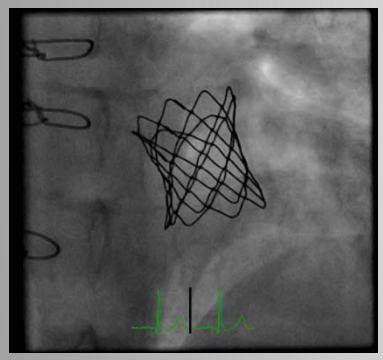
Percutaneous Pulmonary Valve Implantation: 5 years of follow up



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Background

- Percutaneous pulmonary valve implantation (PPVI) is an accepted alternative to surgery
- Indications include Right ventricular outflow tract dysfunction: PS, PI, Mixed disease
- Immediate results have been good: decrease in PI & RVOT gradient, improved RV size & function

Lurz P, et al.. *Circulation* 2008;117:1964-72

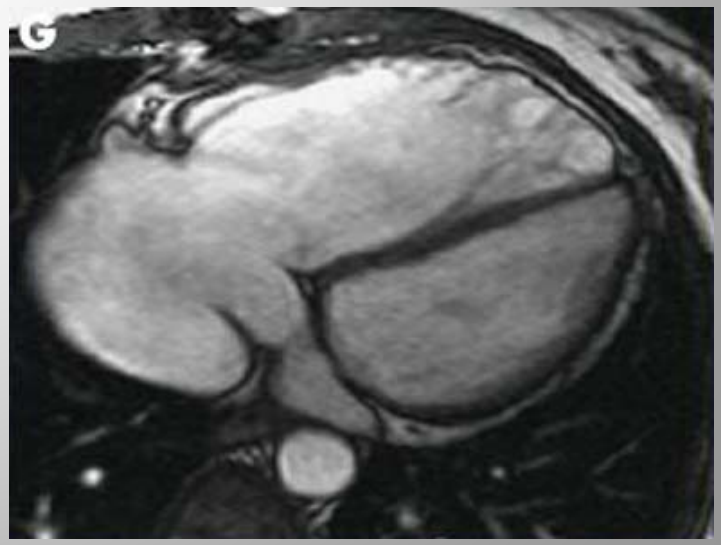
Background

- Some reports note no additional functional improvement after one year (Lurz et al.)
- Long-term outcomes await evaluation
- Debate continues regarding the timing of pulmonary valve replacement

Lurz P, et al.. *Circulation* 2008;117:1964-72; *J Am Coll Cardiol* 2011;57:724-31; Lee C, et al. *J Am Coll Cardiol* 2012;60:1005-14.

Objectives

- To determine if reverse remodeling of the right ventricle following PPVI persists in the long term
- To assess whether earlier timing of PPVI influences functional and anatomical outcomes



Methods

- 51 patients from the Hospital for Sick Children and Toronto General Hospital who underwent PPVI between 2005-11 studied
- Pre-intervention cMRI, echo, metabolic exercise testing and hemodynamics were compared serially in follow-up
- Prospective acquisition of current investigations
- Paired t-tests and linear regression models were used to assess changes over time

Patient Characteristics (n=51)

Age at index procedure (yr)	20.2±10.8
Weight (kg)	58.3±16.0
Female:Male (n)	23:28
Follow up (yr)	4.5±1.9
Diagnoses:	
TOF or DORV with PS	17
TOF with PA	14
PA with intact ventricular septum	2
TOF with absent pulmonary valve	2
Common arterial trunk	8
Ross procedure for aortic valve disease	5
Aortic atresia	1
Congenitally corrected transposition	2
Years from last surgery	12.2±7.1
RVOT dysfunction:	
Predominantly PI	2
Predominantly PS	16
Both PI and PS	31
RVOT morphology:	
Homograft	17
Stented native outflow tract	3
Bioprosthetic conduit or valve	21
Number of previous surgeries	2.39±0.84
Number of previous interventions	1.48±0.86

