The right side of the heart: Innovations in creating a right ventricle to pulmonary artery pathway

david.winlaw@cchmc.org

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Connor

12 years old

VACTRL (cardiac and GI issues), DORV with pulmonary atresia

1. Shunt as newborn
2. Repair at 9 months – 12 mm BJV conduit
3. New conduit at 7 years – 18mm BJV conduit

Elevated RV pressures on routine exam

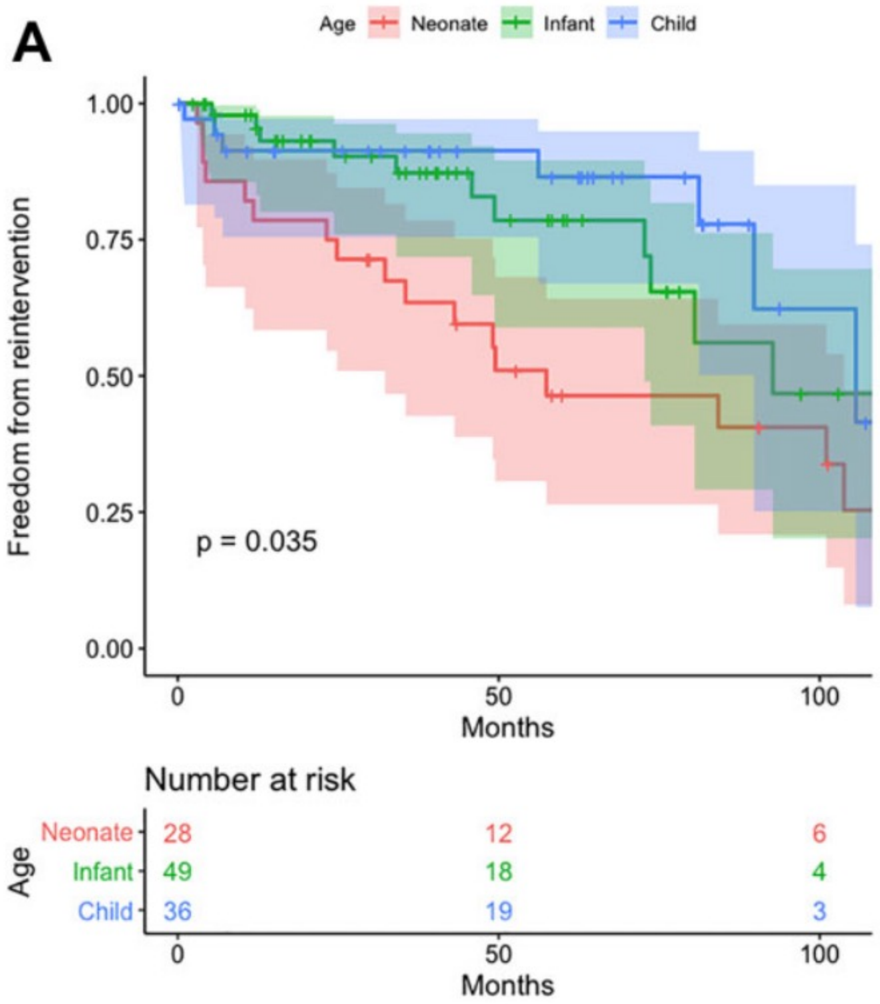
- Anomalous coronary arteries
- RV muscle hypertrophy – proximal obstruction

The need

Freedom from re-intervention is a poor indicator of conduit quality and patient outcome

