RVOT Reconstructive Surgery in Surgeon's View

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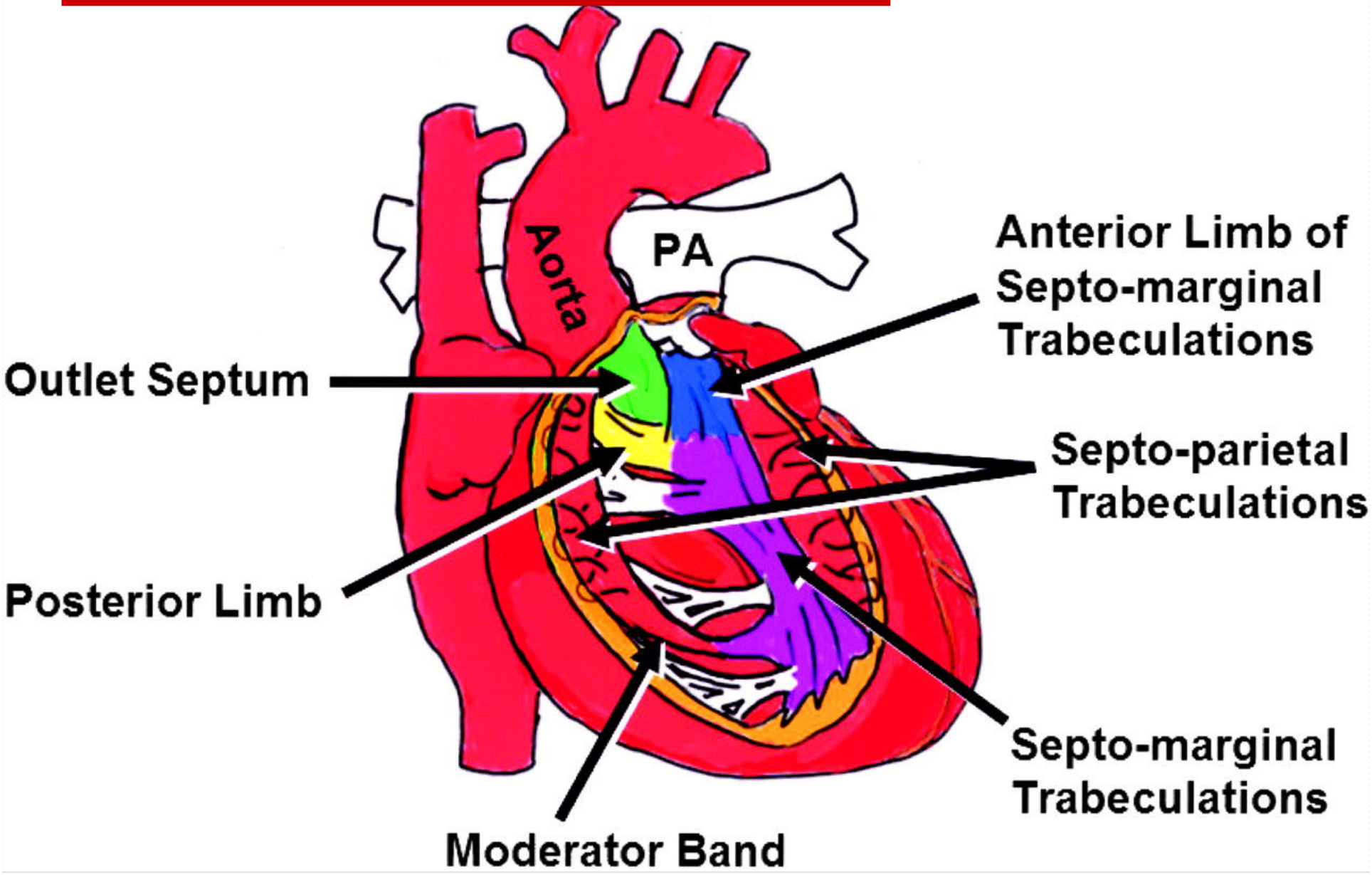
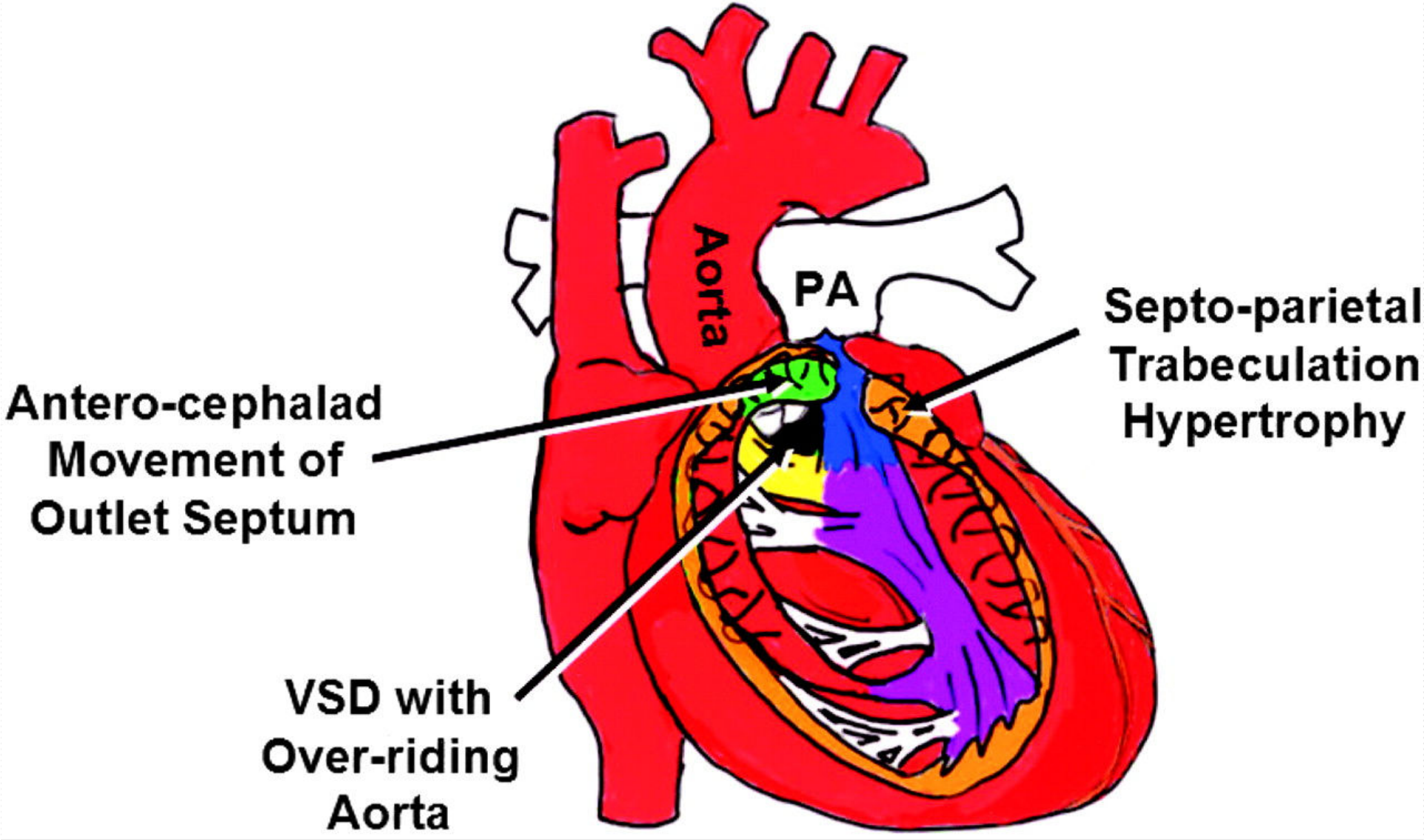
Yonsei University, College of Medicine

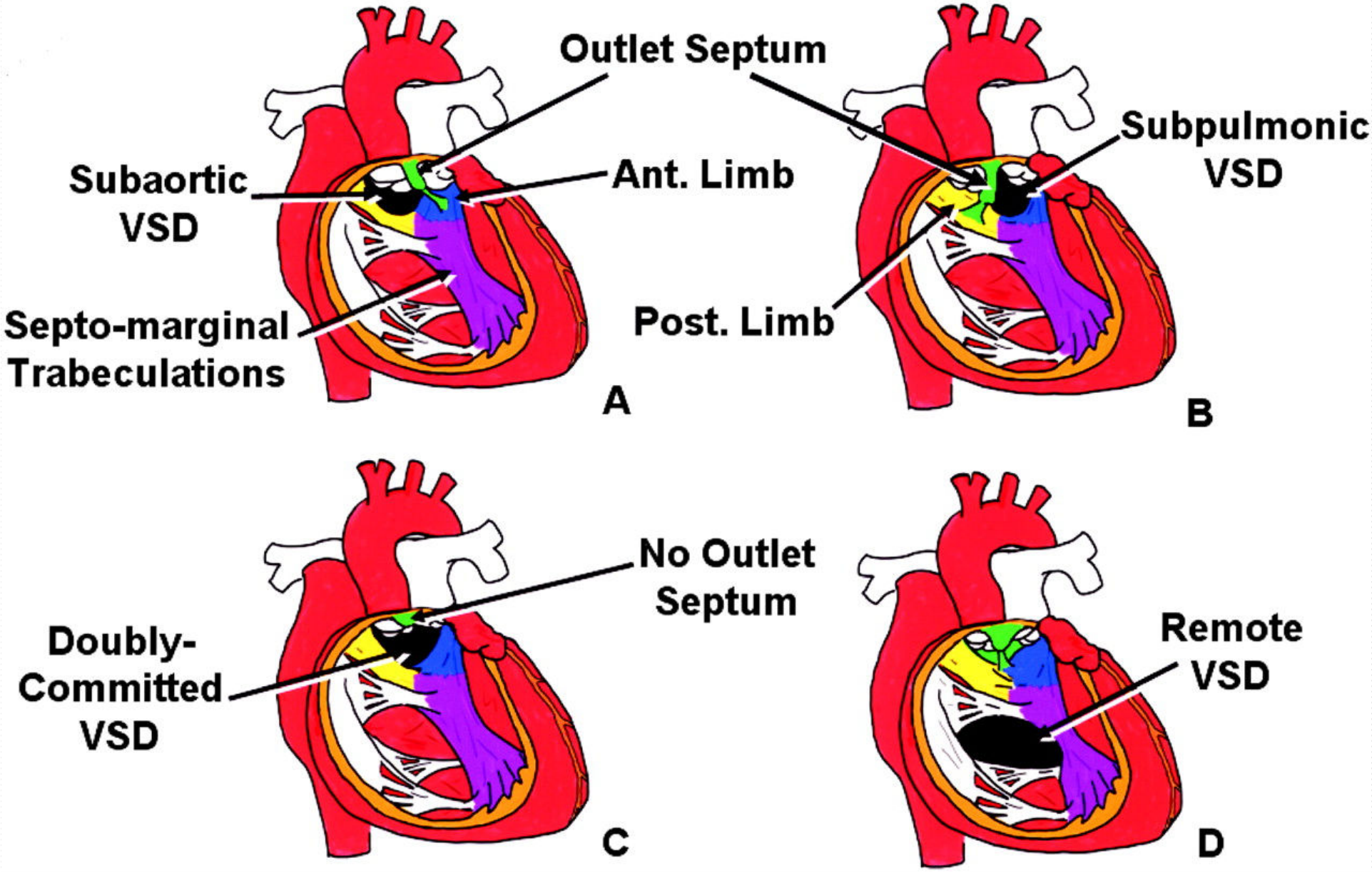
Normal RVOT


Aorta
PA
Anterior Limb of Septo-marginal Trabeculations
Outlet Septum
Septo-parietal Trabeculations
Posterior Limb
Septo-marginal Trabeculations
Moderator Band

Tetralogy of Fallot



Double Outlet of RV



Indications for Right Ventricular Outflow Tract Reconstruction

Congenital RVOT Pathology	**Sample Diagnoses**
Stenosis	TOF or DORV with PS
	Critical PS
Atresia	TOF with PA
	Truncus arteriosus
Iatrogenic RVOT Pathology	
Rastelli procedure	D-TGA, VSD, LVOTO
	IAA, VSD, LVOTO
Ross procedure	Aortic valve pathology +/-LVOTO

Related Causes of RVOTO

- Unoperated
  - Valvular
  - Infundibular stenosis/ obstruction
  - Subinfundibular obstruction
  - Supravalvular stenosis
- Operated
  - Valvular
  - Conduit stenosis
  - Double-chambered RV restenosis
  - Peripheral or branch PS
  - Infundibular stenosis after tunnel repair of DORV

Indications for Reintervention in TOF

- Symptoms of right heart failure
- RV enlargement or evidence for RV dysfunction, especially if PI present
- Clinically significant arrhythmias (atrial or ventricular)
- Progressive aneurysmal dilation of an RVOT patch
- Onset or progression of TR
- Residual VSD with shunt >1.5:1
- Residual patent AP shunts leading to LV volume overload
- Residual RVOTor PS with systolic RV/LV 0.67
- Significant AI with evidence for LV dysfunction
- Dilated aortic root >5.5 cm

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Review

Pulmonary regurgitation: not a benign lesion

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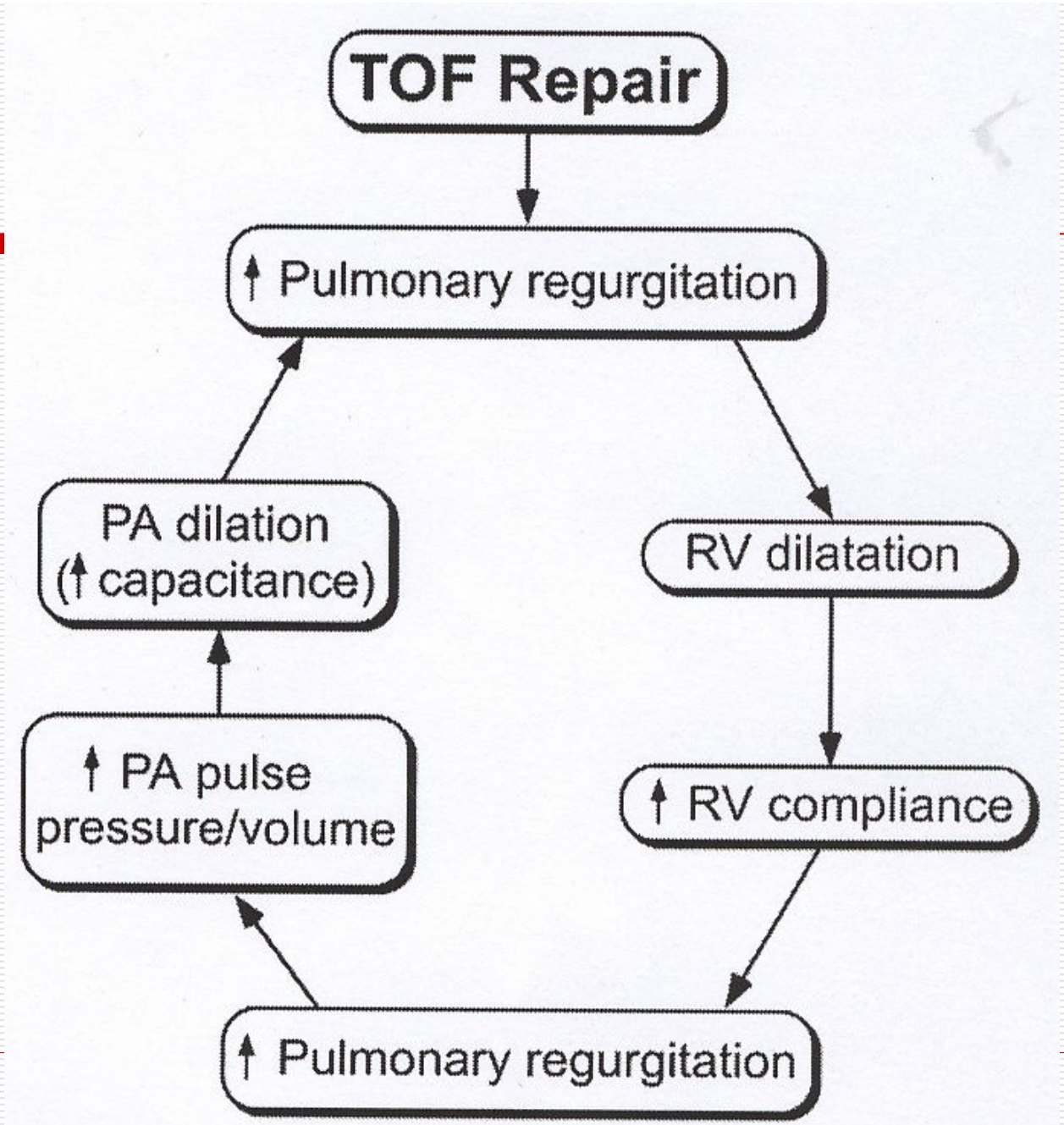
KEYWORDS
Pulmonary regurgitation;
Cardiovascular magnetic resonance;
Ventricular function

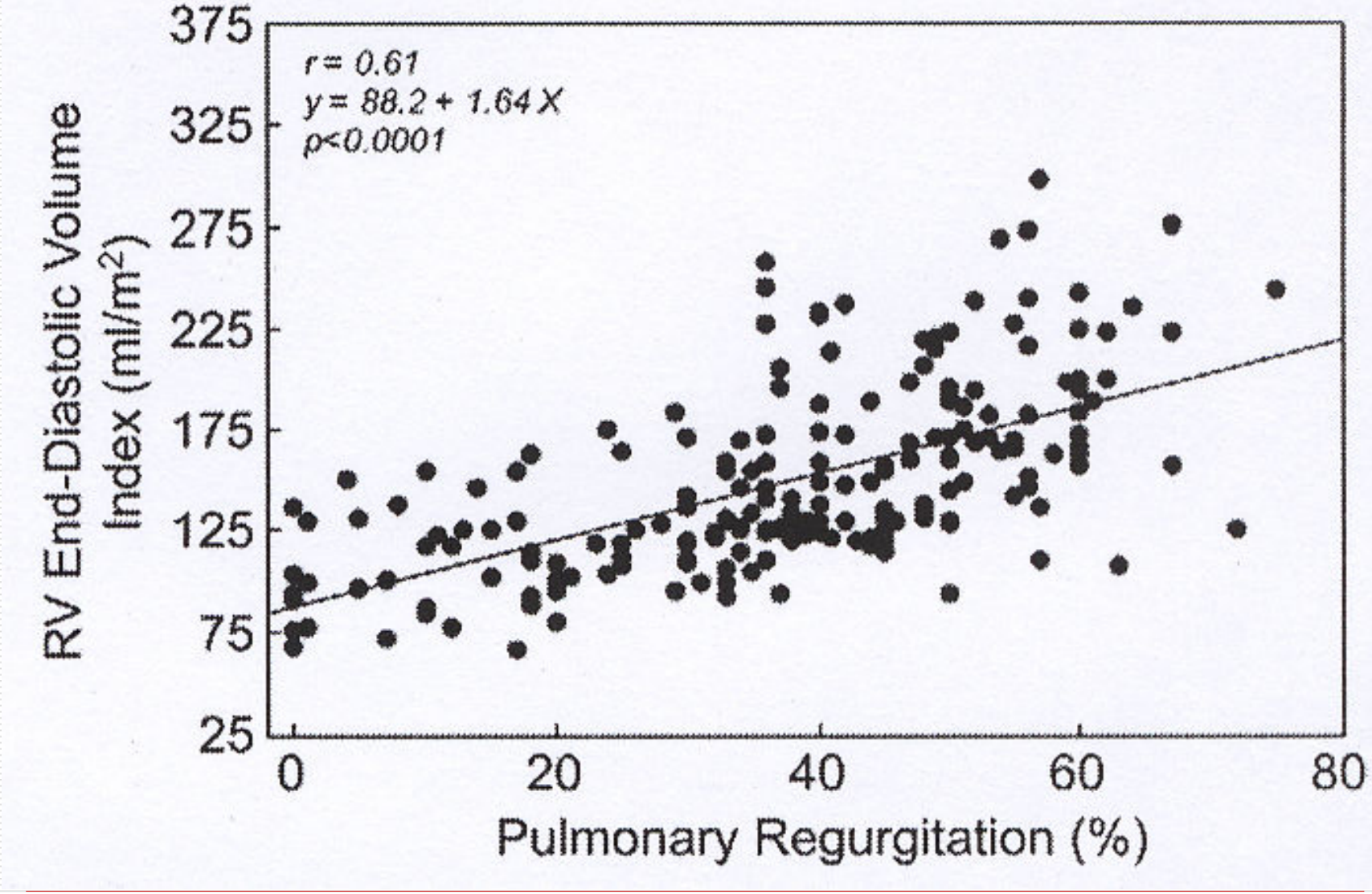
Pulmonary regurgitation (PR) is a common complication after surgical or percutaneous relief of pulmonary stenosis and following repair of tetralogy of Fallot. Significant PR is usually well tolerated in childhood. However, in the long term, chronic PR has a detrimental effect on right ventricular (RV) function and exercise capacity and leads to an increased risk of arrhythmia and sudden cardiac death (SCD). Recent advances in non-invasive imaging and, in particular, wider availability of cardiovascular magnetic resonance (CMR), have improved the assessment of PR and RV function in these patients. This in turn has facilitated decision making on the optimal timing for elective pulmonary valve replacement (PVR), which should be performed before irreversible RV dysfunction ensues.