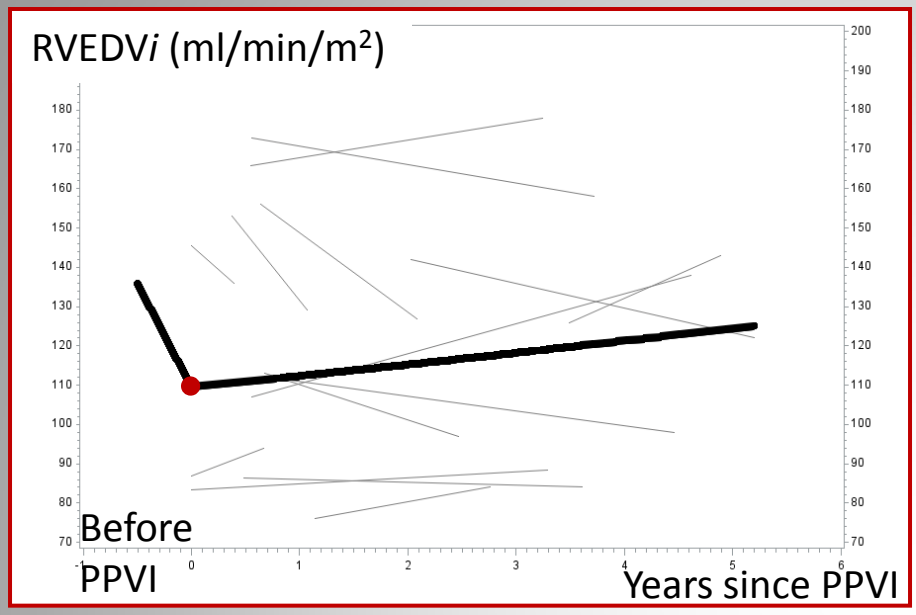
PPVI Outcomes

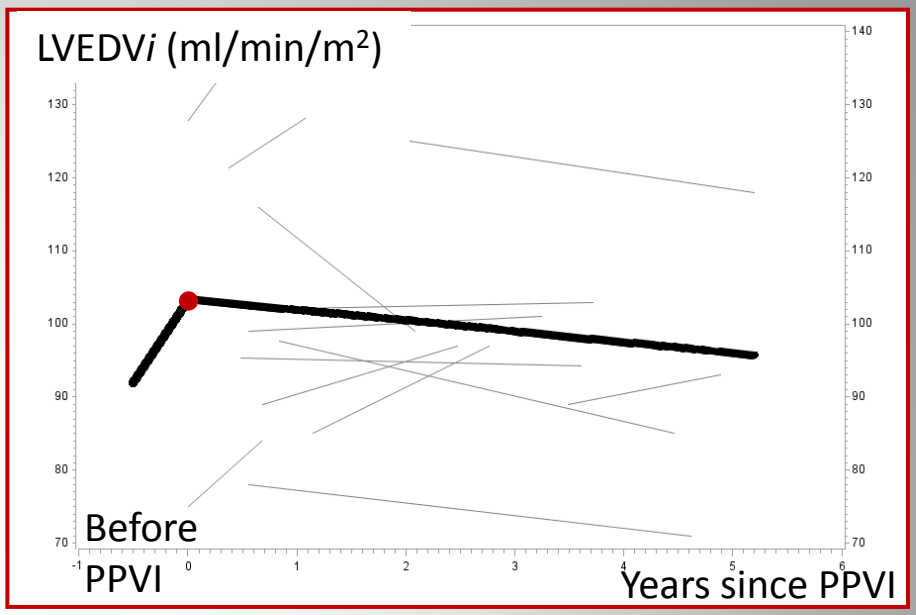
	Before PPVI	Average after PPVI	P value
Hemodynamic:			
RV to PA pressure gradient (mm Hg)	35.2±16.5	11.2±6.6	<0.001
RV systolic pressure (mm Hg)	60.8±17.9	40.6±11.4	<0.001
RV/Ao systolic pressure ratio	0.68±0.20	0.45±0.24	<0.001
Echocardiographic:			
RV to PA pressure gradient (mm Hg)	63.7±23.0	36.0±15.2	<0.001
Estimated RVSp (mm Hg)	78.9±17.7	53.6±15.4	<0.001
RV systolic/systemic blood pressure	0.76±0.19	0.49±0.14	<0.001
RVED dimension z-score	3.84±2.35	3.09±2.45	0.06
LVEF (%)	64.5±9.8	63.2±8.7	0.38