Days in hospital & cost

Psychological impact



Saxena WJPCHS 2021

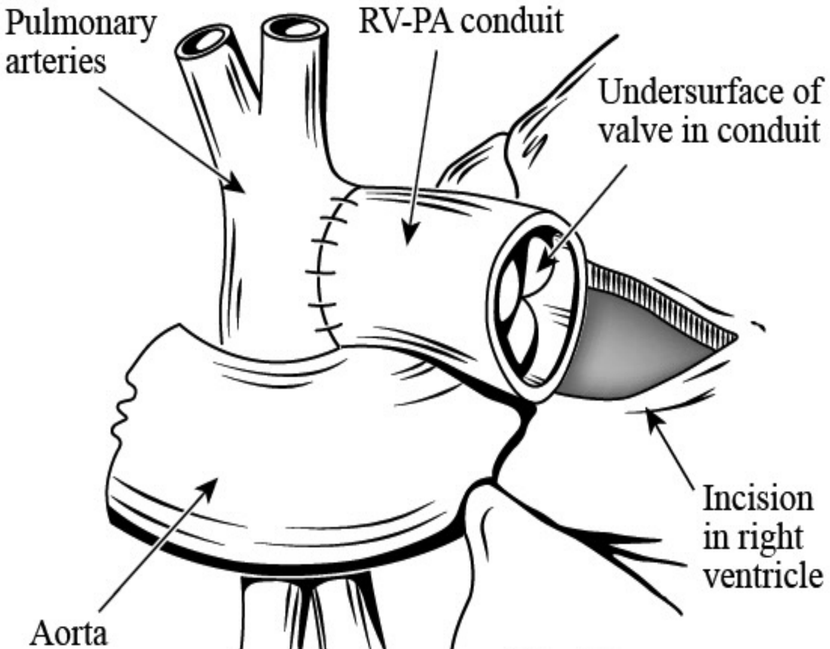
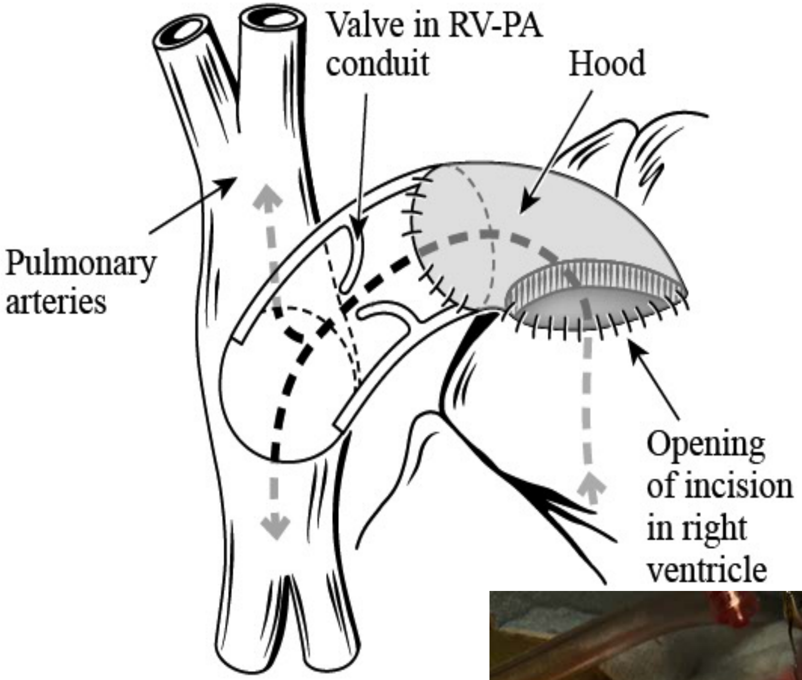
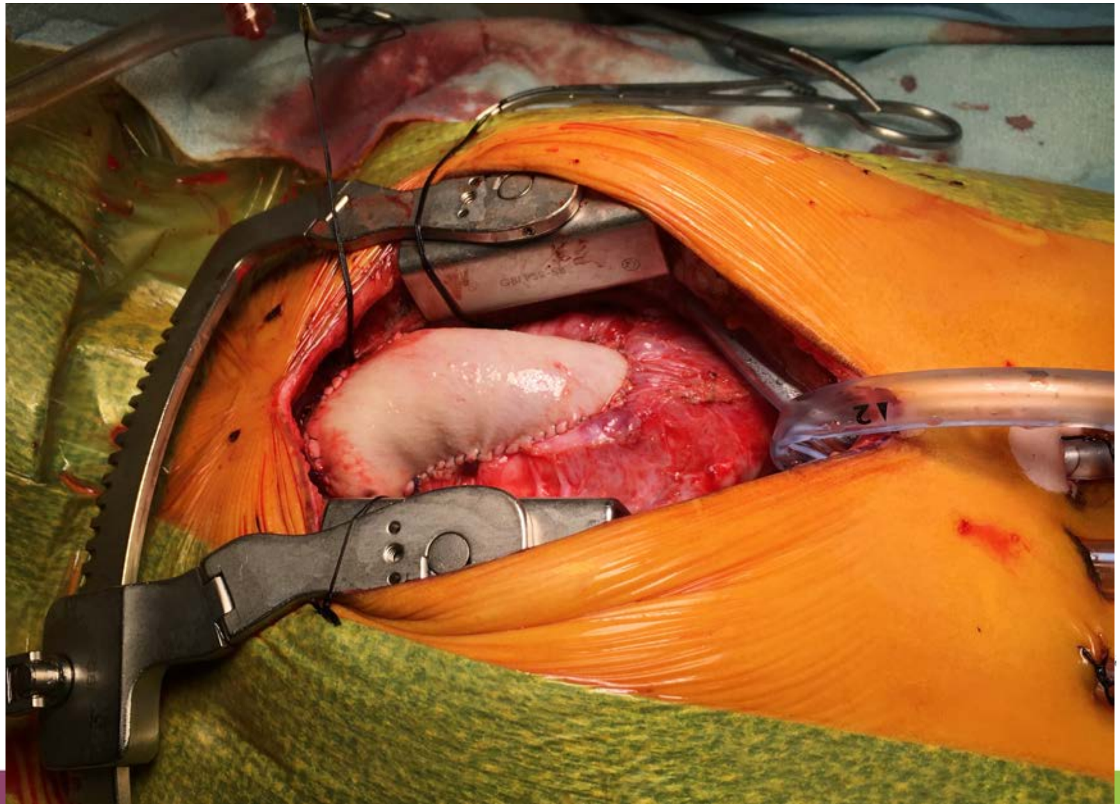