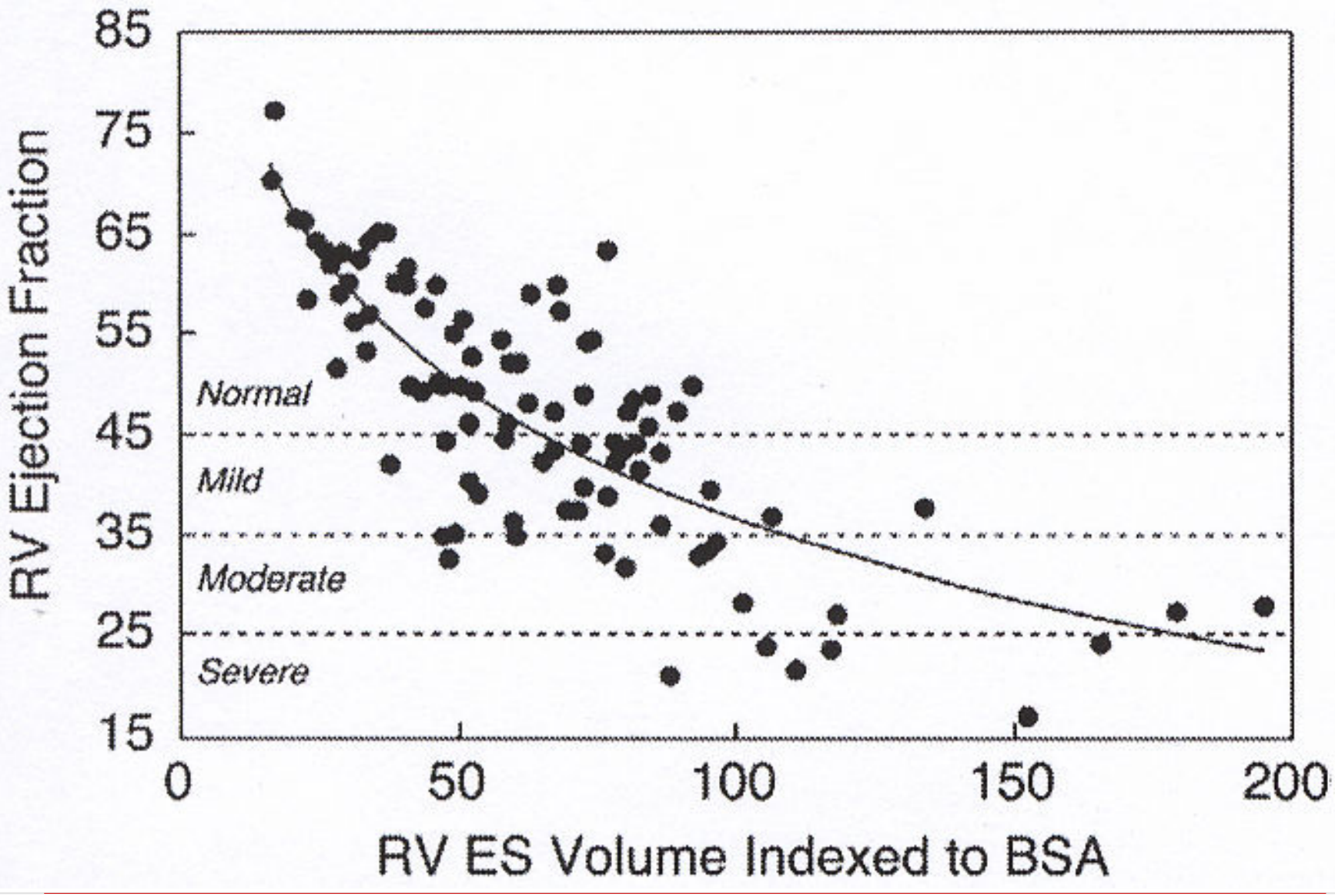
Structural and Functional Abnormalities of RVOT

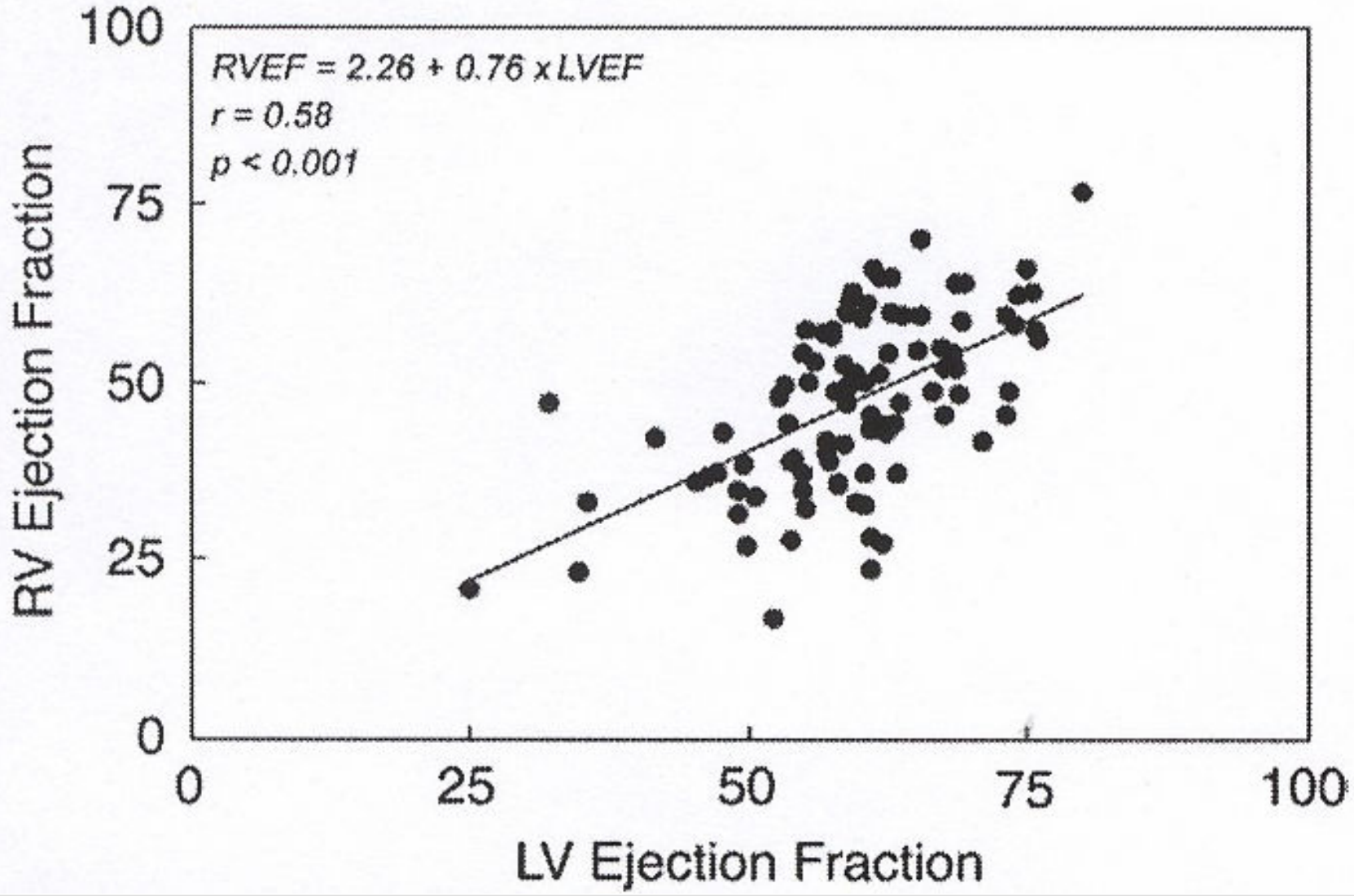
Structural Abnormalities	Functional Abnormalities
Inherent to TOF repair	Right ventricular volume overload
Partial or complete removal of pulmonary valve tissue	Pulmonary regurgitation
Infundibulotomy scar	Tricuspid regurgitation
Resection of RV/infundibular muscle bundles	Left-to-right shunt
Right atriotomy scar	Ventricular septal defect
VSD patch	Atrial septal defect
Residual lesions	Aorto-pulmonary collaterals
Right ventricular outflow tract obstruction	Pressure overload
Pulmonary artery stenosis	Main or branch pulmonary artery stenosis
Ventricular septal defect	Pulmonary vascular disease
Atrial septal defect	Pulmonary venous hypertension secondary to LV dysfunction
Acquired lesions	Right ventricular systolic dysfunction
Tricuspid valve abnormalities	Right ventricular diastolic dysfunction
Right ventricular outflow tract aneurysm	Left ventricular dysfunction
Right ventricular fibrosis (due to cyanosis, pressure and/or volume overload, surgical incision, coronary artery disruption, inadequate myocardial protection)	LV-RV interaction
	Arrhythmias

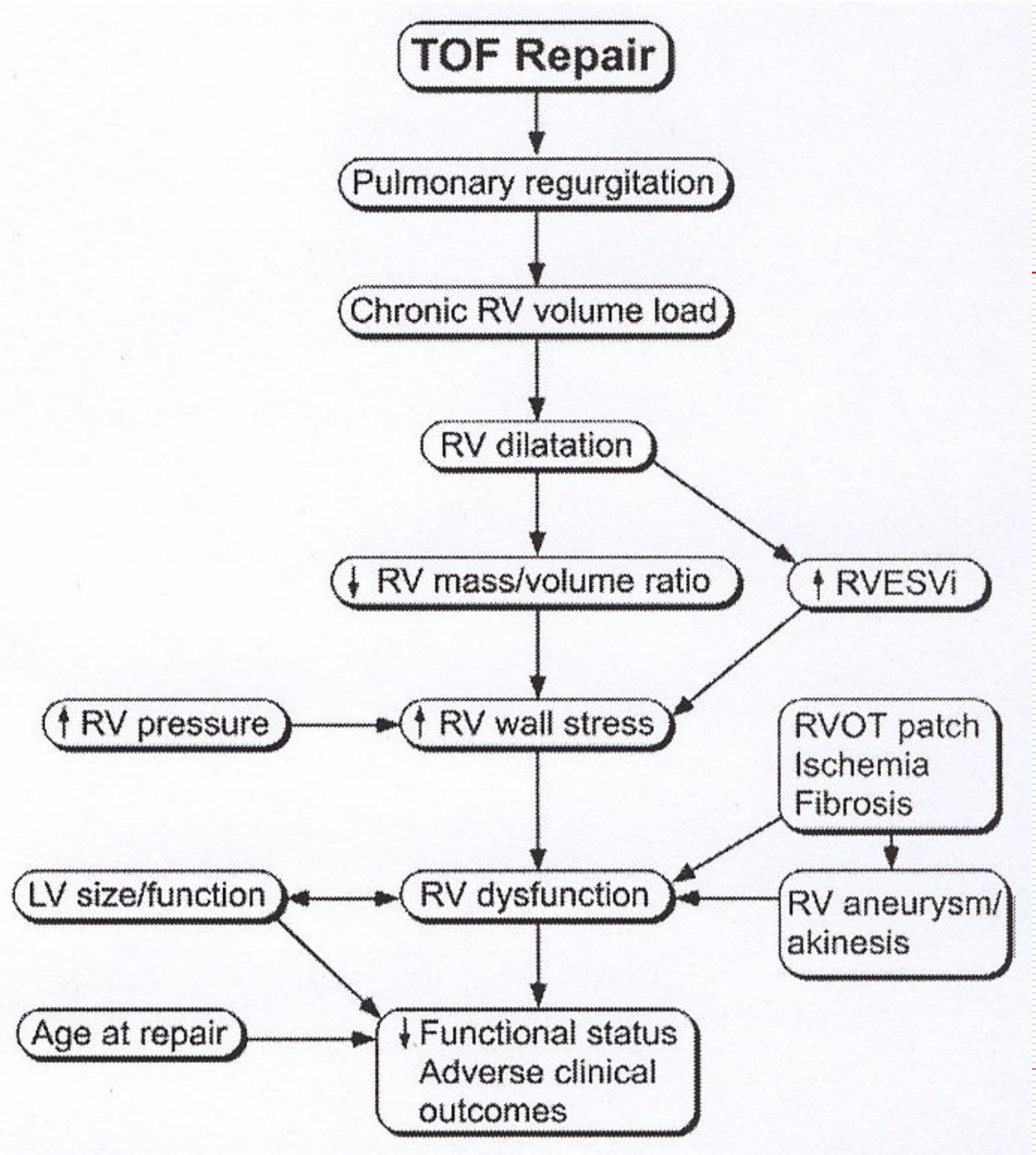
Tel Geva Pediatric Cardiac Surgery Annual 2006


TOF Repair
↑ Pulmonary regurgitation
RV dilatation
↑ RV compliance
↑ Pulmonary regurgitation
↑ PA pulse pressure/volume
PA dilation (↑ capacitance)


r = 0.61
y = 88.2 + 1.64 X
p<0.0001
RV End-Diastolic Volume Index (ml/m²)
375
325
275
225
175
125
75
25
0
20
40
60
80
Pulmonary Regurgitation (%)


RV Ejection Fraction
85
75
65
55
45
35
25
15
Normal
Mild
Moderate
Severe
0
50
100
150
200
RV ES Volume Indexed to BSA


RVEF = 2.26 + 0.76 x LVEF
r = 0.58
p < 0.001
RV Ejection Fraction
LV Ejection Fraction
0
25
50
75
100


TOF Repair
Pulmonary regurgitation
Chronic RV volume load
RV dilatation
↓ RV mass/volume ratio
↑ RVESVi
↑ RV pressure
↑ RV wall stress
RVOT patch
Ischemia
Fibrosis
LV size/function
RV dysfunction
RV aneurysm/
akinesis
Age at repair
↓ Functional status
Adverse clinical
outcomes

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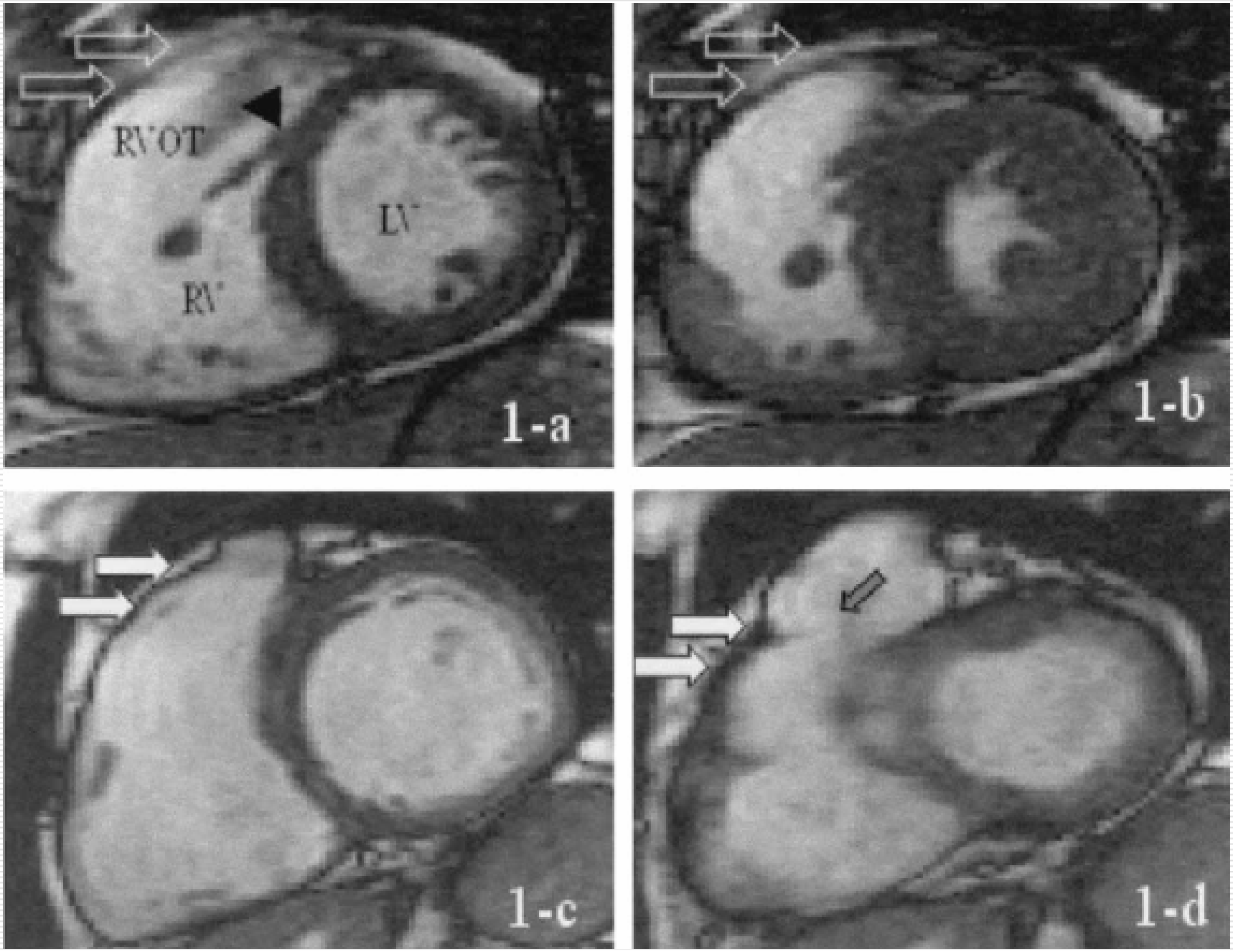
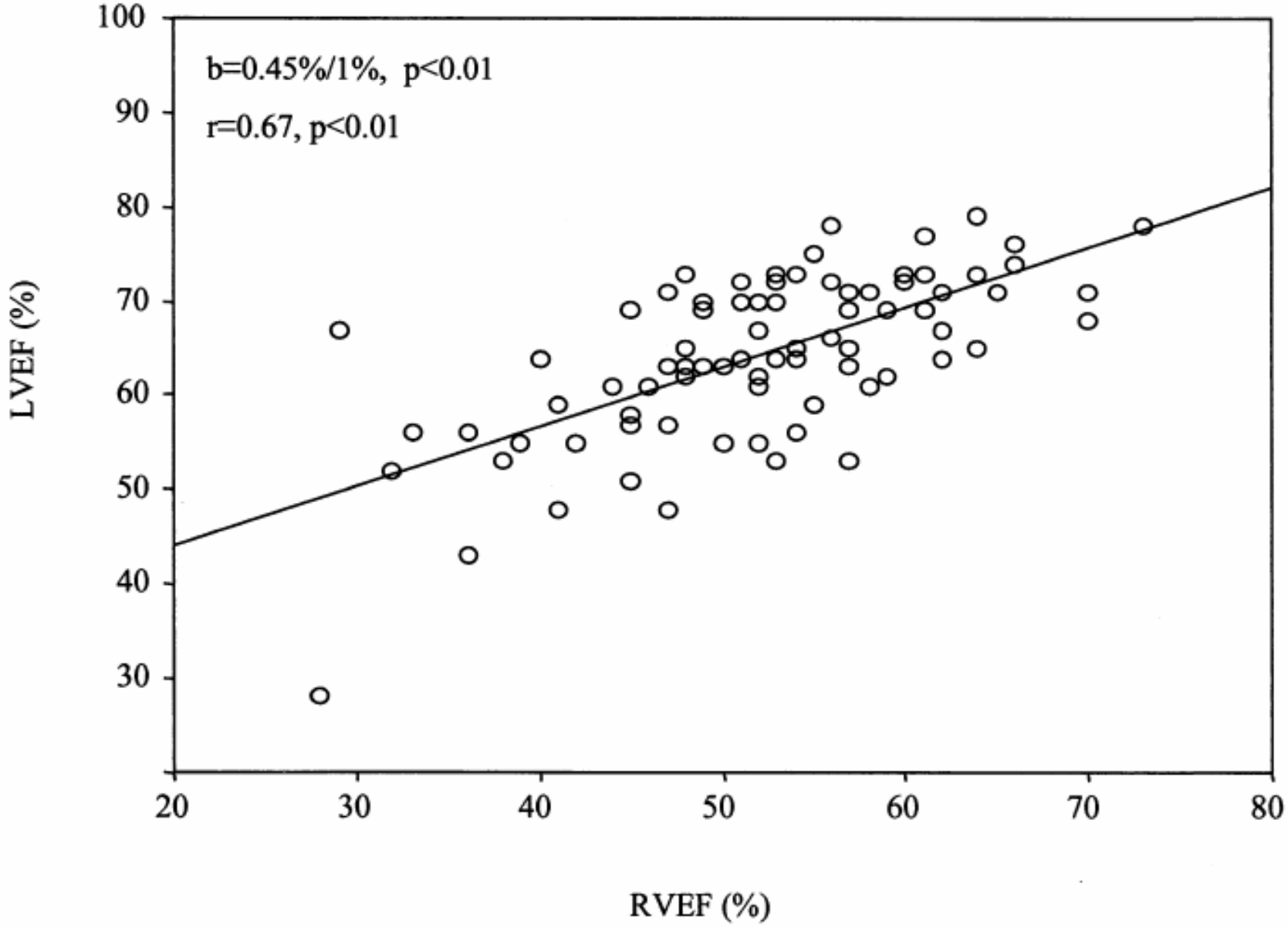
Adult Congenital Disease