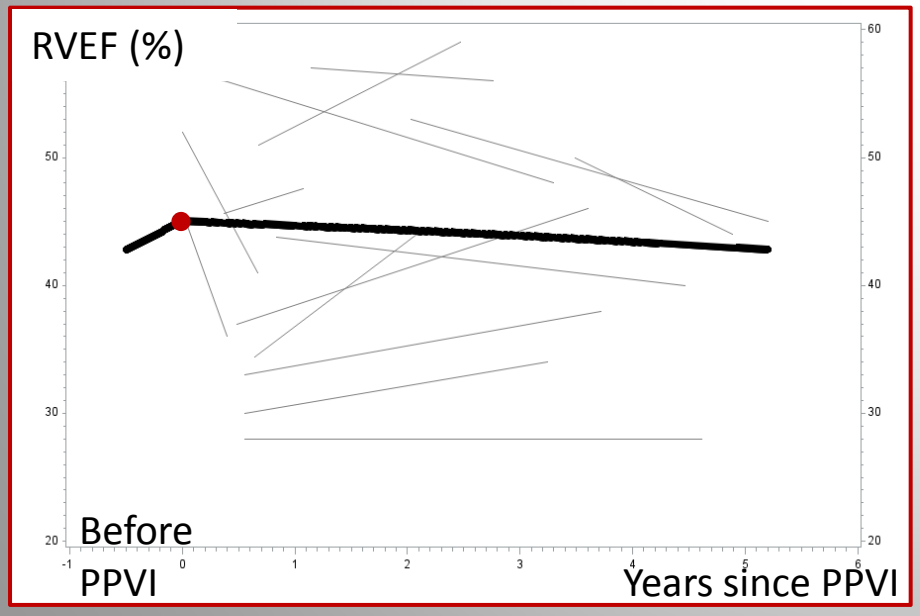
PPVI Outcomes

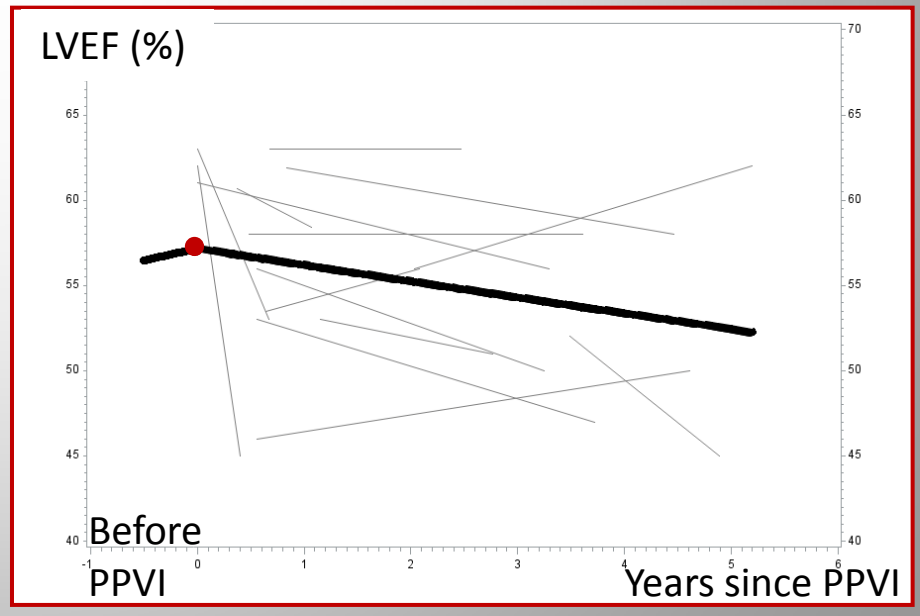
	Before PPVI	Average after PPVI	P value
Exercise testing:			
Maximum VO_2 ($ml/min/m^2$)	23.2±6.8	26.2±6.7	0.02
% predicted maximum VO_2	56.3±13.6	62.0±14.8	0.04
VO_2 at anaerobic threshold ($ml/min/m^2$)	18.3±5.2	19.6±6.7	0.007
Work performed (watts)	87.5±26.7	104.1±33.5	0.63
Peak heart rate (bpm)	157.6±27.1	166.0±22.6	0.07
MRI:			
RVEDVi (ml/m^2)	136.3±42.9	116.3±33.9	0.03
RVESVi (ml/m^2)	79.4±40.5	68.6±32.6	0.22
RVEF (%)	42.7±12.3	44.0±9.8	0.05
LVEDVi (ml/m^2)	91.9±18.4	98.5±18.6	0.14
LVESVi (ml/m^2)	41.2±14.9	44.9±11.7	0.26
LVEF (%)	56.6±8.9	54.5±7.1	0.27
RVEDVi/LVEDVi ratio	1.51±0.44	1.19±0.32	0.08

