Tetralogy of Fallot - Factors Affecting Pulmonary Valve Replacement Timing

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Tetralogy of Fallot and Pulmonary Valve Replacement

• Scope of the problem

• Why need pulmonary valve replacement (PVR)?

• Defining the cardiac phenotype for PVR

• Indications for PVR?

• It’s all in timing, is it?

• Things to ponder!
Scope of Pulmonary Valve Replacement by Number

• Incidence of Tetralogy of Fallot (TOF): 1 in 3600 live births
• ~ 4% of all infants born with congenital heart disease (CHD)
• 40,000 infants are born with CHD/year in the U.S.
• ~ 1600 infants born with TOF/year in the U.S.

CDC data and stat, CDC.gov; Lancet 2009;374:1462; https://nicor4.nicor.org.uk
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- ~ 1600 infants born with TOF/year in the U.S.
- ~ 17% to 41% may need right ventricular outflow tract (RVOT) reconstruction with a valve at mean age of 20±13 years
- Pulmonary valve replacement (PVR): now the most common operation undertaken for adults with CHD

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Why need a Pulmonary Valve Replacement?

• Kirklin and colleagues documented that severe residual right ventricular (RV) hypertension was poorly tolerated.

• Trans-annular enlargement of the hypoplastic pulmonary annulus/RVOT and its resultant obligatory pulmonary regurgitation (PR): seemed to have little medium-term disadvantage.

• The patients: committed to a new history of chronic PR and RV volume overload
Why need a Pulmonary Valve Replacement?

Chronic RV volume overload
Dyskinesis of the RVOT wall,
Conduction delay from the right bundle-branch block (RBBB)
→
A cascade of pathophysiological abnormalities
→
RV dilatation and ultimately dysfunction

Why need a Pulmonary Valve Replacement?

Right Ventricular Function and Exercise Performance Late After Primary Repair of Tetralogy of Fallot with the Transannular Patch in Infancy


- Evaluated the late (>10 years) effects of chronic PR against the putative benefits from the early primary repair of TOF with a trans-annular patch in infancy.

- Impaired RV diastolic function and decreased exercise capacity, both significantly associated with pulmonary regurgitation.
Why need a Pulmonary Valve Replacement?

Beginning during the third decade of life increasing rates of morbidity and mortality:

- Left ventricular dysfunction,
- Arrhythmias,
- Exercise intolerance,
- Heart failure symptoms,
- Death: Surviving patients (10 and 50 years of age): An annual risk of death of 4 times that of normal population.

Why need a Pulmonary Valve Replacement?

AHA/ACC Guideline for the Management of Patients With Valvular Heart Disease (based on outcomes):

Aortic Regurgitation (AR):

Class I

- AVR is indicated for **symptomatic patients** with severe AR regardless of LV systolic function,
- AVR is indicated for **asymptomatic patients** with chronic severe AR and LV systolic dysfunction (LVEF <50%) at rest,
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**Class IIa/IIb**

- AVR is reasonable for **asymptomatic patients** with severe AR with normal LV systolic function (LVEF >50%) but with severe LV dilation (LV end-systolic dimension >50 mm) (LV end-diastolic dimension >65 mm).

J Am Coll Cardiol 2008; Circulation. 2014.
Defining the Cardiac Phenotype

Ventricular Morphology by CMR:
- RV morphology
- LV morphology
- Septal motion and curvature
- Residual defects
Defining the Cardiac Phenotype

Measurement of Volumetric and Function by CMR:

• RV end-diastolic volume index
• RV end-systolic volume index
• RV Ejection Fraction
• LV end-diastolic volume index
• LV end-systolic volume index
• LV Ejection Fraction
Defining the Cardiac Phenotype

Flow Quantification by CMR:

- Pulmonary regurgitant fraction
- RVOT flow and velocity
- LVOT flow and velocity
- Cardiac Index
Defining the Cardiac Phenotype

Flow Quantification by CMR:
- RPA flow and velocity
- LPA flow and velocity
- RPA:LPA flow ratio
- Branch PA dimensions
Defining the Cardiac Phenotype

Measurements for per cath PVR:
- RVOT dimensions
- MPA dimensions
Defining the Cardiac Phenotype
Indications for Pulmonary Valve Replacement

The current indications are based on the available evidence analyzing pre-PVR markers of post-PVR normalization of RV size or function:

I. Asymptomatic patients with ≥2 of the following quantitative criteria:

- Phenotype Indicators for PVR:
  a. RV end-diastolic volume index >150 mL/m² or z score >4.
  b. RV/LV end-diastolic volume ratio >2
  c. RV end-systolic volume index >80 mL/m²
  d. RV ejection fraction <47%
  e. Large RVOT aneurysm

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• Hemodynamic Indicators for PVR:
  a. RVOT obstruction with RV systolic pressure ≥0.7 systemic
  b. Severe branch pulmonary artery stenosis with <30% flow to affected lung) not amenable to trans-catheter therapy
  c. ≥ Moderate tricuspid regurgitation

Indications for Pulmonary Valve Replacement

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• **Electrophysiological Indicators for PVR:**
  a. QRS duration >160 ms
  b. Sustained tachyarrhythmia related to right-sided heart volume load
Indications for Pulmonary Valve Replacement

The current indications are based on the available evidence analyzing pre-PVR markers of post-PVR normalization of RV size or function:

II. **Symptomatic patients fulfilling ≥1 of the quantitative criteria + :**
   a. Exercise intolerance not explained by extra-cardiac causes
   b. LV EF z score < -2.0
   b. Signs and symptoms of heart failure
   c. Syncope attributable to arrhythmia

Indications for Pulmonary Valve Replacement

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III. Special considerations fulfilling ≥1 of the quantitative criteria:
   a. TOF repair at ≥3 years of age
   b. Pre-pregnancy PVR

Pulmonary Valve Replacement

Pulmonary valve replacement (PVR) performed by:
• Trans-catheter technique
• Surgical procedure
• Hybrid procedure
Early Results of Pulmonary Valve Replacement

- Resolution or marked reduction of pulmonary regurgitation,
- 30% to 40% reduction in RV end-diastolic and end-systolic volumes,
- Unchanged RV ejection fraction,
- Decrease in RV systolic pressure,
Early Results of Pulmonary Valve Replacement

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- Slightly increased LV size with unchanged ejection fraction,
- No change in arrhythmia burden.
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- No change in arrhythmia burden.
- Improvement in NYHA functional class
- No clear change in objective exercise parameters
Little or no information is currently known for:

- Ventricular performance late after PVR,
- Pre-PVR risk factors for post-PVR arrhythmias,
- Exercise intolerance late after PVR
- Long-term reduction in arrhythmia burden
- Improved survival
RV and LV are not the same:

**RV:**
- Oblique arrangement of the RV fibers externally, and longitudinally internally.
- Less contractile forces
- Evidence of myocardial fibrosis in fetal heart with TOF

Sanchez-Quintana et al. Heart 1999
RV and LV are not the same:

**LV:**
- Helical arrangement of myofibers
- More contractile forces due to counter-directional movement
- More myocardial reserve
Things to Ponder!

- Need to know how to apply pre-PVR risk factors to different anatomic or surgical phenotypes.
Things to Ponder!

Repair of Conotruncal Cardiac Defects that disrupts the integrity of the pulmonary valve or RVOT reconstruction that results in PR.

- RVOT reconstruction with a trans-annular patch: TOF, Pulmonary Atresia with intact septum

TOF: VSD with over-riding aorta  
TOF: RVOT obstruction  
PA-IVS: membranous PV atresia
Repair of Conotruncal Cardiac Defects that disrupts the integrity of the pulmonary valve or RVOT reconstruction that results in PR.

- RV-PA continuity with a homograft: Pulmonary Atresia with VSD, Truncus Arteriosus.

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• Need to know whether therapeutic interventions designed to modify these risk factors will, in fact, translate into a clinical benefit.
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- Need to know whether therapeutic interventions designed to modify these risk factors will, in fact, translate into a clinical benefit.

- Need for a large multicenter studies to create an evidence-based consensus on the optimal timing and indications for PVR.
Thank you
Who Does Not Need Pulmonary Valve Replacement

Phenotype of TOF patients free of late PVR requirement:

Follow-up of TOF patients 10-50 years after the repair with/without Transannular patch:

- Mildly dilated RV \( (RVEDVI \leq 101 \pm 26 \text{ mL/m}^2) \)
- Mild residual RVOT obstruction
- Pulmonary annulus diameters <0.5z,
- Unobstructed branch pulmonary arteries.
- Good systolic function \( (RV-EF \geq 59 \pm 7\%) \).
- Normal Exercise capacity \( (z \text{ peak Vo2 } \approx 0.91 \pm 1.3) \).