Right Ventricular Function in Adults With Repaired Tetralogy of Fallot Assessed With Cardiovascular Magnetic Resonance Imaging: Detrimental Role of Right Ventricular Outflow Aneurysms or Akinesia and Adverse Right-to-Left Ventricular Interaction

Periklis A. Davlouros, MD,* Philip J. Kilner, MD, PHD,† Tim S. Hornung, MD,* Wei Li, MD, PHD,*
Jane M. Francis, DCR(R),† James C. C. Moon, MD,† Gillian C. Smith, BSE,† Tri Tat, PHD,‡
Dudley J. Pennell, MD, FACC,† Michael A. Gatzoulis, MD, PHD, FACC*

London, United Kingdom


RVOT
LV
RV
1-a
1-b
1-c
1-d


b=0.45%/1%, p<0.01
r=0.67, p<0.01
LVEF (%)
RVEF (%)
100
90
80
70
60
50
40
30
20
30
40
50
60
70
80

Factors Responsible for the Functional Deterioration

- RV dilatation with unfavoralbe alteration in the RV mass to volume ratio
- Scarring and fibrosis from the initial ventriculotomy, with late remodeling because of the pressure/volume overload
- Electrical uncoupling of ventricular contraction (wide QRS) with RBBB
- Left ventricular dysfunction

Prevention of Late Problems after Surgical Repair

- Mechanical problems

1. Significant pulmonary regurgitation

   Less aggressive approach and avoidance of a transannular patch

2. Right ventricular dilatation

   Prevent subsequent free PR

3. Restrictive right ventricle

   Protection of myocardial ischemia

Prevention of Late Problems after Surgical Repair

4. Aneurysmal dilatation of RVOT

   Minimize RVOT incision, size of the patch

5. Dilation of aortic root

   No data on the effect of beta blocking therapy

6. Left ventricular dysfunction

   Avoid prolonged cyanosis, myocardial protection

7. Endocarditis

   Life long protection against endocarditis

Prevention of Late Problems after Surgical Repair

- Electrical problems

1. Supraventricular arrhythmia

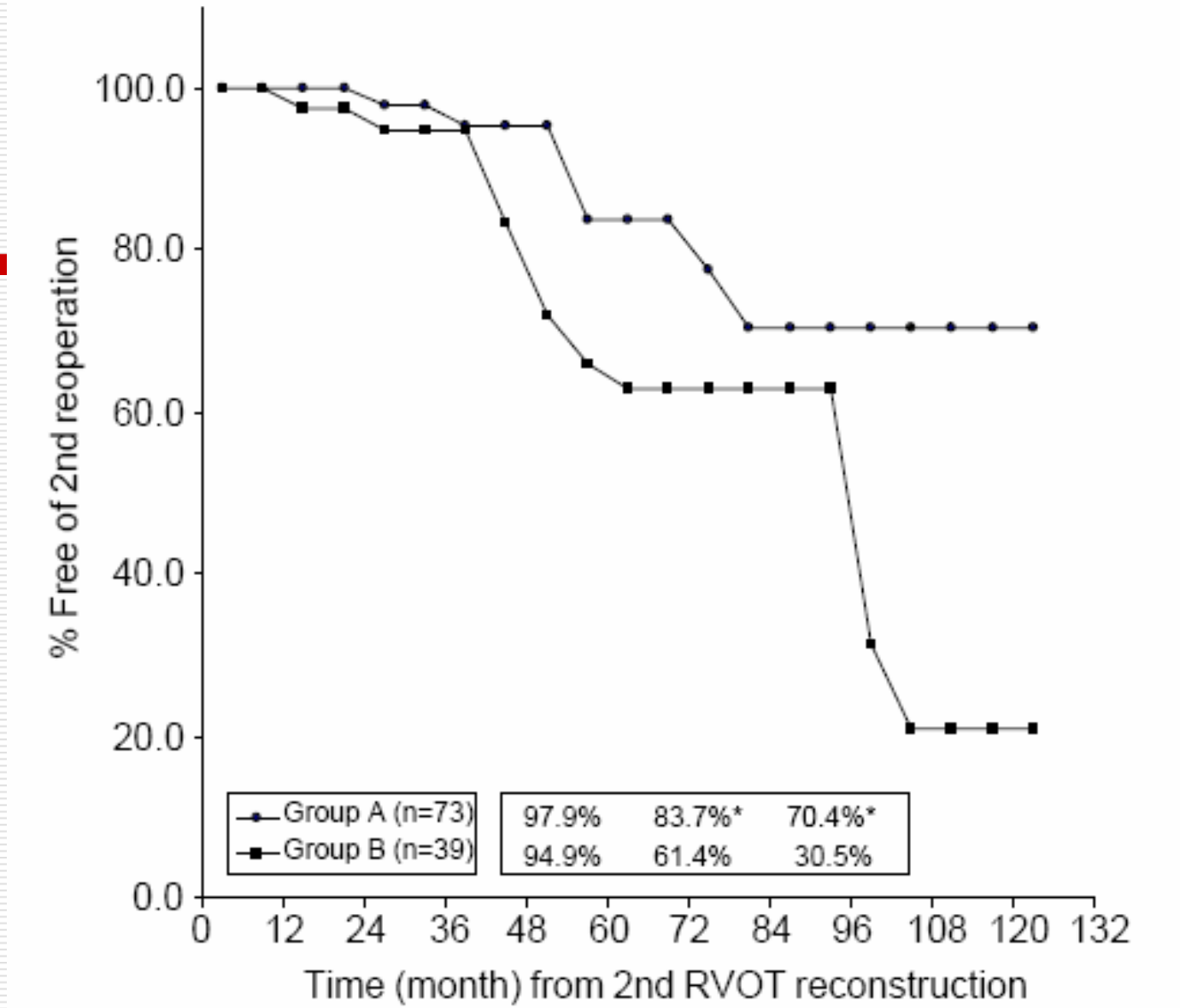
   Minimize atrial scar, preserve TV during VSD repair

2. Sustained ventricular tachycardia

   Minimize ventricular scar, avoid significant residual hemodynamic lesions

3. Sudden cardiac death

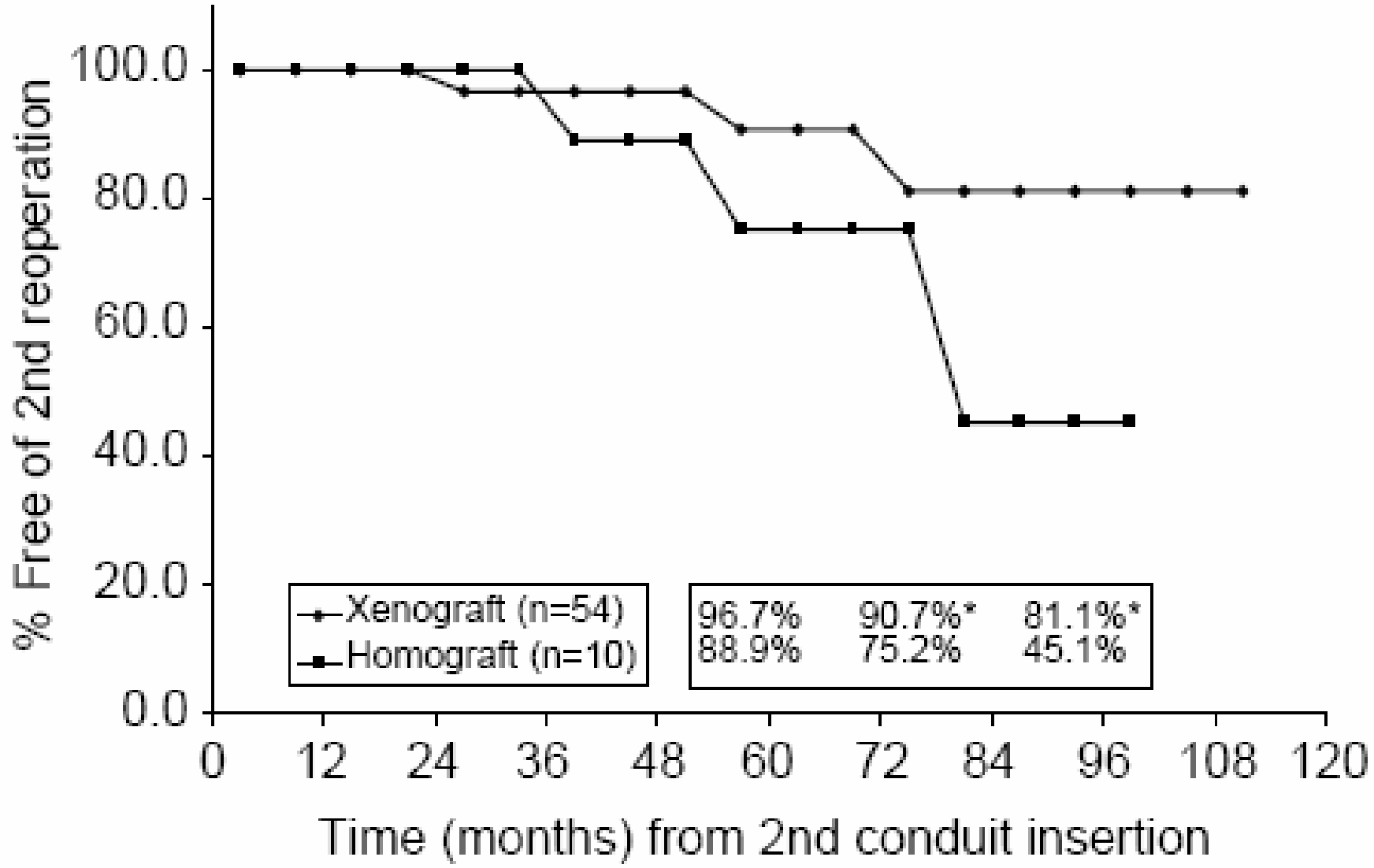
   AICD implantation



Group A: valved and non valved conduit

Group B: patch enlargement using posterior wall of previous conduit

Claude Planche: Euro Car-Thorac Surg 2005



Claude Planche: Euro Car-Thorac Surg 2005

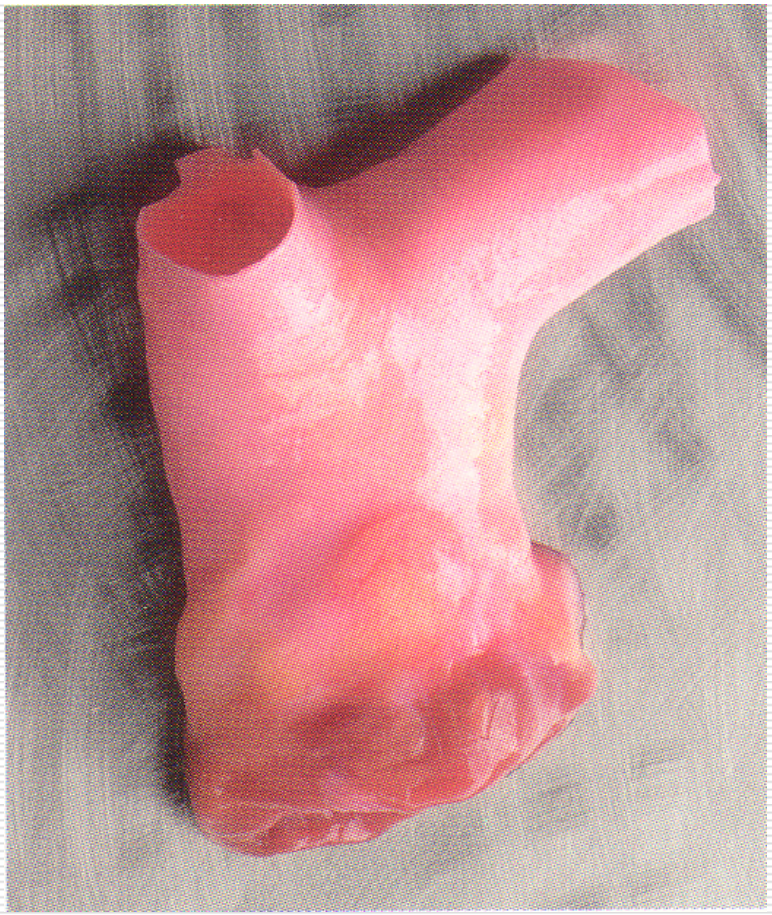
Attributes of the “Ideal” Right Ventricle-to-Pulmonary Artery Conduit

- Long-term patency
- Availability in a range of sizes
- Excellent handling characteristics
- Long-term valve function
- Growth potential
- Low cost
- Low infectious potential
- Non-thrombogenic

Problems with Current Conduit

- Obstruction inside the tube
- Fixed diameter- difficulty positioning
- Rapid calcification
- No potential growth

Cryopreserved Homograft



- 가장 많이 사용

Conduit of Choice

문제점:

- 작은 사이즈가 없고
- 공급자체가 적다.
- **Stenosis** 가 발생하는데

a. outgrowth 로 인하거나

b. size mismatching- unfavorable blood flow

c. Iimmune reaction,

d. aaccelerated calcium turn over in children

Pulmonary Position Cryopreserved Homograft

: *Yonsei Experience for 7 years*

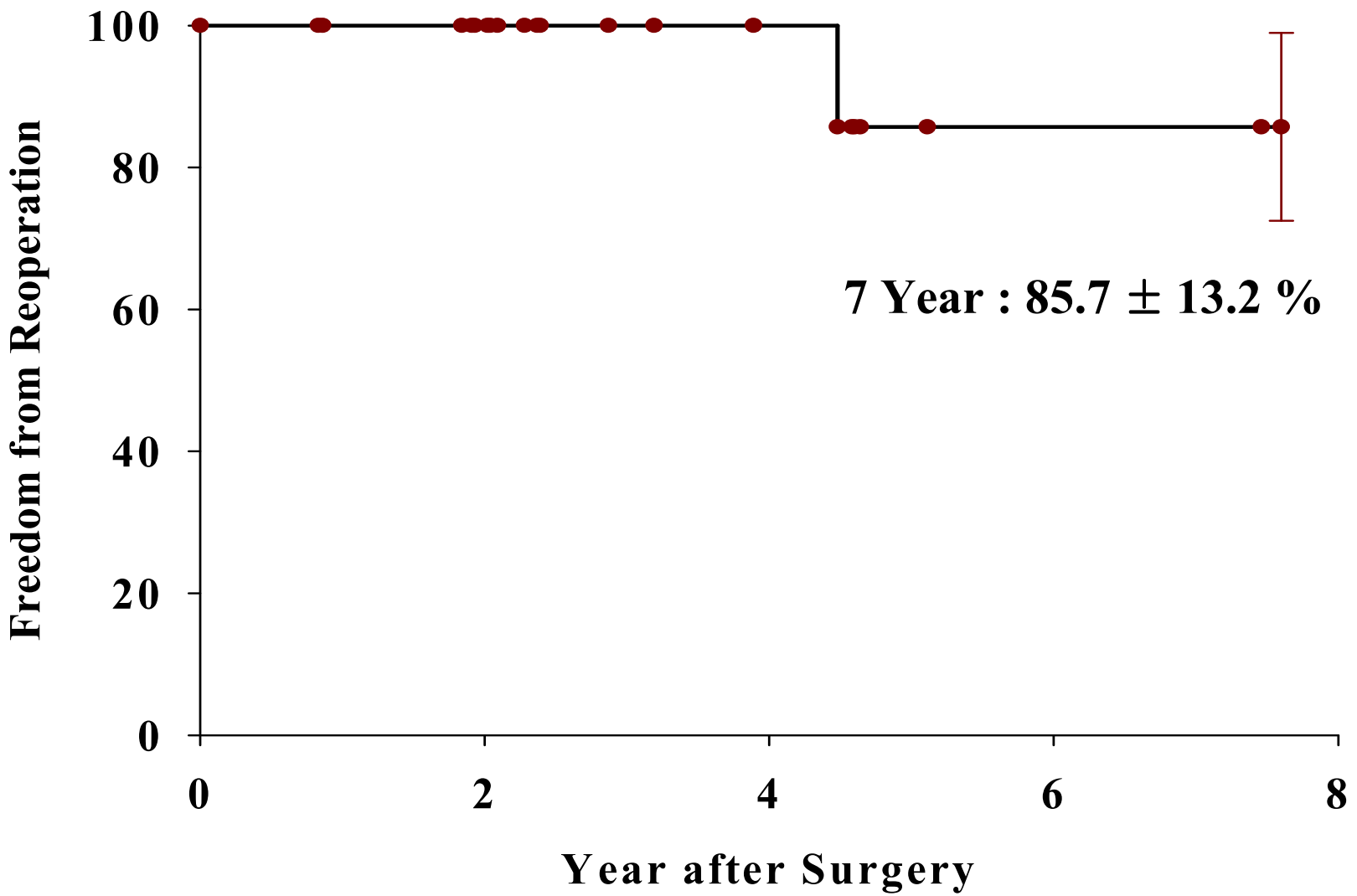
Young-Hwan Park, Young-Nam Youn, Han Ki Park

Department of Thoracic & Cardiovascular Surgery
Severance Hospital, Human Tissue Bank
Yonsei University College of Medicine
Seoul, Korea

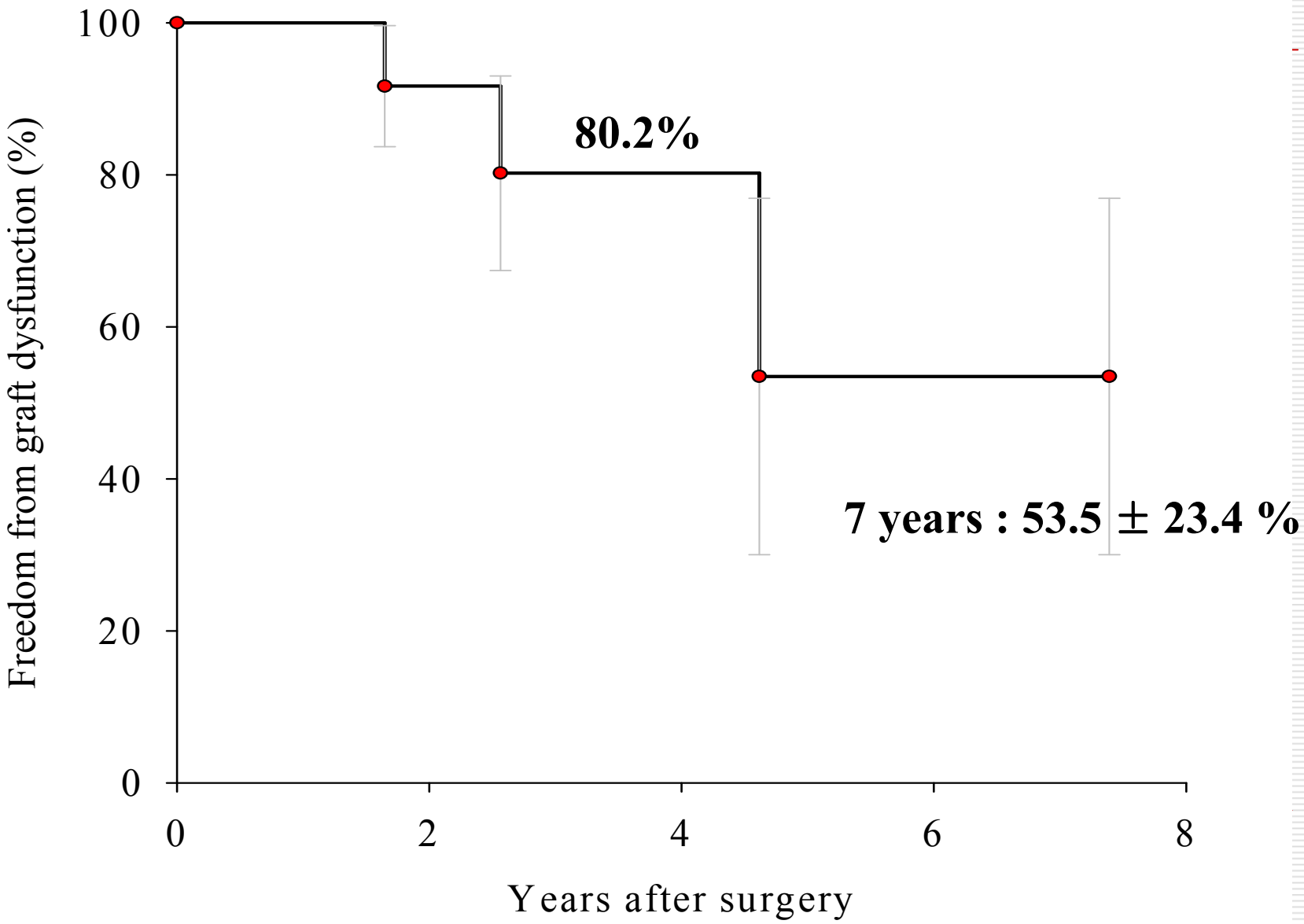
Patients and Methods

	N = 21	
Period	July, 1998 to April, 2005	
Age	0.9 ~ 43.3 years (mean : 21.5 ± 11.7)	
Sex	M : F = 10 : 11	
Reason for operation	PI After TOF total correction	13(61.9%)
	After Rastelli operaton	5 (23.8%)
	After DORV total correction	2 (9.5%)
	For Ross operation (SBE, AR)	1 (4.8%)