Changes Over Time



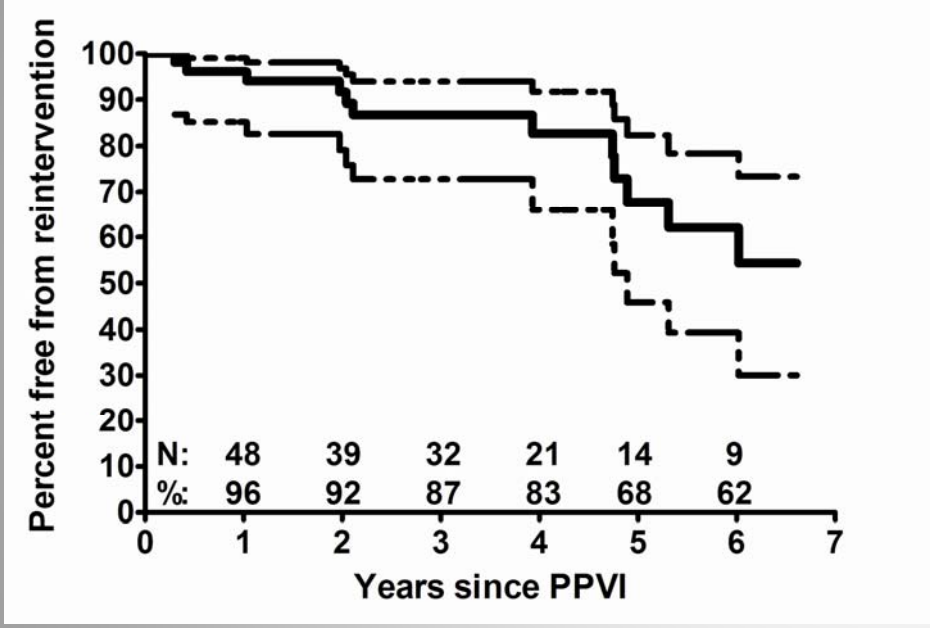


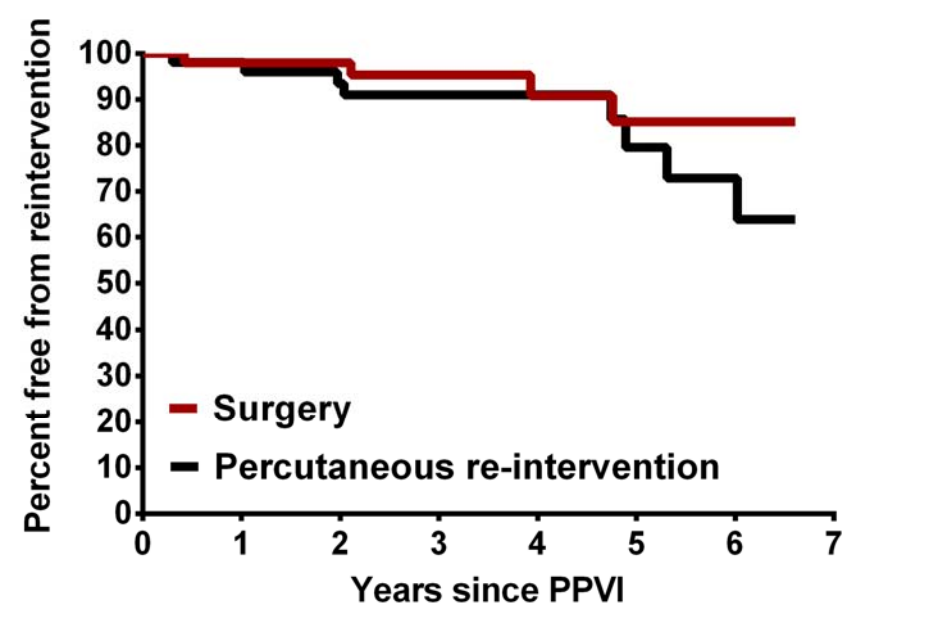




Late Outcomes

Freedom from Intervention





Patient Characteristics by Age

Characteristic	Age ≤ 16 years (n=23)	Age > 16 years (n=28)	P Value
Age at Catheterization (years)	13.3 ± 1.6	25.9 ± 11.84	<0.001
Weight at intervention (kg)	55.9 ± 18.2	61.2 ± 13.0	0.27
Sex: Female:Male (n)	12:11	11:17	0.41
Follow up duration (y)	4.8 ± 1.8	4.2 ± 2.0	0.27
Years from previous operation	6.3 ± 1.6	13.6 ± 7.2	0.002
Diagnosis: (n) Right sided obstruction	15	22	
Left sided obstruction	3	3	0.22
Common Arterial Trunk	5	3	
Pre Systolic MPA Pressure (mmHg)	23.0 ± 5.9	29.0 ± 10.1	0.01
Pre Systolic Aortic Pressure (mmHg)	85.3 ± 8.1	95.8 ± 20.1	0.02
Pre RV Systolic Pressure (mmHg) by Cath	61.9 ± 15.2	60.0 ± 20.2	0.69
RV-PA Gradient (mmHg) by Cath	39.2 ± 12.6	31.7 ± 18.8	0.10

Patient Characteristics by Age

Characteristic	Age ≤ 16 years (n=23)	Age > 16 years (n=28)	P Value
Pre RVED dimension z-score by Echo	2.53 ± 1.62	4.97 ± 2.32	0.001
