6 (1.2-2.8)	1.7 (1.3-2.8)	0.81
PV diameter on last fetal (mm)	5.0 (3.6-8.1)	4.5 (3.4-5.2)	0.047
PV z-score last fetal	-2.8 (-0.6 to -4.5)	-3.8 (-2.8 to -4.8)	<0.001
Aortic valve: pulmonary valve	0.6 (0.4-1.1)	0.8 (0.6-1.4)	0.006
Changes over gestation			
Rate of PV change over fetal life (mm/mo)	0.8 (0.2-2.7)	0.4 (0.5-1.2)	0.08
z-score change over fetal life	-0.4 (-2.9 to 1.6)	-0.1 (-0.4 to 1.5)	0.12
% of patients with increase in z-score	9/27 (33%)	6/15 (40%)	0.85

Values represent median (range) or count (%)

PV, pulmonary valve; AV, aortic valve; RVOT, right ventricular outflow

Table 3
Postnatal Echocardiographic Data

	Fetal PV z-score >-3.5 n=48	Fetal PV z-score <-3.5 n=18	p value
Newborn echocardiogram			
PV diameter (mm)	5.9 (4.0-8.8)	5.1 (3.5-6.5)	0.037
PV z-score	-1.9 (0.5 to -3.1)	-2.8 (-0.1 to -3.7)	0.001
Presurgical echocardiogram			
PV diameter (mm)	7.0 (4.5-1.3)	6.0 (3.6-1.0)	0.013
PV z-score echo	-1.7 (-3.5 to 2.0)	-2.9 (-4.7 to -0.6)	0.007
PV z-score change over postnatal life	0 (-2.7 to 4.2)	-0.3 (-1.9 to 2.5)	0.128
Rate of PV change postnally (mm/month)	0.5 (0-2.6)	0 (0-1.4)	0.002
Main pulmonary artery z-score	-1.3 (1.5 to -3.7)	-2.8 (-1.4 to -4.5)	0.04
Right pulmonary artery z-score	-0.5 (-2.8 to 2.8)	-1.7 (-3.7 to 3.4)	0.04
Left pulmonary artery z-score	-0.5 (-3.0 to 2.7)	-2.1 (-3.34 to 2.6)	0.03

Values represent median (range)

PV, pulmonary valve