Freedom from reoperation



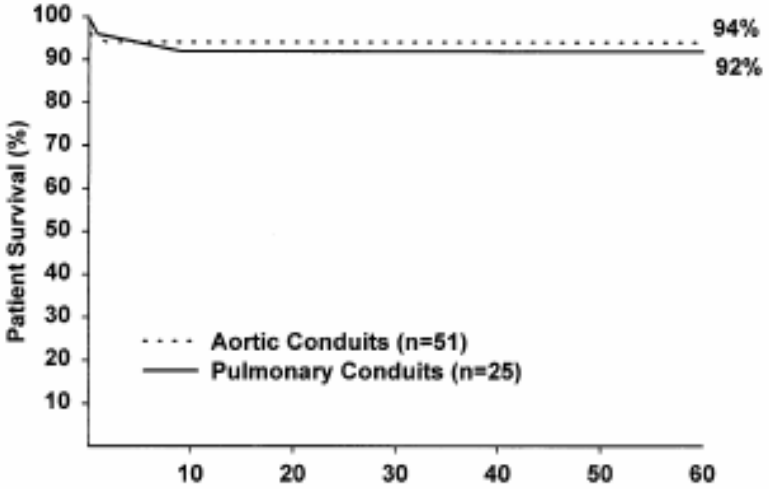
Freedom from Graft Dysfunction

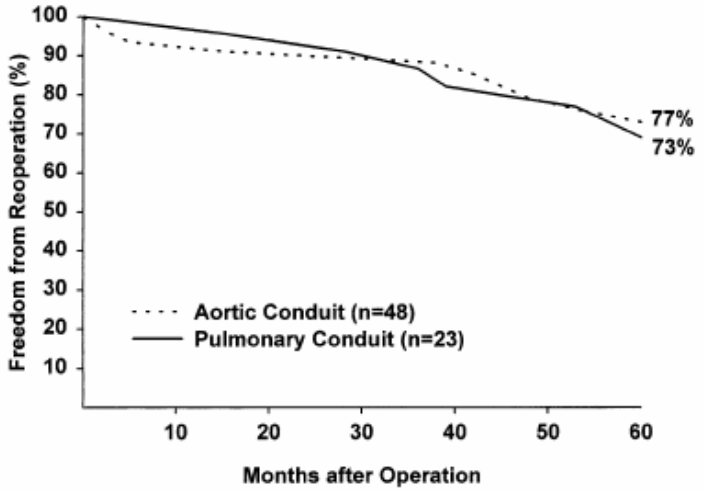


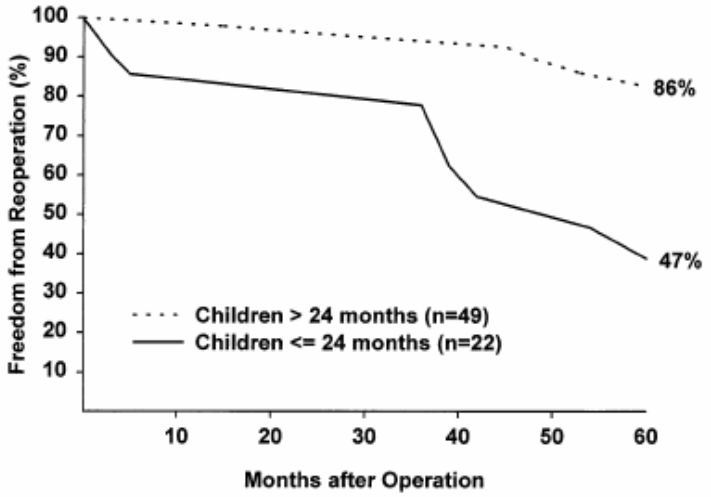
Intermediate Follow-up of Right Ventricular Outflow Tract Reconstruction With Allograft Conduits

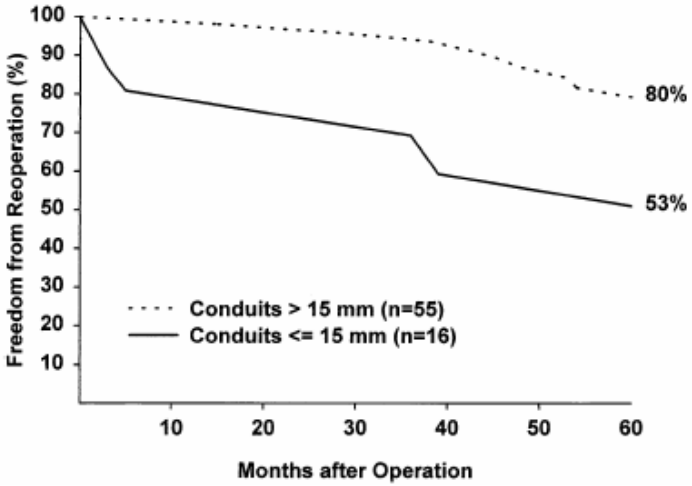
Jacques G. LeBlanc, MD, Jennifer L. Russell, MD, Suvro S. Sett, MD, and James E. Potts, PhD

Division of Cardiovascular and Thoracic Surgery, British Columbia's Children's Hospital, Vancouver, Canada







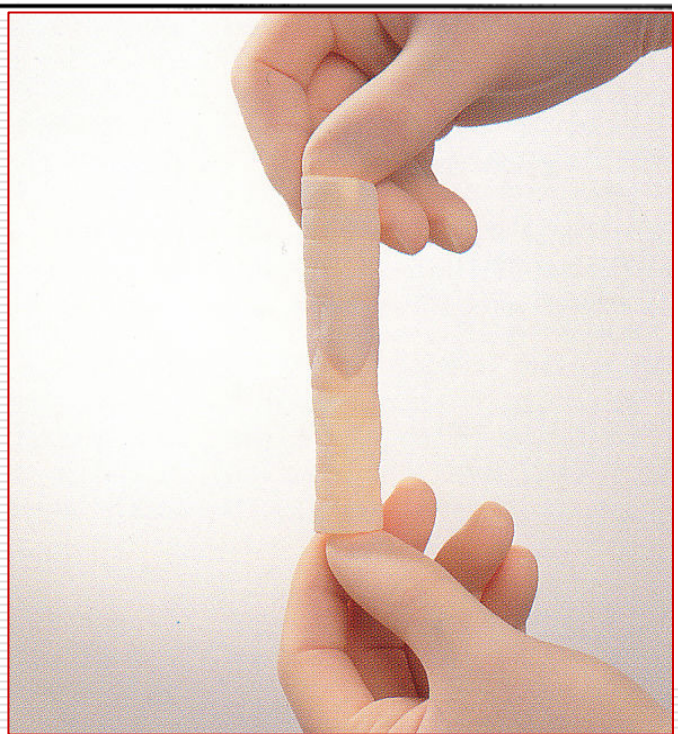


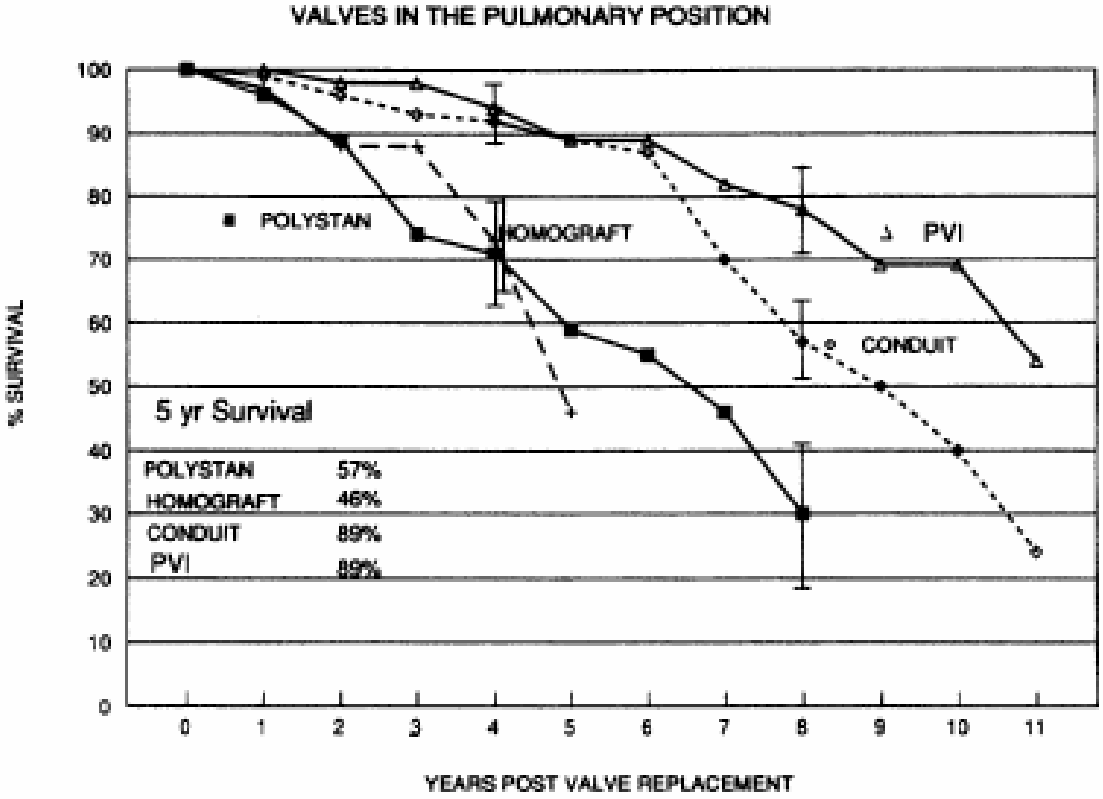
Surgical Connections From Ventricle to Pulmonary Artery

Comparison of Four Types of Valved Implants

Anees J. Razzouk, MD; William G. Williams, MD; David C. Cleveland, MD; John G. Coles, MD; Ivan M. Rebeyka, MD; George A. Trusler, MD; and Robert M. Freedom, MD

Valve type	No. of patients	No. of deaths	5-Year survival	
			%	No. at risk
Polystan conduit	47	19	64±7	23
Homograft conduit	178	37	77±3	7
Valved Dacron conduit	126	52	61±4	61
Pulmonary valve implant	106	14	87±3.9	35

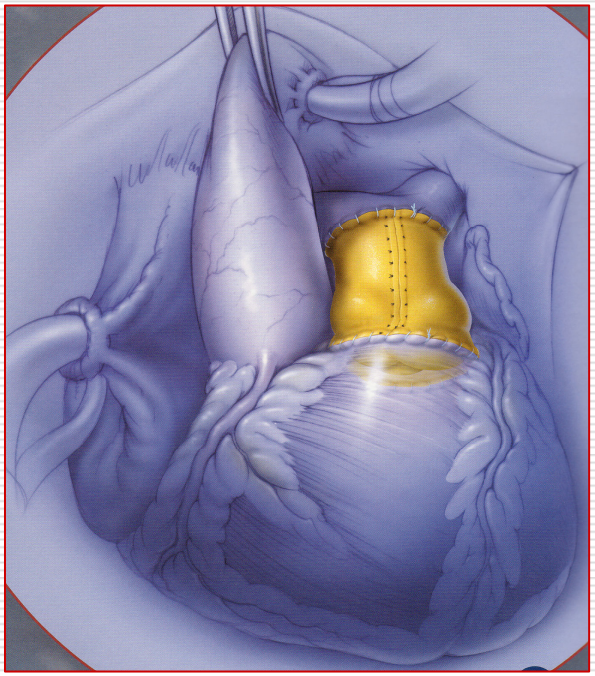




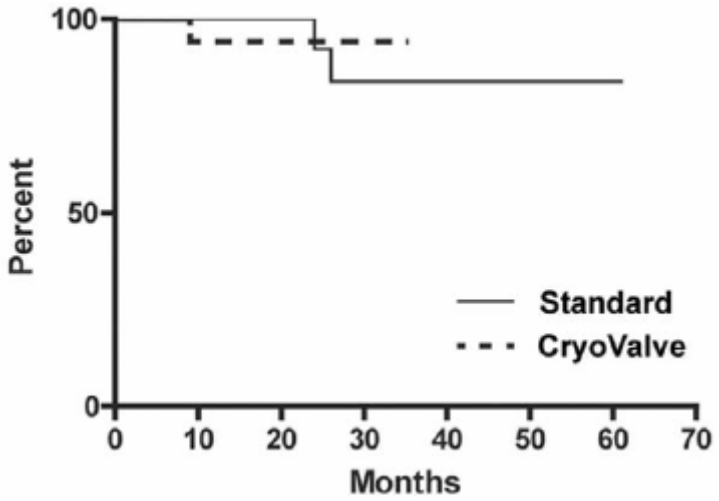
Superior Durability of Synergraft Pulmonary Allografts Compared With Standard Cryopreserved Allografts

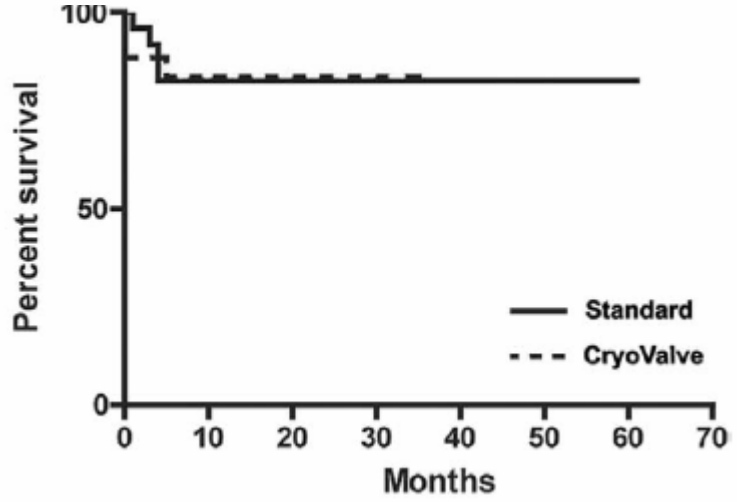
Zarry Tavakkol, MD, Sarah Gelehrter, MD, Caren S. Goldberg, MD, MS, Edward L. Bove, MD, Eric J. Devaney, MD, and Richard G. Ohye, MD

Department of Surgery, University of Washington, Seattle, Washington; Departments of Pediatrics and Communicable Diseases, and Surgery, University of Michigan Medical School, Ann Arbor, Michigan



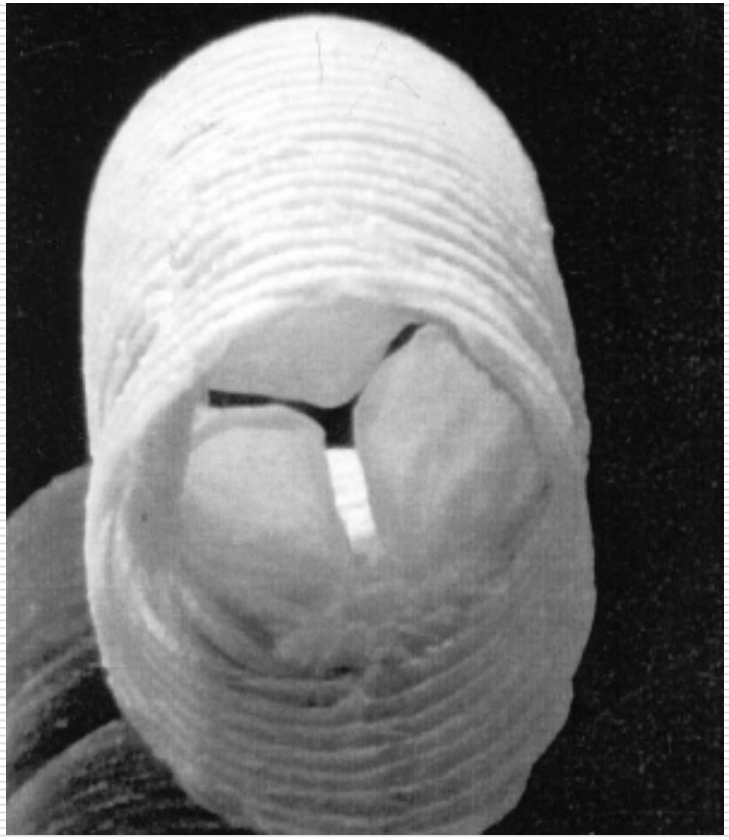
Glutaraldehyde Treated Porcine Valve(Synergraft By Cryolife.co.)