Pre LVEF (%) by Echo	70.1 ± 7.6	59.8 ± 9.2	0.001
Pre Maximal VO_2 (ml/min/m^2)	25.1± 5.7	21.7 ± 7.4	0.11
Pre % Predicted VO_2 at anaerobic threshold	61.6 ± 16.0	49.2 ± 14.9	0.04
Pre RVEDVi (ml/m^2)	127.7 ± 40.6	141.7 ± 44.6	0.39
Pre RVESVi (ml/m^2)	67.4 ± 33.7	87.4 ± 43.8	0.21
Pre RVEF (%)	46.5 ± 12.2	40.2 ± 12.1	0.20
Pre LVEF (%)	59.5 ± 7.3	54.9 ± 9.5	0.16

Serial Findings after PPVI by Age

	Age ≤16 years	Age >16 years	*P* value
Echocardiographic:			
RV to PA gradient (mm Hg)	38.2±14.5	33.2±15.8	0.21
Estimated RVSp (mm Hg)	53.5±15.0	53.7±15.9	0.24
RVED dimension (cm)	2.99±1.15	3.78±1.12	<0.001
RVED dimension z-score	2.35±2.45	4.08±2.09	<0.001
LVEF (%)	64.7±7.7	61.2±9.5	0.009
RV Function (3-point scale)	2.8±0.5	1.9±0.9	<0.001
Exercise test:			
Maximal VO2 (ml/min/m2)	24.8±6.1	27.6±7.0	0.27
VO2 at anaerobic threshold (ml/min/m2)	19.3±7.3	19.9±6.2	0.10
Work performed (watts)	86.9±21.9	121.2±34.5	0.09
Exercise duration (min)	8.21±2.21	10.2±3.01	0.36
Peak systolic BP (mm Hg)	141.8±16.9	155.7±30.1	0.24