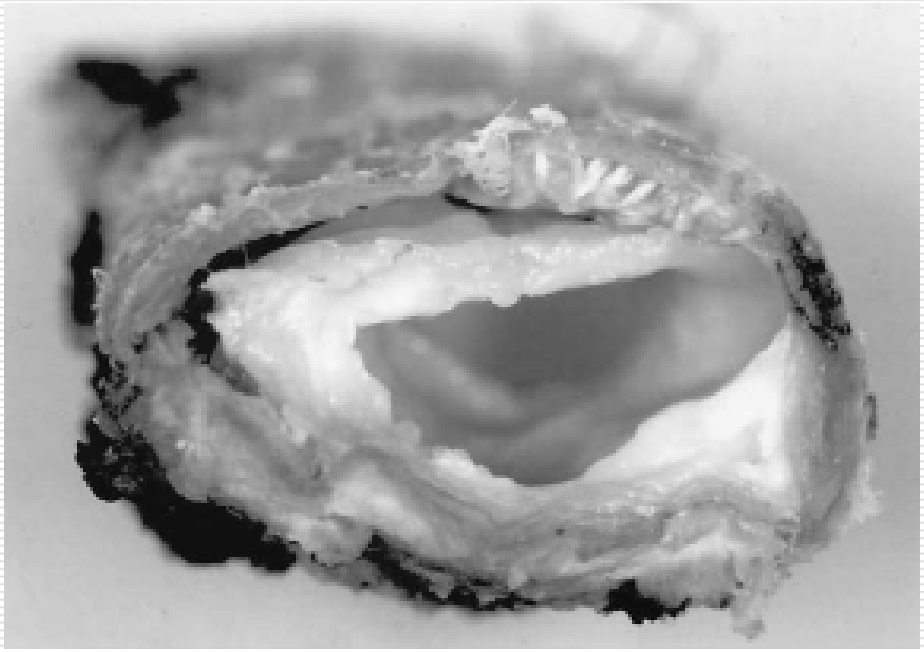




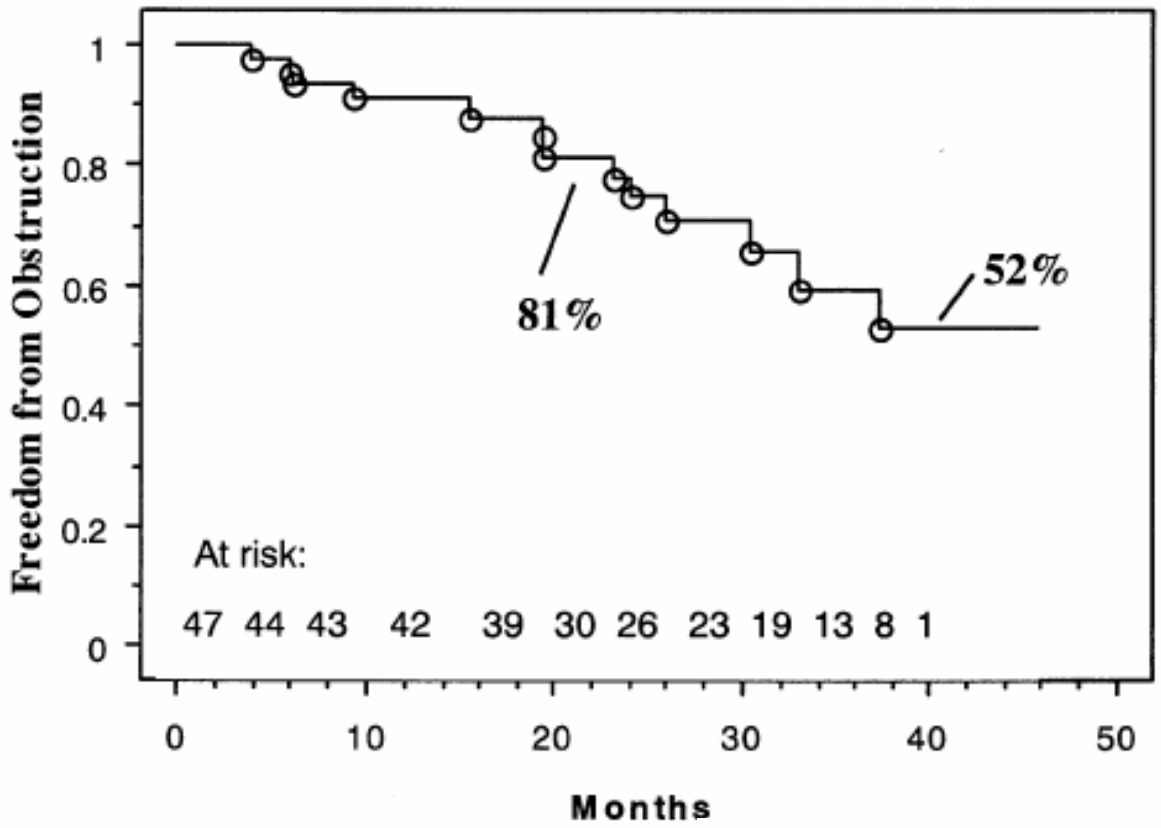
Intermediate Follow-Up of a Composite Stentless Porcine Valved Conduit of Bovine Pericardium in the Pulmonary Circulation

Bertrand Aupècle, MD, Alain Serraf, MD, PhD, Emre Belli, MD,
Siamak Mohammadi, MD, François Lacour-Gayet, MD, Paul Fornes, MD,
and Claude Planché, MD

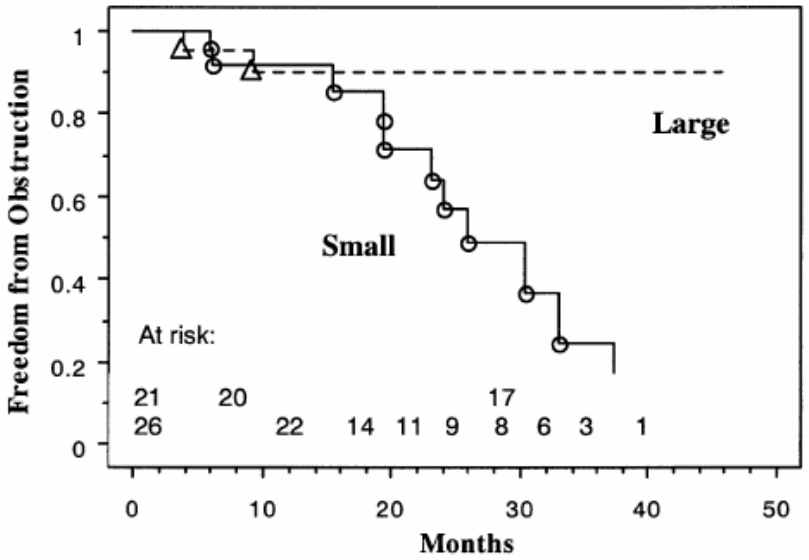


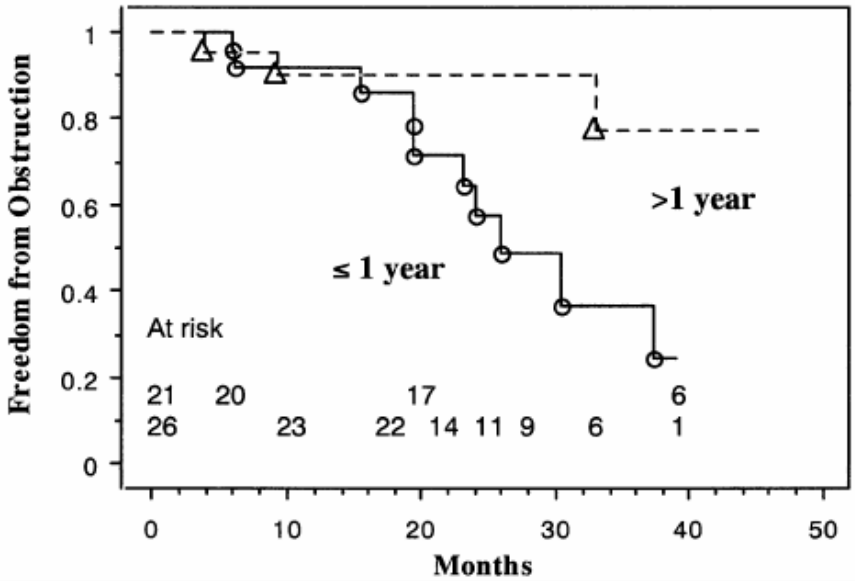


Composite Stentless Porcine Valved Conduit of Bovine Pericardium(LabCor)


Freedom from Obstruction
1
0.8
0.6
0.4
0.2
0
81%
52%
At risk:
47 44 43 42 39 30 26 23 19 13 8 1
0 10 20 30 40 50
Months

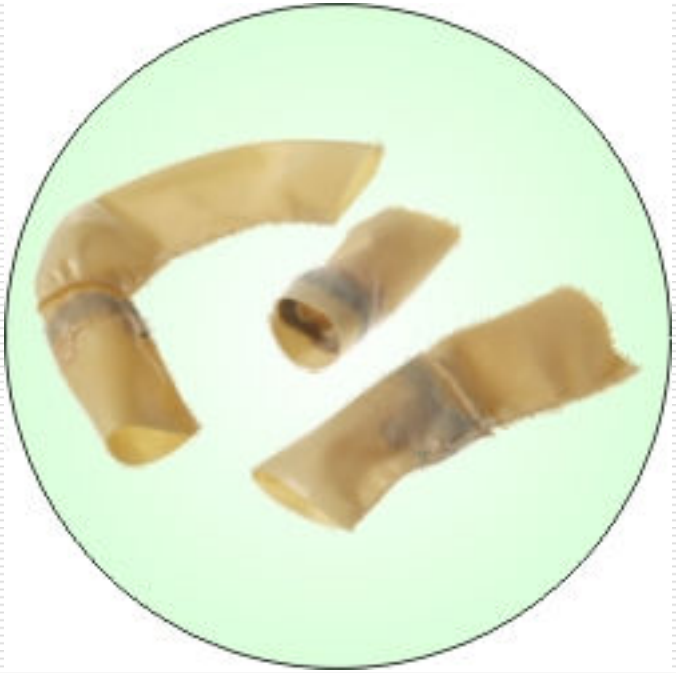
55명
27개월


Freedom from Obstruction
1
0.8
0.6
0.4
0.2
0
Large
Small
At risk:
21 20 17
26 22 14 11 9 8 6 3 1
0 10 20 30 40 50
Months

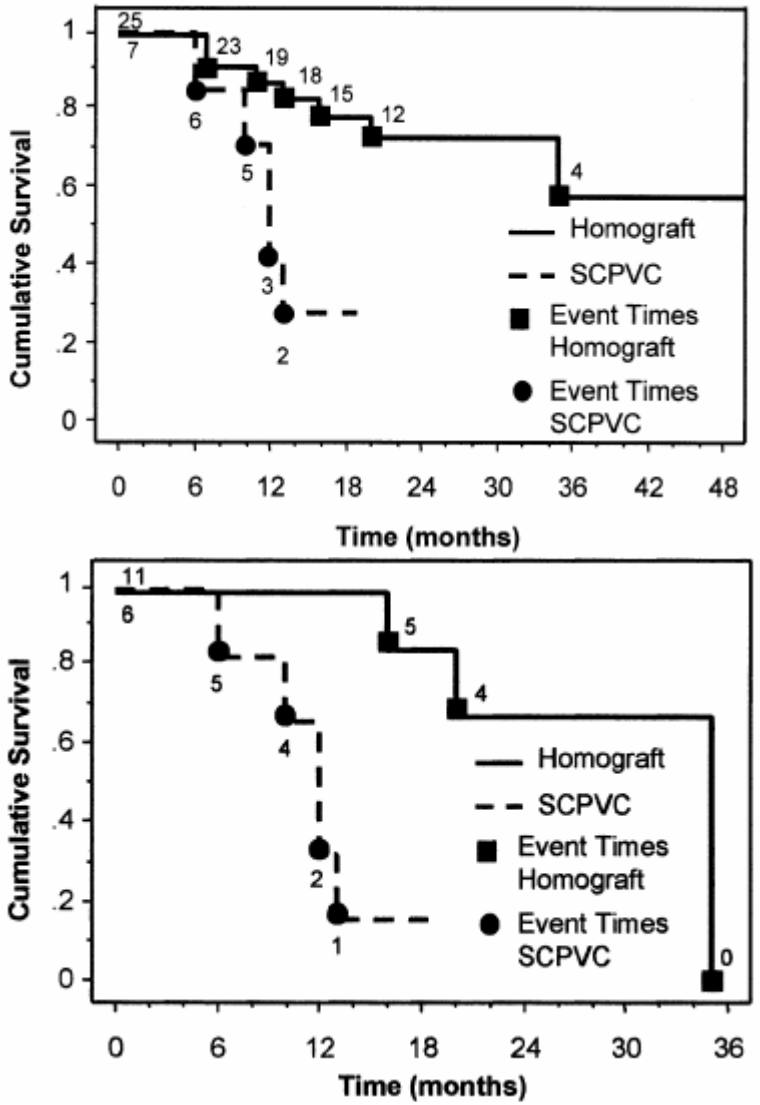

Freedom from Obstruction
1
0.8
0.6
0.4
0.2
0
>1 year
≤ 1 year
At risk
21 20 17 6
26 23 22 14 11 9 6 1
0 10 20 30 40 50
Months

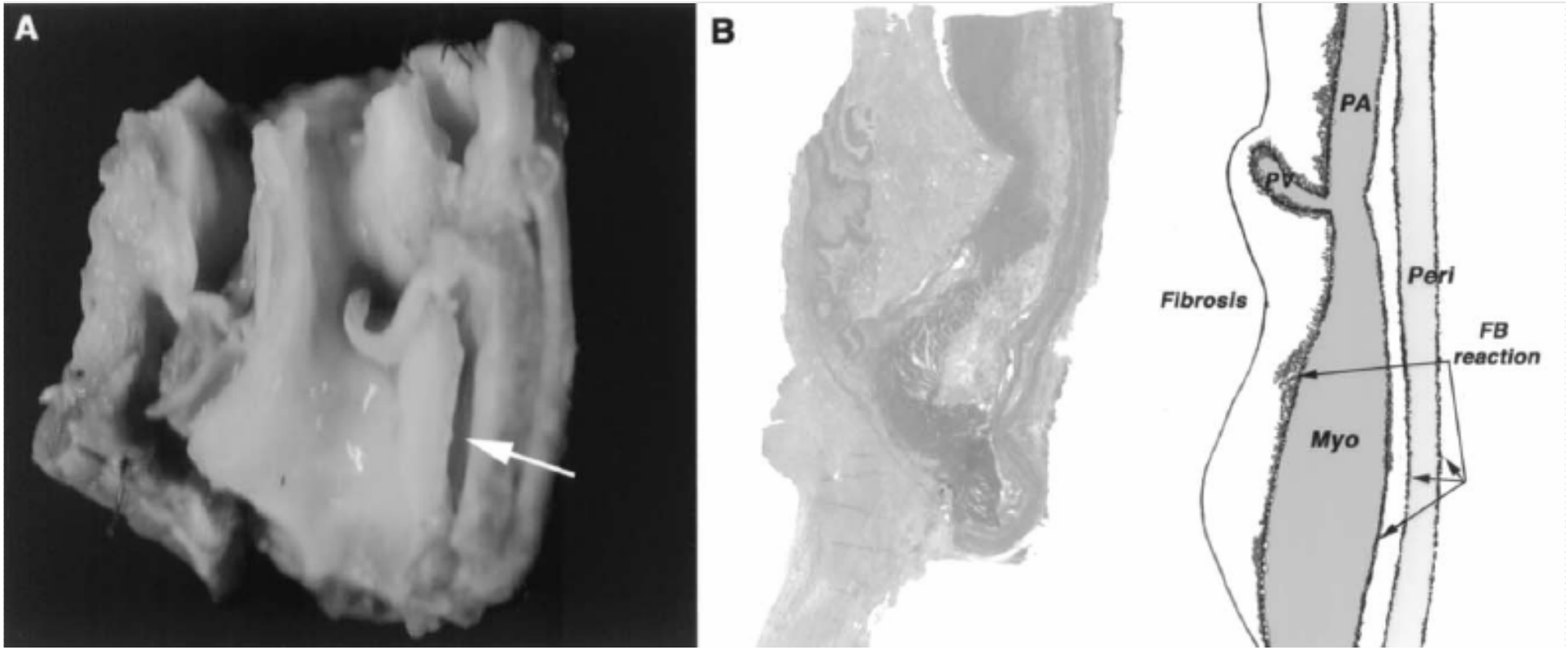
Early Failure of the Shelhigh Pulmonary Valve Conduit in Infants

Jeffrey M. Pearl, MD, David S. Cooper, MD, Kevin E. Bove, MD, and Peter B. Manning, MD



Shelhigh Bovine tube with a stentless porcine pulmonary valve
treated by anti-calcification agent

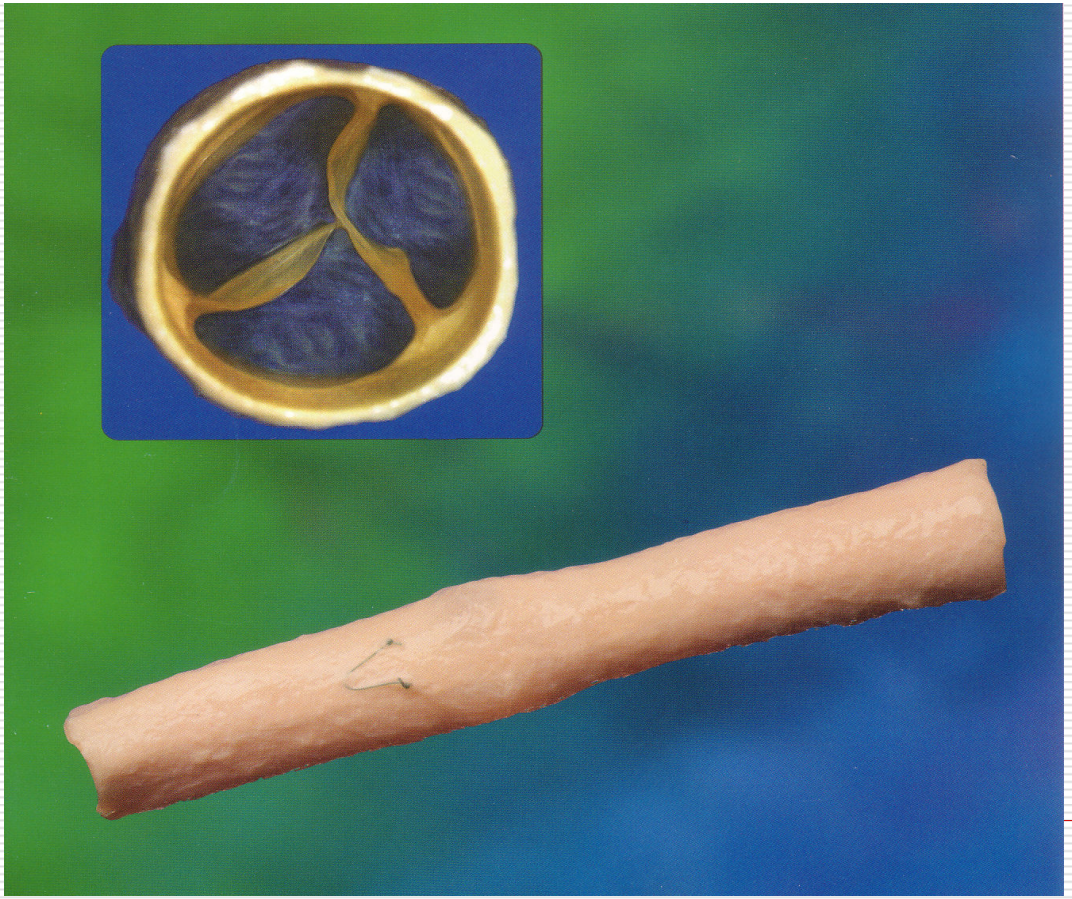



A
B
PA
PV
Peri
Fibrosis
FB
reaction
Myo

Adverse Mid-Term Outcome Following RVOT Reconstruction Using the Contegra Valved Bovine Jugular Vein

Volkhard Göber, MD, Pascal Berdat, MD, Mladen Pavlovic, MD,
Jean-Pierre Pfammatter, MD, and Thierry P. Carrel, MD

Clinic for Cardiovascular Surgery and Division of Pediatric Cardiology, University Hospital, Berne, Switzerland

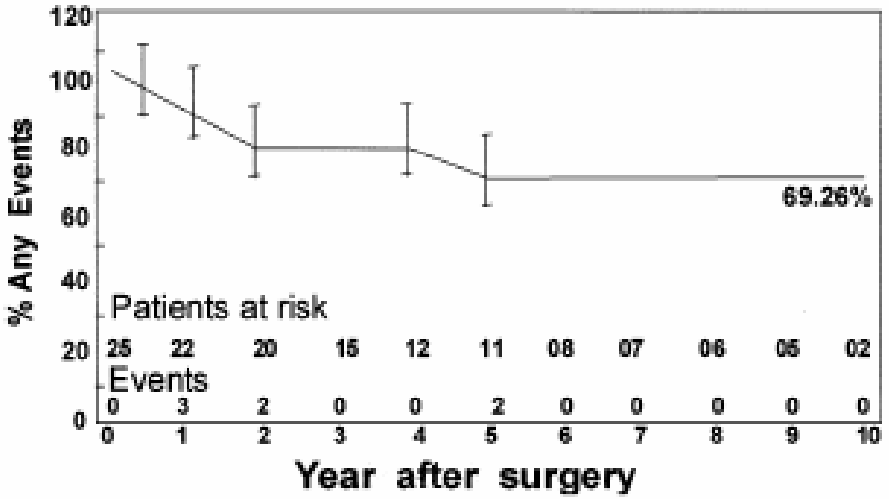


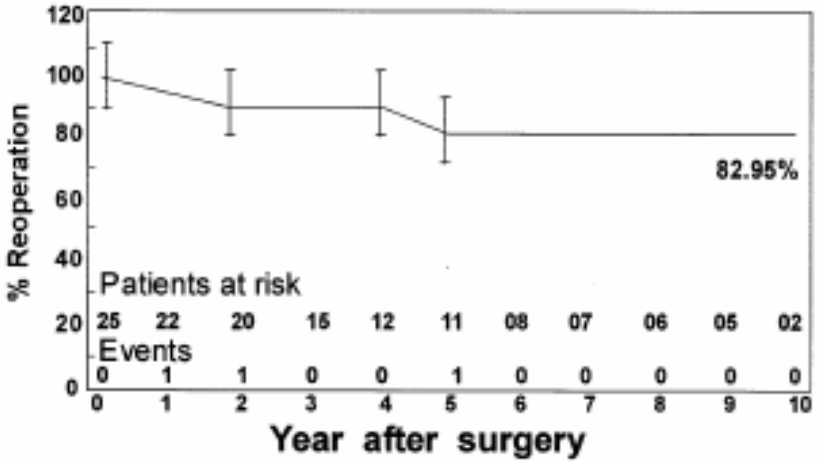
Decellularized Bovine
Jugular Vein Valved Conduit
(Contegra by Medtronic)

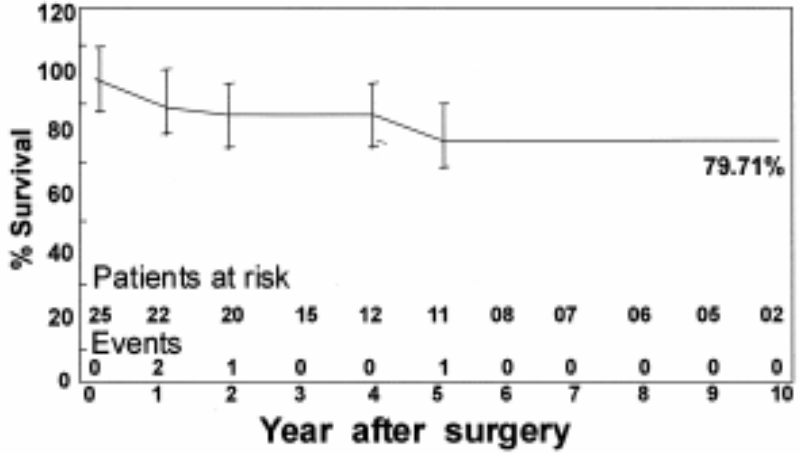
Porcine Stentless Valve/Bovine Pericardial Conduit for Right Ventricle to Pulmonary Artery

Mario O. P. Vrandecic, MD, Fernando A. Fantini, MD, Bayard F. Gontijo, MD, Cristiane Nunes Martins, MD, and Erika Vrandecic, MD

Biocor Institute, Belo Horizonte, Brazil





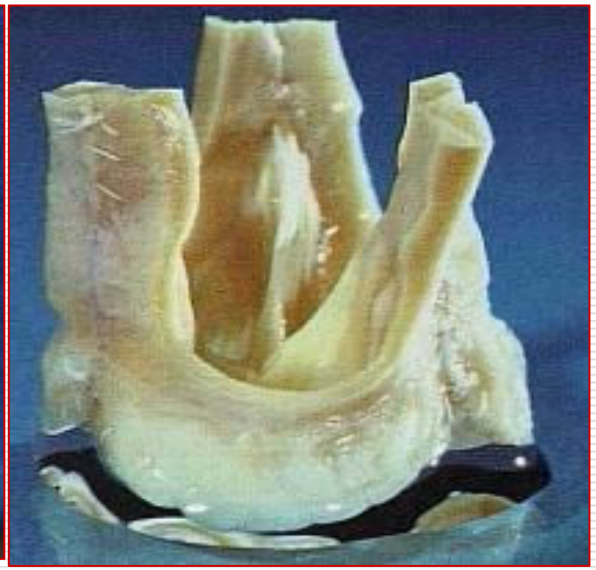


Bovine pericardial conduit with an aortic 3 porcine leaflet valve (BioCor)

Results With the Freestyle Porcine Aortic Root for Right Ventricular Outflow Tract Reconstruction in Children

Kirk R. Kanter, MD, Derek A. Fyfe, MD, PhD, William T. Mahle, MD, Joseph M. Forbess, MD, and Paul M. Kirshbom, MD

Division of Cardiothoracic Surgery, Department of Surgery, and Division of Pediatric Cardiology, Emory University School of Medicine, Atlanta, Georgia



Medtronic

Stentless Freestyle® Valve

Pulmonary valve replacement with a mechanical prosthesis. Promising results of 28 procedures in patients with congenital heart disease☆

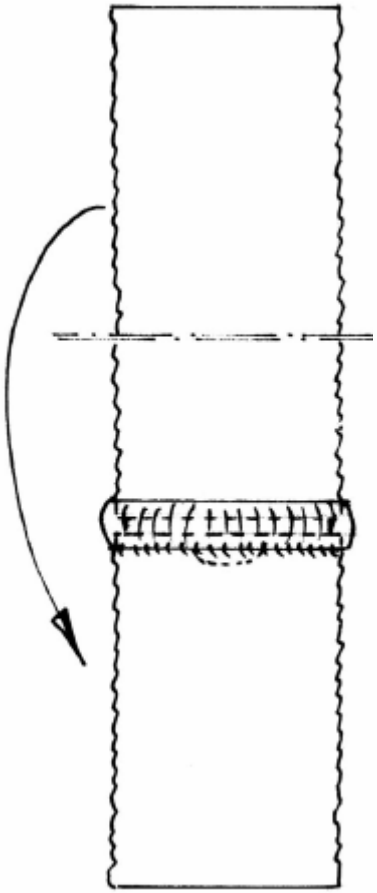
Tjalling W. Waterbolk [a,*], Elke S. Hoendermis [b], Inez J. den Hamer [a], Tjark Ebels [a]

Author	Year	mPVR	Age	Failure	Interval/follow-up	Anticoagulant therapy
Ilbawi et al. [8]	1986	8	2–10	6	1–6 months after PVR	Salicylates and dipyramidol
Miyamura et al. [9]	1987	5	13–30	1	10 months after PVR	'Adequate' warfarin therapy
Kiyota et al. [10]	1992	11	?	3	?	?
Rosti et al. [11]	1998	8	6–17	0	3 months–9 years	Coumadine (INR 2.0)
Nurozler and Bradley [12]	2002	5	1–20	4	1–18 years	Aspirin[a]
Iscan et al. [13]	2003	1	10	0	15 years	None
Reiss et al. [14]	2003	32	3–43	3	Mean follow-up 6.5 years	Dicoumarol (INR ?)
Haas et al. [15]	2005	14	10–38	0	1–5 years	Dicoumarol (INR 3–4.5)

Anticoagulation
Tissue ingrowth

Is There a Role for Mechanical Valved Conduits in the Pulmonary Position?

Felix Haas, MD, Christian Schreiber, MD, Jürgen Hörer, MD, Martin Kostolny, MD, Klaus Holper, MD, and Rüdiger Lange, MD

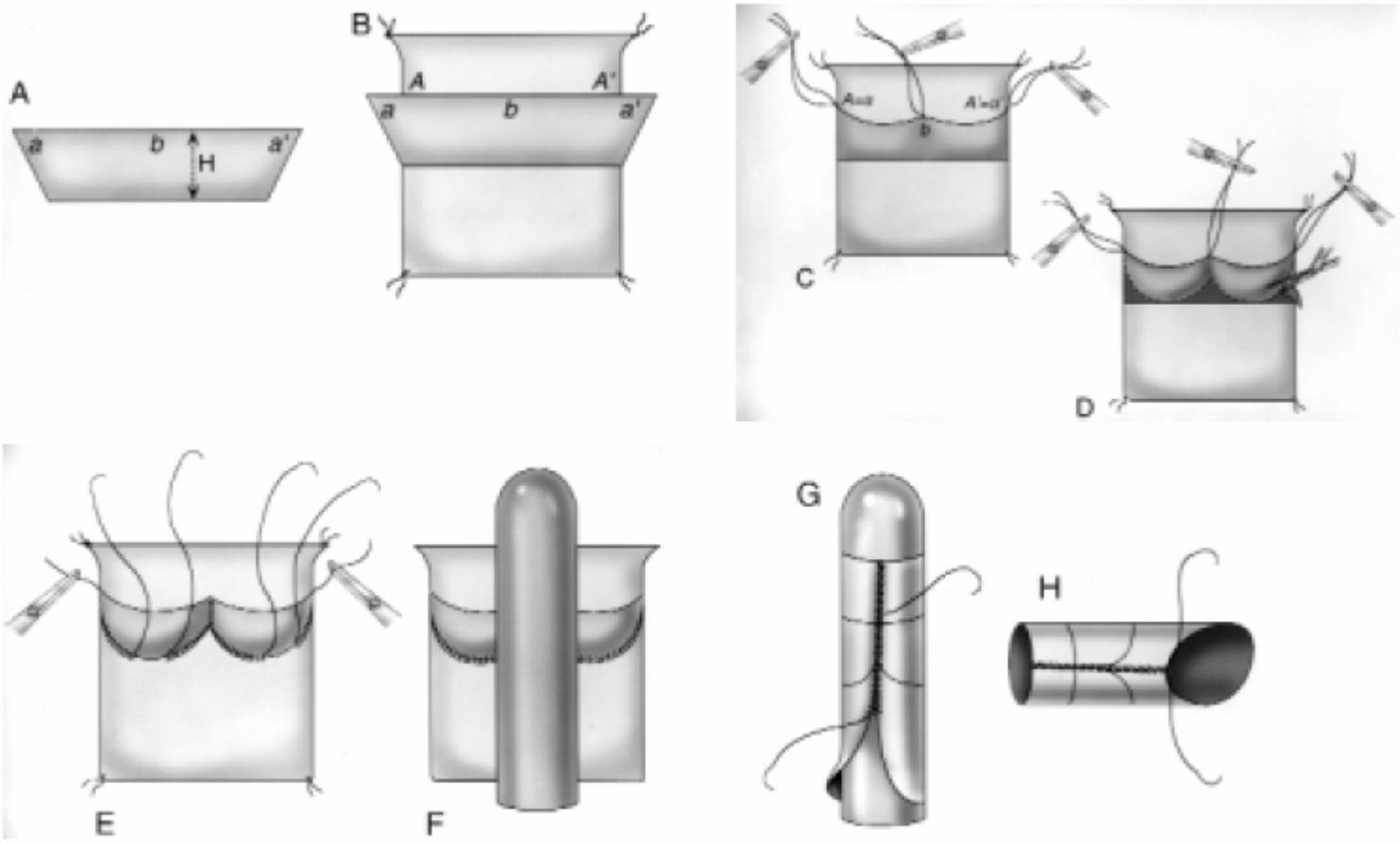


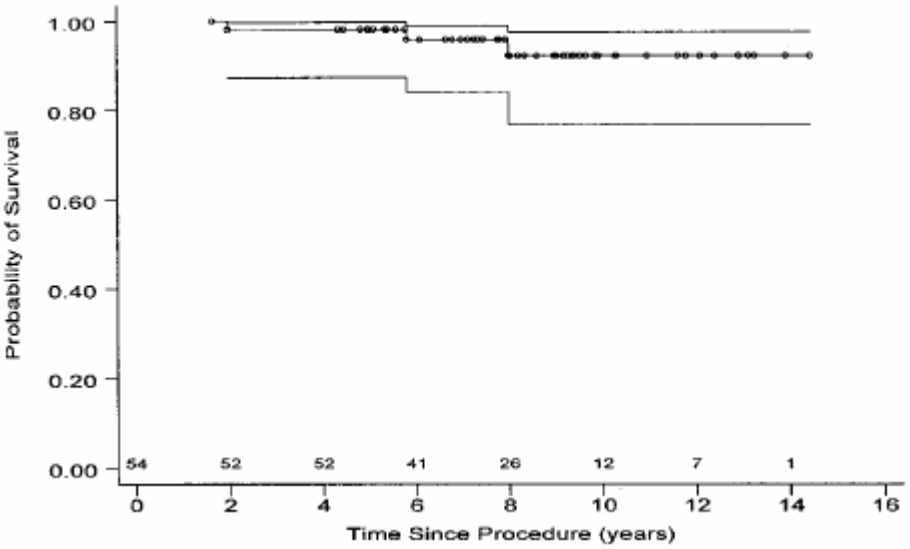
Older age to Ovoid outgrowth
Multiple operation-increased reop-morbidity
Current use of anticoagulants
Compliance with anticoag. Tx

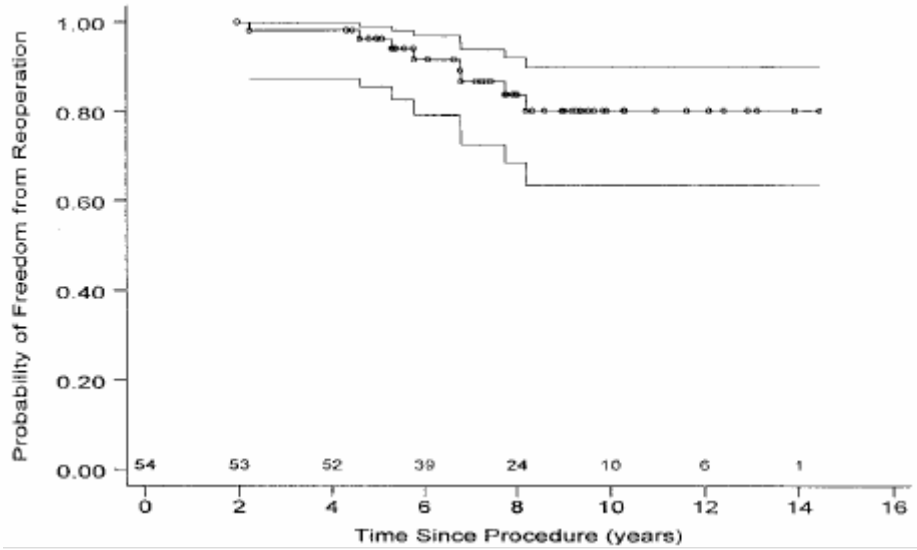
FIVE- TO FIFTEEN-YEAR FOLLOW-UP OF FRESH AUTOLOGOUS PERICARDIAL VALVED CONDUITS

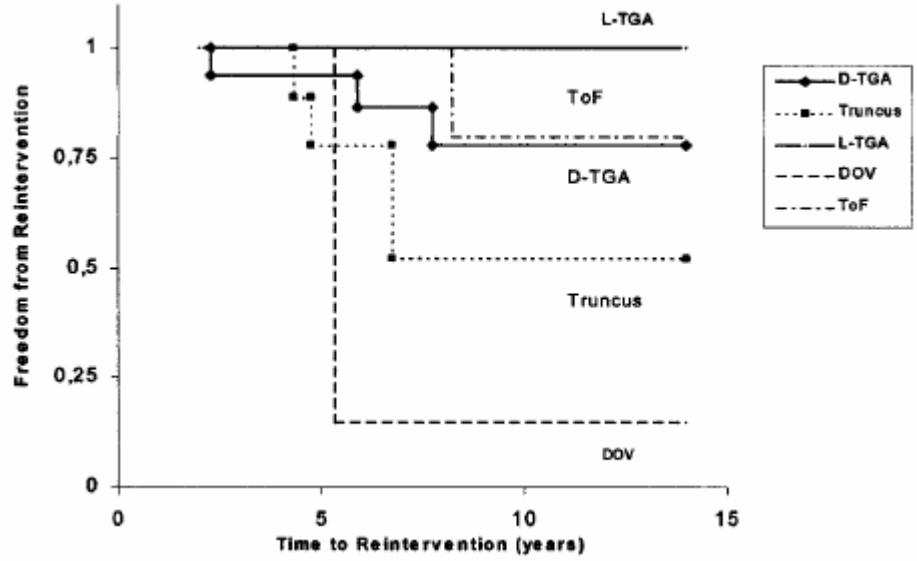
Andrés J. Schlichter, MD[a,b]
Christian Kreutzer, MD[a,b*]
Rita de Cassia Mayorquim, MD[b]
Jorge L. Simon, MD[a,b]
Maria I. Román, MD[a,b]
Haydee Vazquez, MD[a]
Eduardo A. Kreutzer, MD[a,b]
Guillermo O. Kreutzer, MD[a,b]

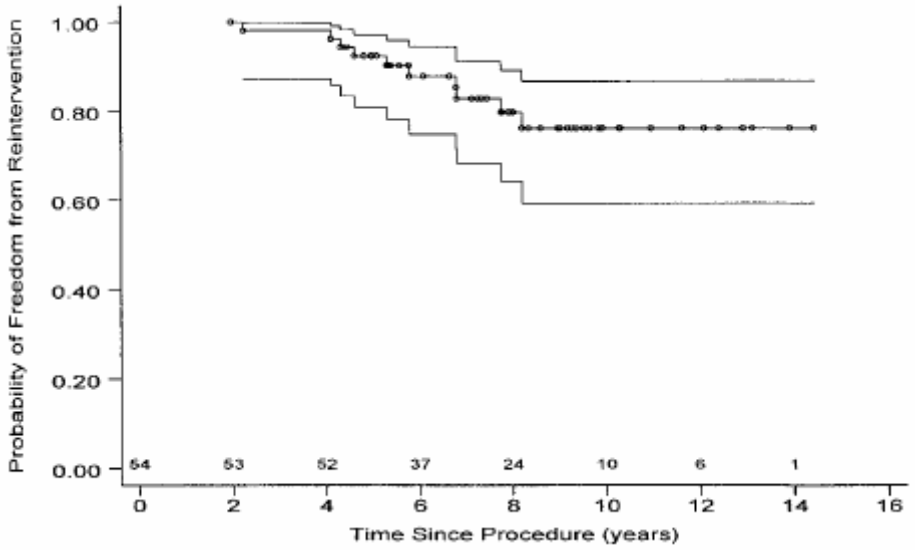
Autologous Pericardial Tube



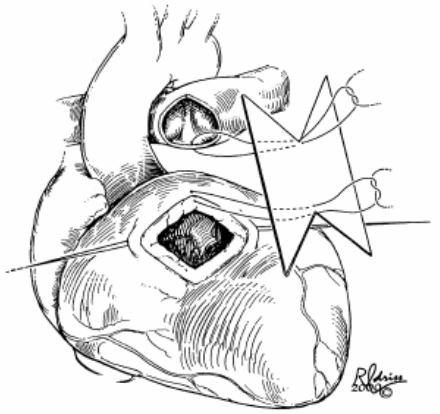

Probability of Survival
1.00
0.80
0.60
0.40
0.20
0.00
54 52 52 41 26 12 7 1
0 2 4 6 8 10 12 14 16
Time Since Procedure (years)

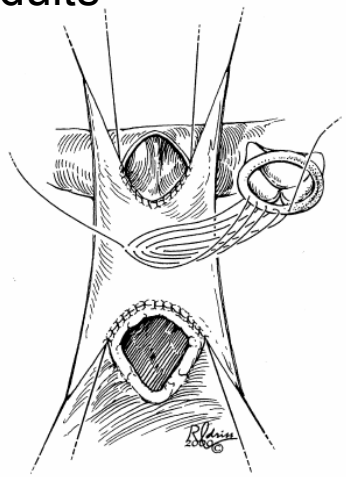

Probability of Freedom from Reoperation
1.00
0.80
0.60
0.40
0.20
0.00
54 53 52 39 24 10 6 1
0 2 4 6 8 10 12 14 16
Time Since Procedure (years)

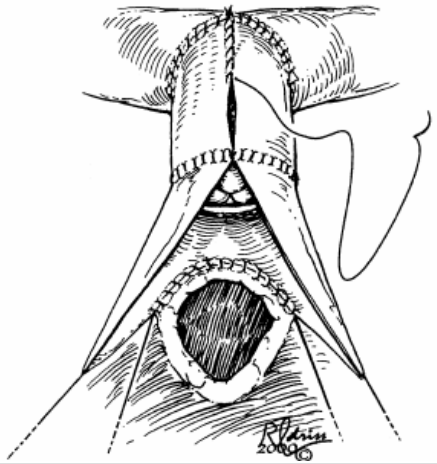

Freedom from Reintervention
1
0,75
0,5
0,25
0
0 5 10 15
Time to Reintervention (years)
L-TGA
ToF
D-TGA
Truncus
DOV
D-TGA
Truncus
L-TGA
DOV
ToF