Serial Findings after PPVI by Age

	Age ≤16 years	Age >16 years	*P* value
MRI:			
RVEDVi (ml/m^2)	110.0±22.9	122.7±42.1	0.64
RVESVi (ml/m^2)	61.7±17.4	75.6±42.1	0.55
RVSVi (ml/min/m^2)	52.1±11.8	47.6±9.6	0.13
RVEF (%)	46.9±6.7	41.1±11.6	0.07
LVEDVi (ml/m^2)	103.2±18.0	93.7±18.3	0.30
LVESVi (ml/m^2)	44.9±10.3	44.9±13.2	0.61
LVSVi (ml/min/m^2)	58.7±12.0	52.7±12.0	0.48
LVEF (%)	56.7±5.8	52.3±7.7	0.12
RVEDVi/LVEDVi	1.08±0.19	1.33±0.38	0.21

Factors associated with improved ventricular function after PPVI

	Post RVEF EST (SE)	P value	Post LVEF EST (SE)	P value
Age ≤16 years	-5.78 (3.31)	0.08	**-4.87 (2.13)**	**0.02**
Pre RV to PA gradient (cath)	**0.24 (0.09)**	**0.009**	**0.14 (0.06)**	**0.03**
Pre diastolic MPA pressure	**-0.53 (0.27)**	**0.05**	**-0.30 (0.14)**	**0.04**
Pre % predicted maximal VO_2	**0.31 (0.15)**	**0.04**	**0.23 (0.09)**	**0.01**
Pre RVEDVi	**-0.13 (0.02)**	**<0.001**	**-0.05 (0.02)**	**0.01**
Pre RVESVi	**-0.18 (0.03)**	**<0.001**	**-0.07 (0.02)**	**<0.001**
Pre RV cardiac index	**6.26 (2.64)**	**0.02**	**7.33 (1.41)**	**<0.001**
Pre RVEF	**0.58 (0.08)**	**<0.001**	**0.33 (0.05)**	**<0.001**
Pre ratio of RV to LV volume	**-13.94(2.35)**	**<0.001**	**-5.55 (1.96)**	**0.005**
Pre LVEDVi	0.03 (0.09)	0.73	0.05 (0.05)	0.24
Pre LVESVi	-0.19 (0.14)	0.17	**-0.14 (0.05)**	**0.01**
Pre LVSVi	**0.25 (0.10)**	**0.02**	**0.17 (0.05)**	**0.001**
Pre LVEF (MRI)	**0.62 (0.15)**	**<0.001**	**0.48 (0.08)**	**<0.001**
Pre LVEF (echo)	0.20 (0.15)	0.20	**0.31 (0.09)**	**0.001**
Pre RV function (echo)	-1.45 (0.80)	0.07	**3.54 (1.59)**	**0.03**
Pre RV z-score	**5.36 (2.13)**	**0.01**	**-1.54 (0.56)**	**0.006**
Prior stenting	**10.41 (3.64)**	**0.004**	**6.70 (2.55)**	**0.009**
Orthotopic position	**9.05 (3.19)**	**0.005**	3.52 (2.77)	0.20

Conclusions

- Good intermediate-term functional & hemodynamic results with low re-intervention & re-operation rates after PPVI
- Gradual late decrease in aerobic capacity & biventricular function & a rise in RV volume – likely due to anatomical & conduit limitations
- PPVI favorably alters the interventional history & postpones the requirements for repeat surgical procedures

Conclusions

- Improved outcomes when PPVI performed at younger age, smaller ventricular volumes & preserved ventricular function
- Findings support previous investigators advocating early pulmonary valve replacement

Lee C, et al. *J Am Coll Cardiol* 2012;60:1005-14; Frigiola A, et al. *Circulation* 2008;118:S182-90.

Thank You

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