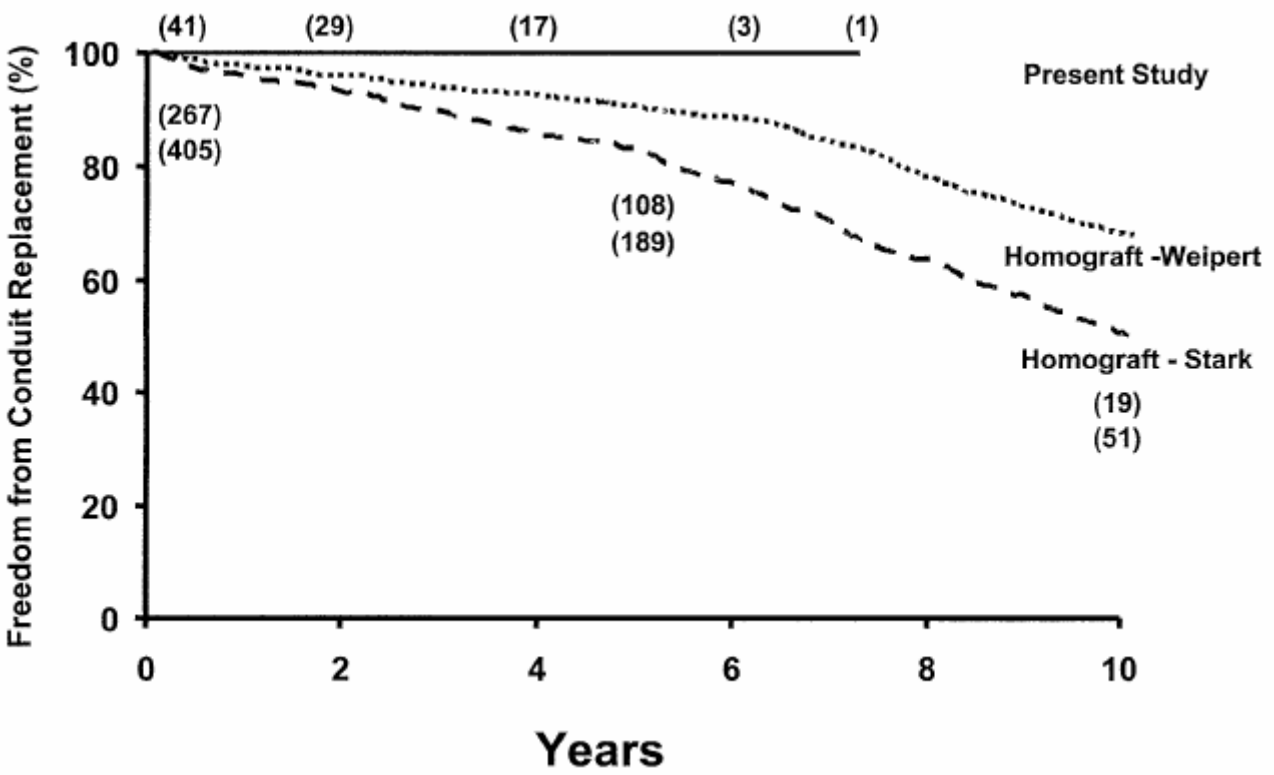

Probability of Freedom from Reintervention
1.00
0.80
0.60
0.40
0.20
0.00
54 53 52 37 24 10 6 1
0 2 4 6 8 10 12 14 16
Time Since Procedure (years)

Pericardial Tissue Valve and Gortex conduits









Ilbawi, Ann Thorac Surg. 2002

Long-term outcome of right ventricular outflow tract reconstruction using a handmade tri-leaflet conduit☆

Masahiro Koh, Toshikatsu Yagihara*, Hideki Uemura, Koji Kagisaki, Ikuo Hagino, Toru Ishizaka, Soichiro Kitamura

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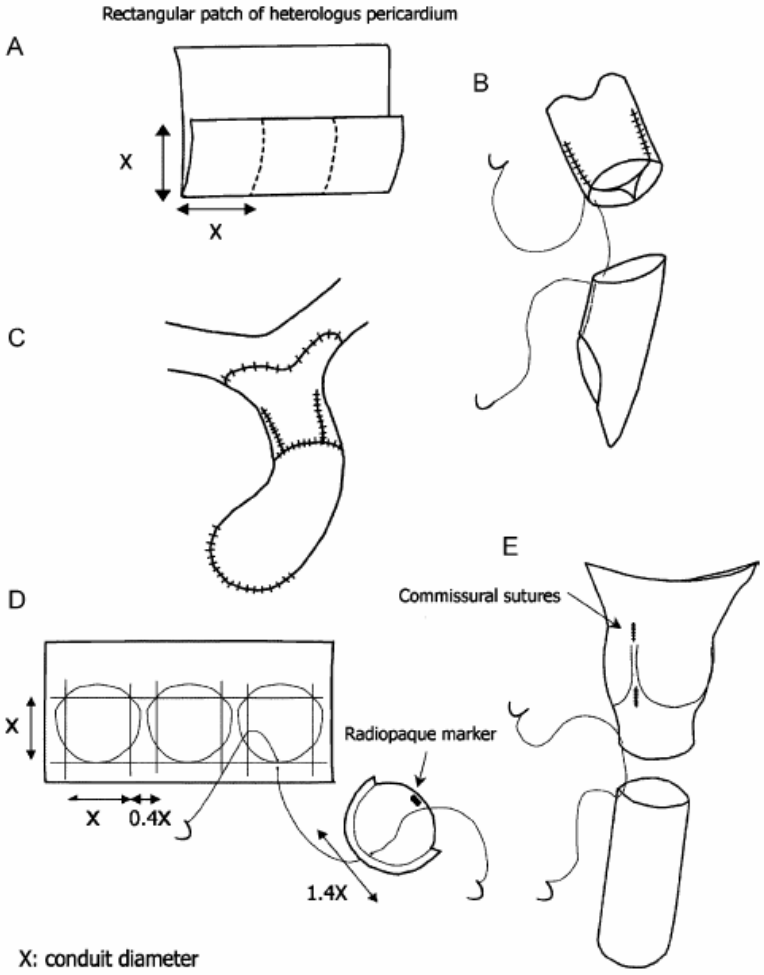
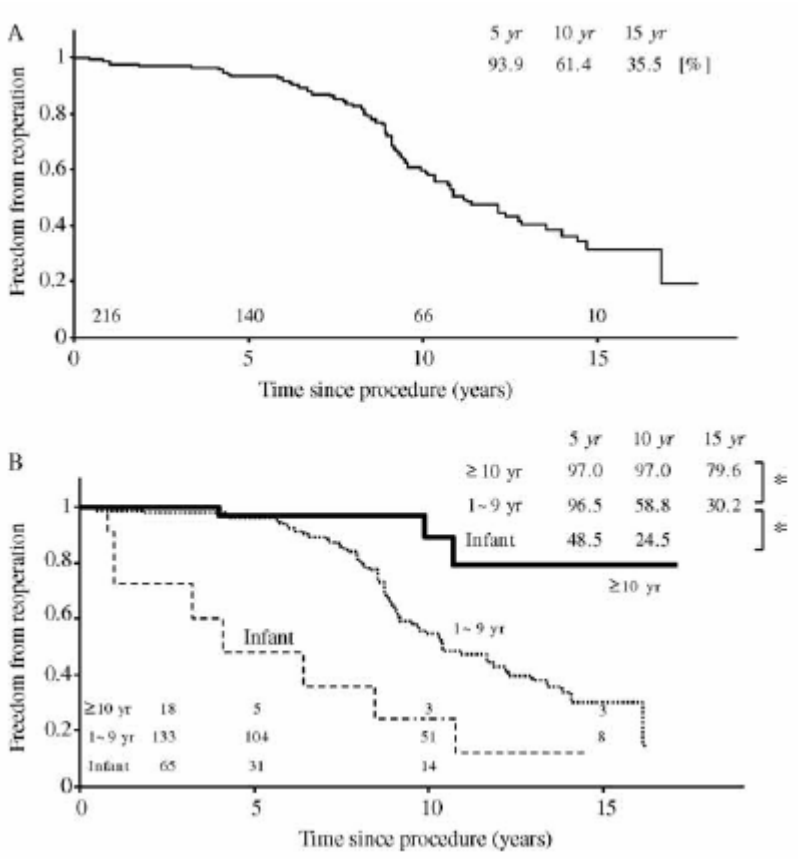
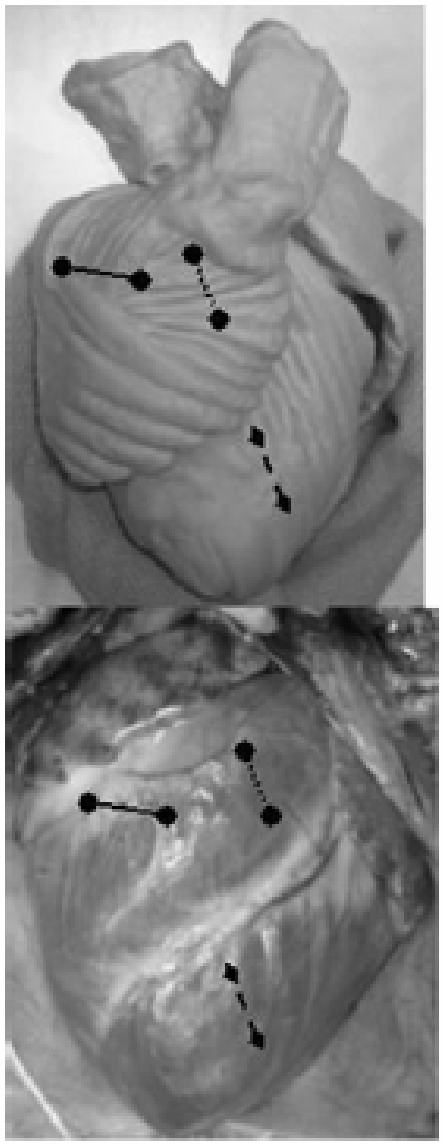
Received 5 October 2004; received in revised form 17 January 2005; accepted 25 January 2005; Available online 11 March 2005







(a)

Right Ventricle / fiber selection

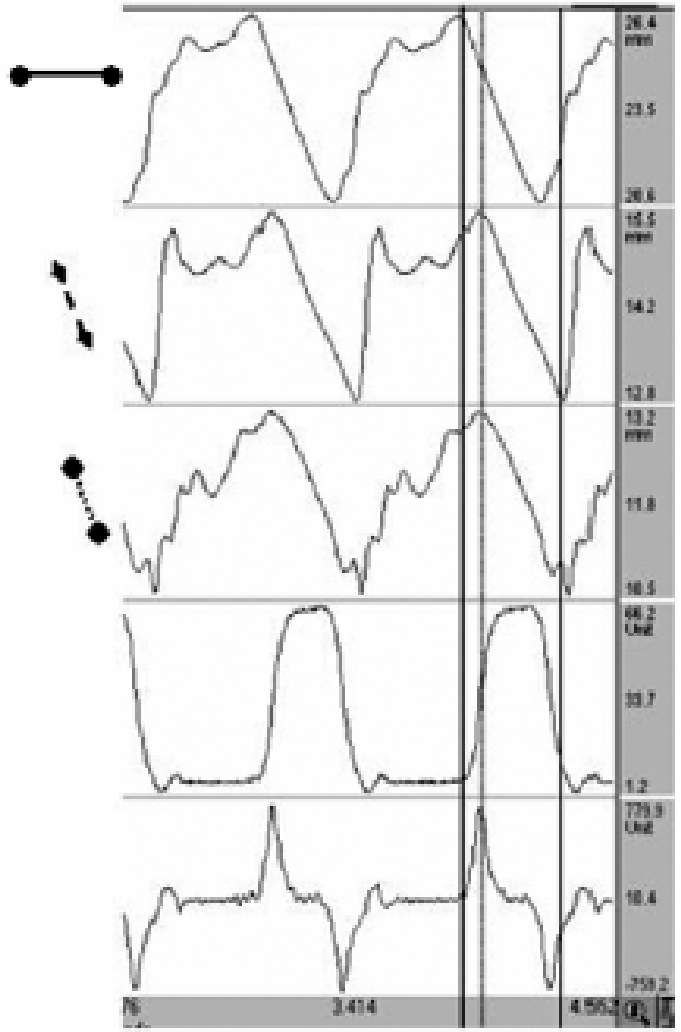
Free Wall
(RV)

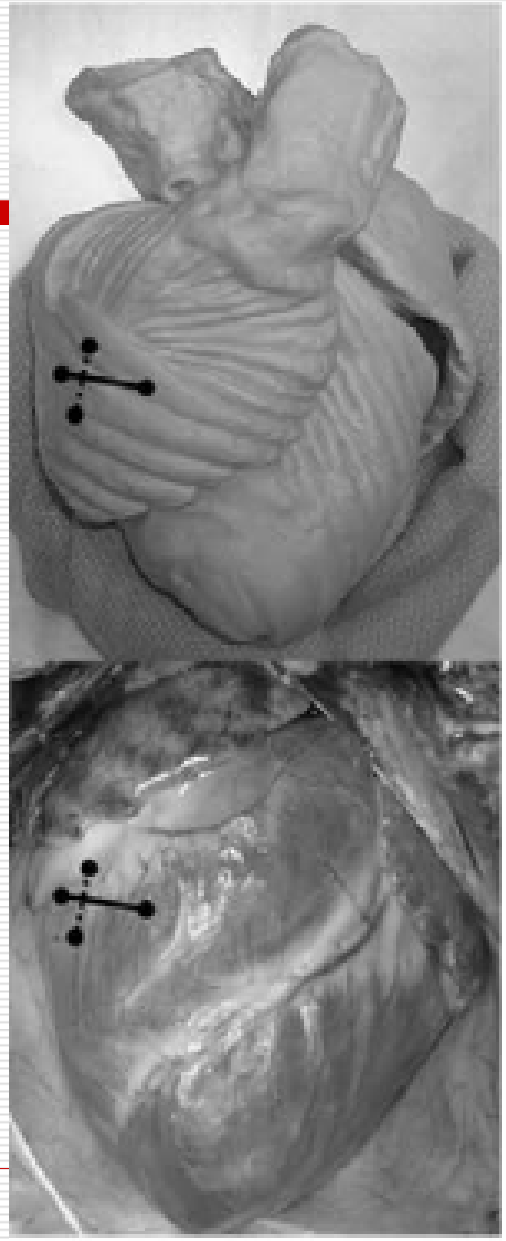
Asc. Seg

RV Outflow tract
(Aberrant fibers)

LVP

dP/dt





RV Selection of angles

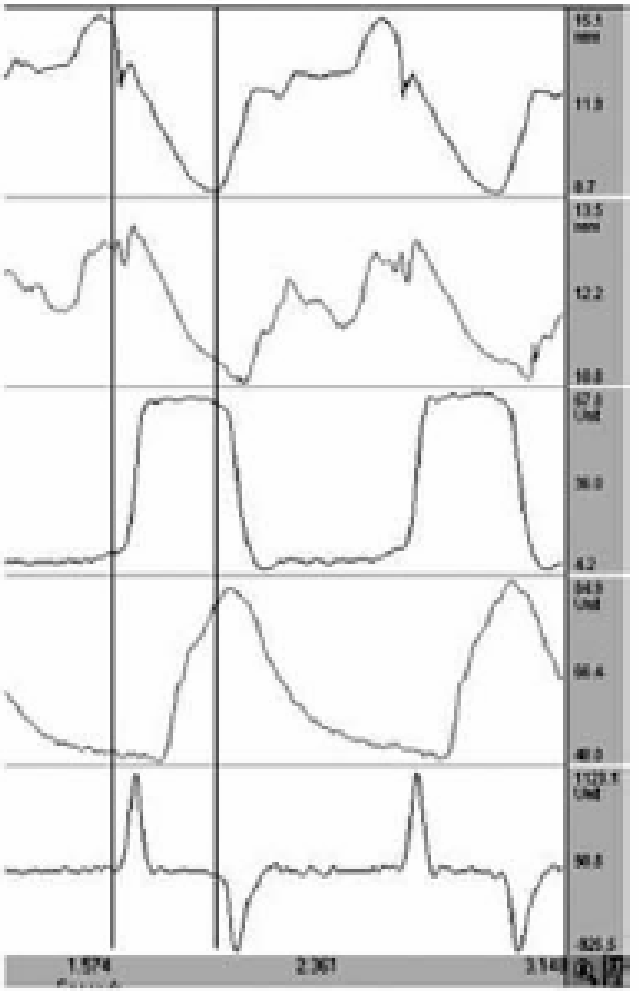
RV
(transverse

RV
(longitudinal

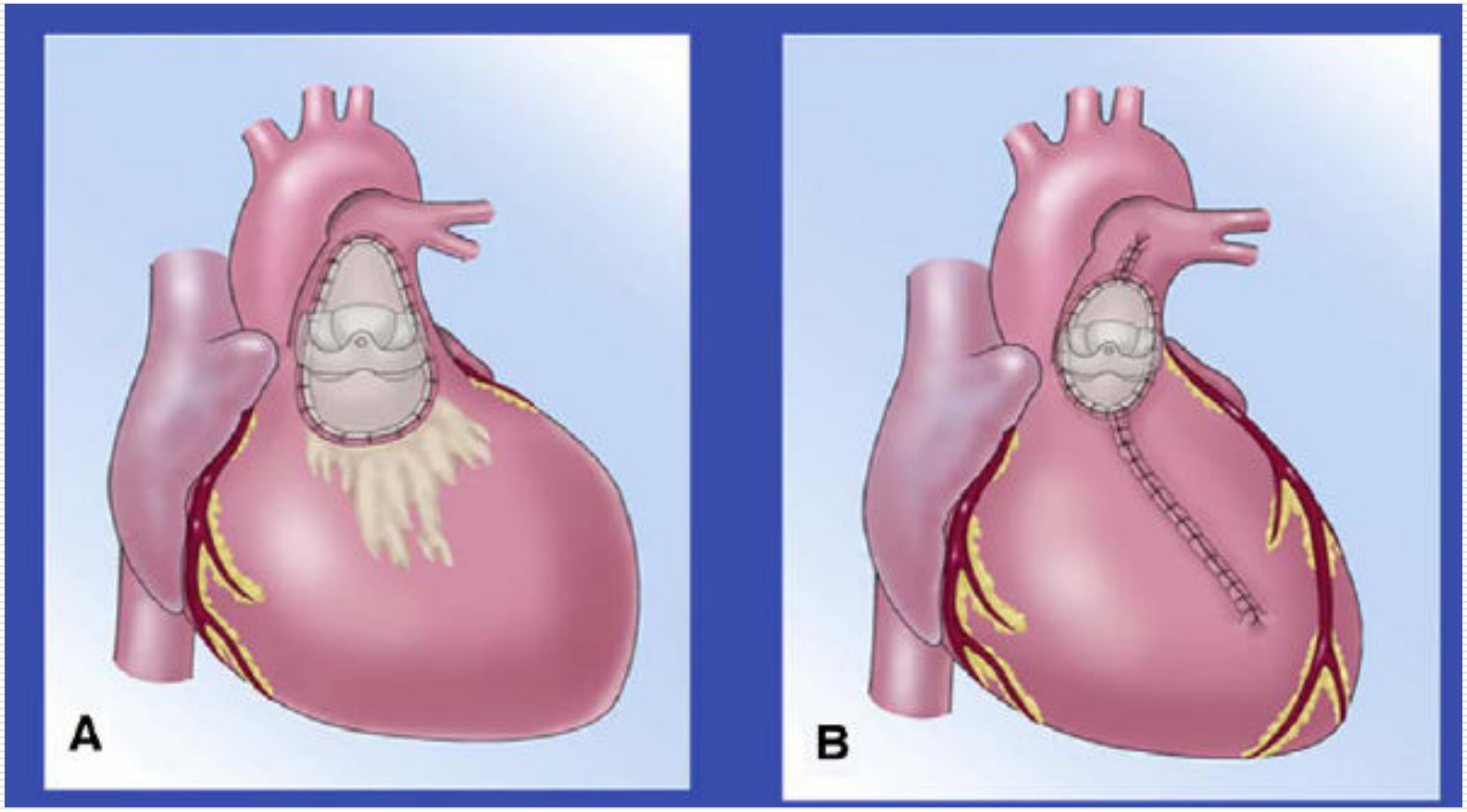
LVP

Fem P

dP/dt



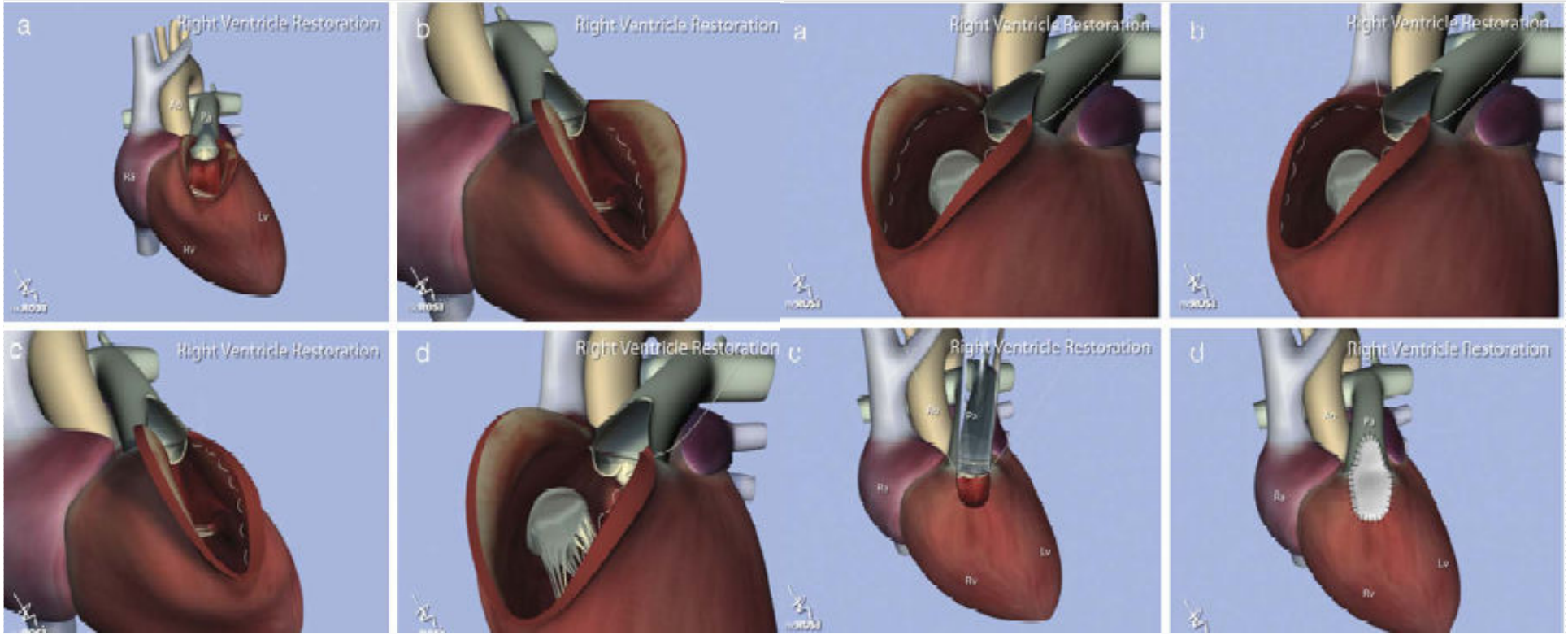
Right Ventricular Remodeling Surgery



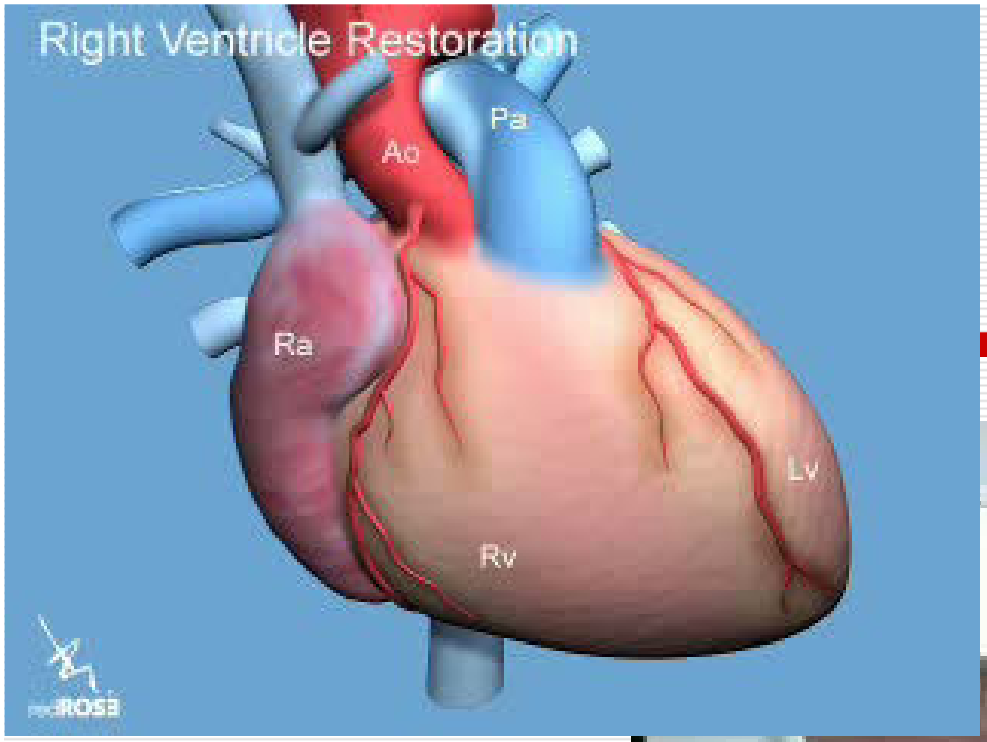
Del Nido. Pediatric Cardiac Surgery Annual, 2006

Right ventricular restoration during pulmonary valve implantation in adults with congenital heart disease☆

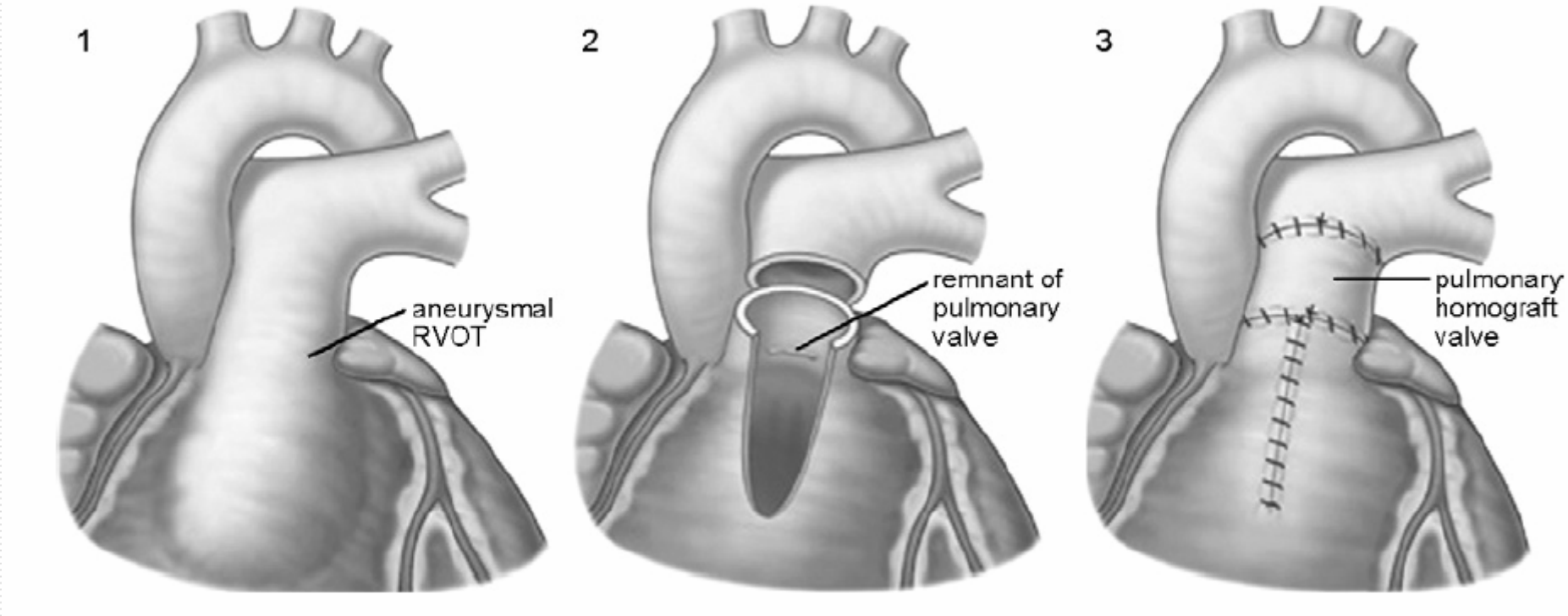
Alessandro Frigiola [a], Alessandro Giamberti [a,*], Massimo Chessa [a], Marisa Di Donato [a], Raul Abella [a], Sara Foresti [a], Concettina Carlucci [a], Diana Negura [a], Mario Carminati [a], Gerald Buckberg [b,c], Lorenzo Menicanti [a] and the RESTORE group



Frigiola. Euro J Cardio-Thorac Surg 20006


Right Ventricle Restoration
Pa
Ao
Ra
Lv
Rv

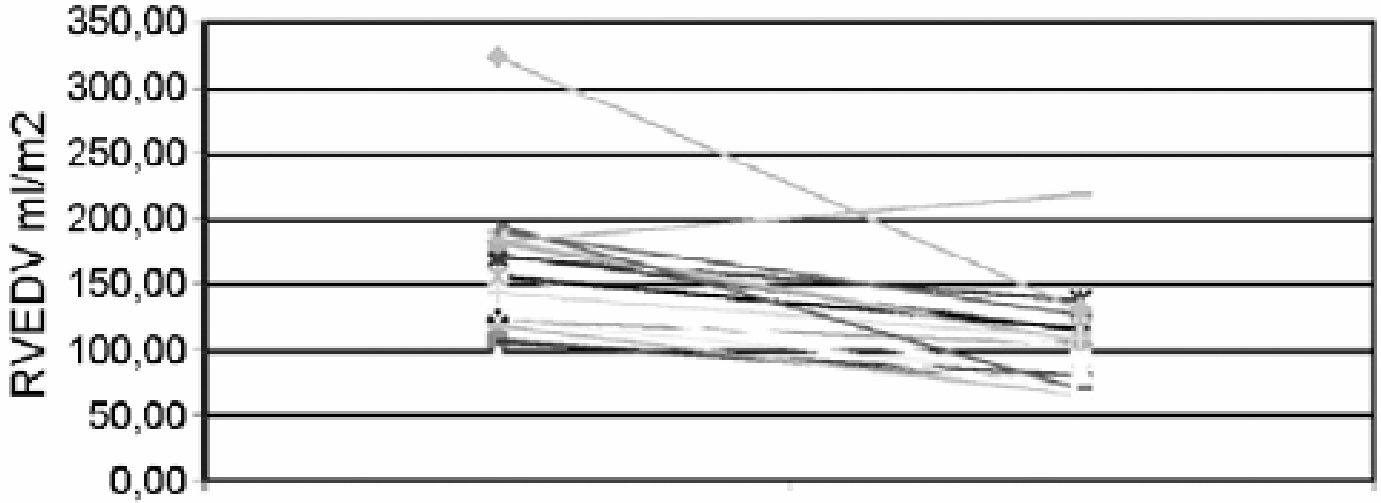
Right Ventricular Remodeling Surgery



M De Leval. Euro J Cardio-thorac Surg 2007

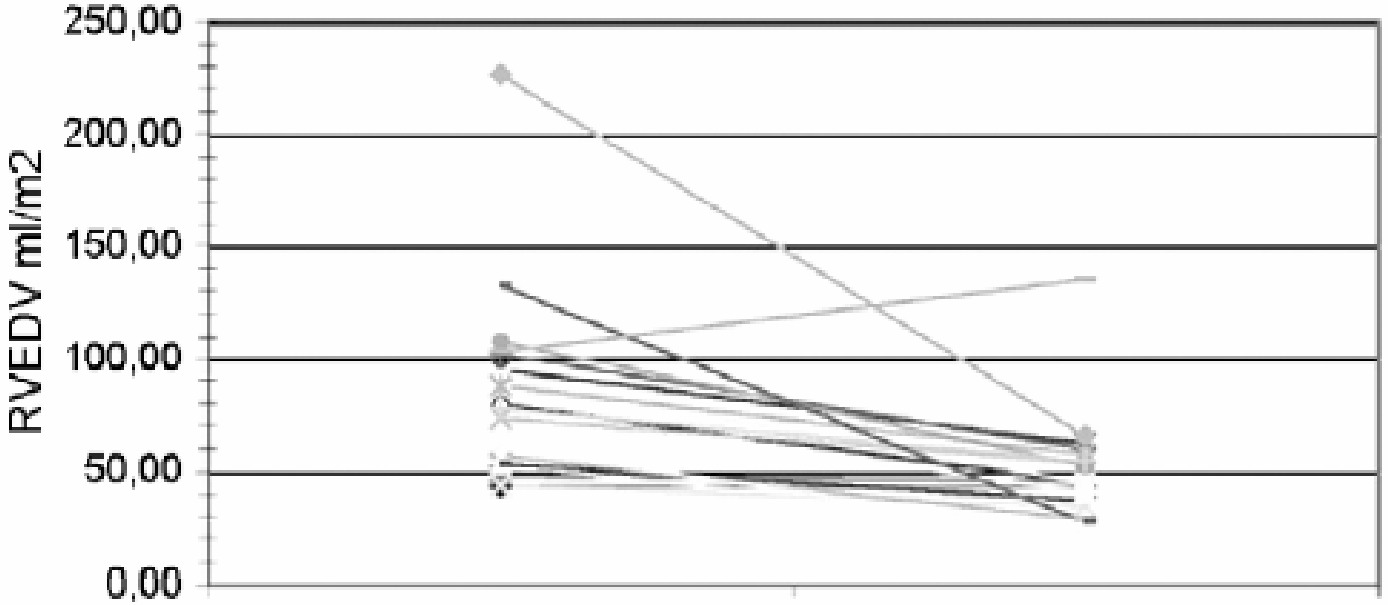
RVEDV ml/m2

Value before operation and after one year



RVESV ml/m2

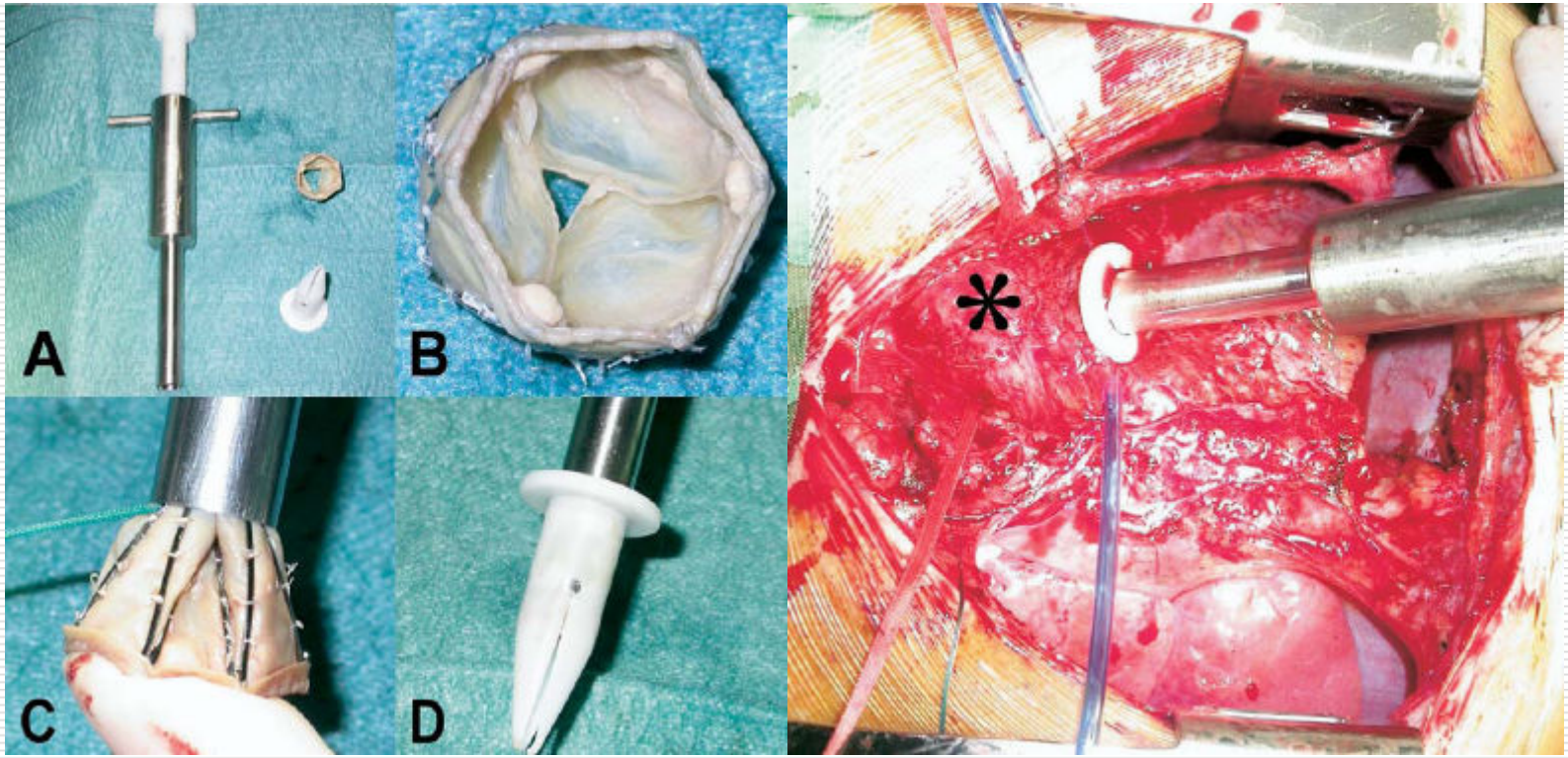
Value before operation and after one year



Percutaneous implantation of a Pulmonary Valve

- Bovine valve of jugular veins mounted in a stent
- Relieve obstruction and restore competence of the RVOT
- RVOT aneurysm and/or akinesia
- focus of sustained vent. tachycardia
- Progress dilating

Percutaneous implantation of a Pulmonary Valve

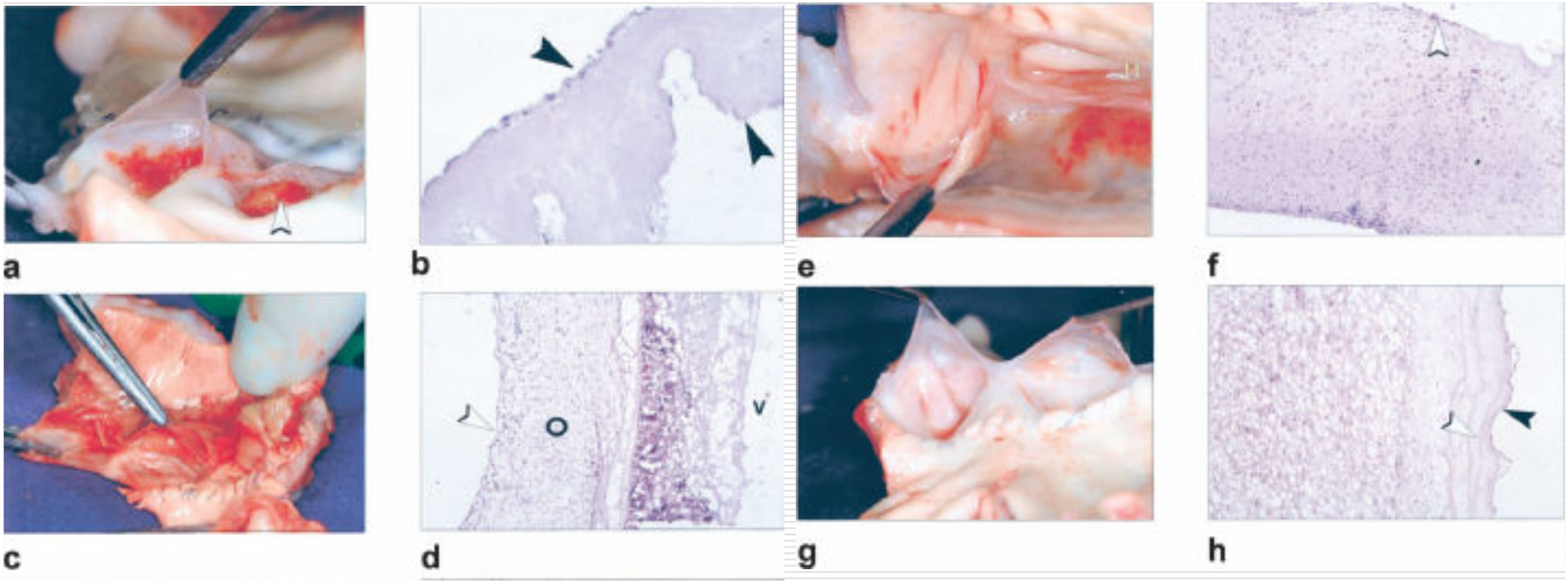


Injectable, self expandable stented porcine pulmonic valve, 2007

Tissue Engineering of Pulmonary Heart Valves on Allogenic Acellular Matrix Conduits

In Vivo Restoration of Valve Tissue

Gustav Steinhoff, MD, PhD; Ulrich Stock, MD; Najibulla Karim; Heike Mertsching, PhD;
Adine Timke; Rolf R. Meliss, MD; Klaus Pethig, MD;
Axel Haverich, MD, PhD; Augustinus Bader, MD, PhD



결론

1. TOF 등 RVOT reconstruction 은 결과가 좋아져서 생존자가 늘어남에 따라 long term 에 RVOT의 문제가 많이 나타난다.
2. 재수술 후 경과가 좋기 때문에 RV failure 가 되기 전에 하는 것이 좋겠다.
3. 우심실유출로의 확장은 plication을 같이 해 주는 것이 좋겠다.
4. 그러나 ideal 판막이 없으므로 어느 판막을 사용할 것인가에 대해서는 case by case 의 신중한 선택이 필요하다.
5. 가까운 미래에 tissue engineering conduit가 개발되면 growth potential 이 있는 long -term durable 할 수 있을 것이다.