Fig 1A

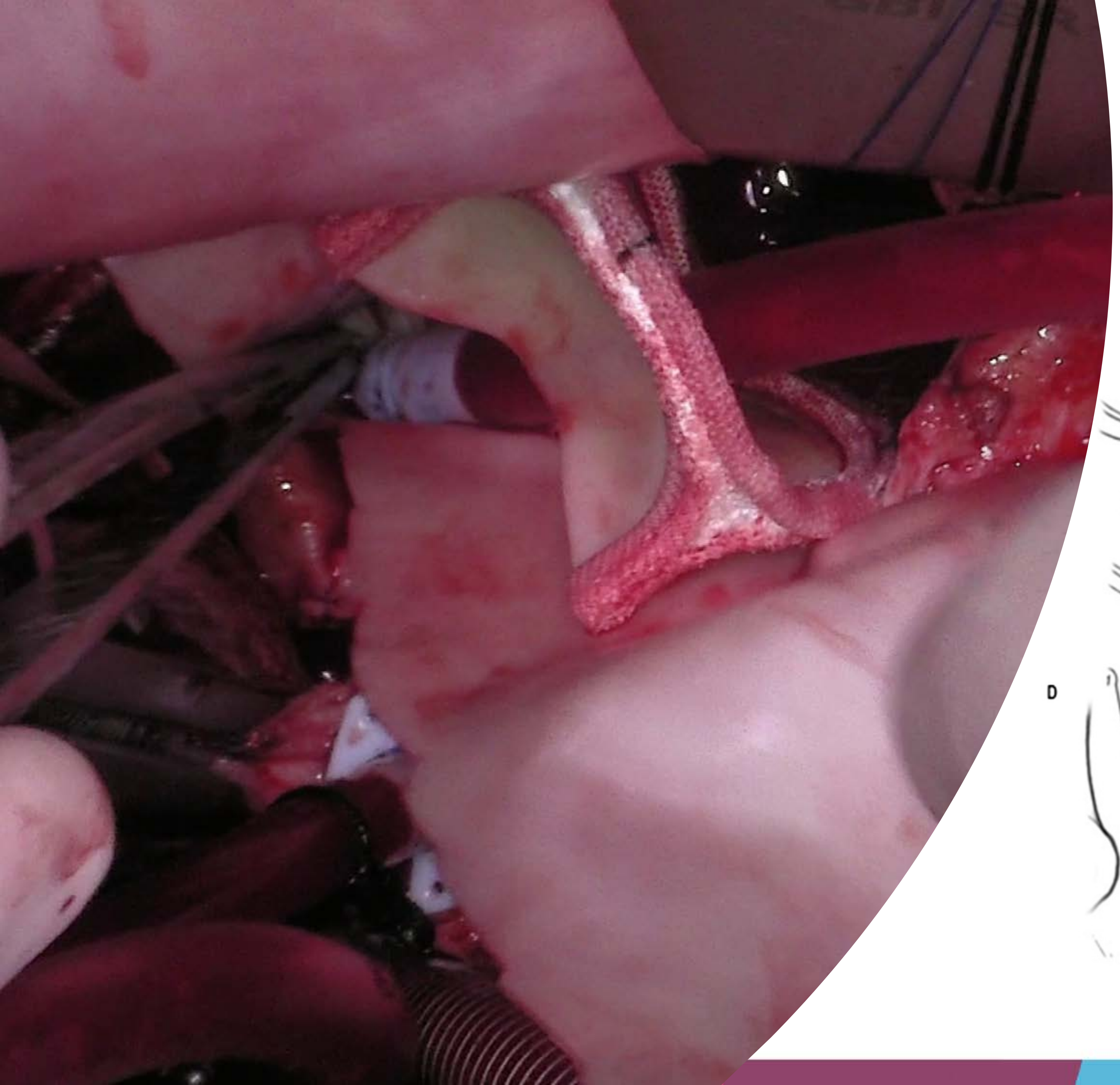


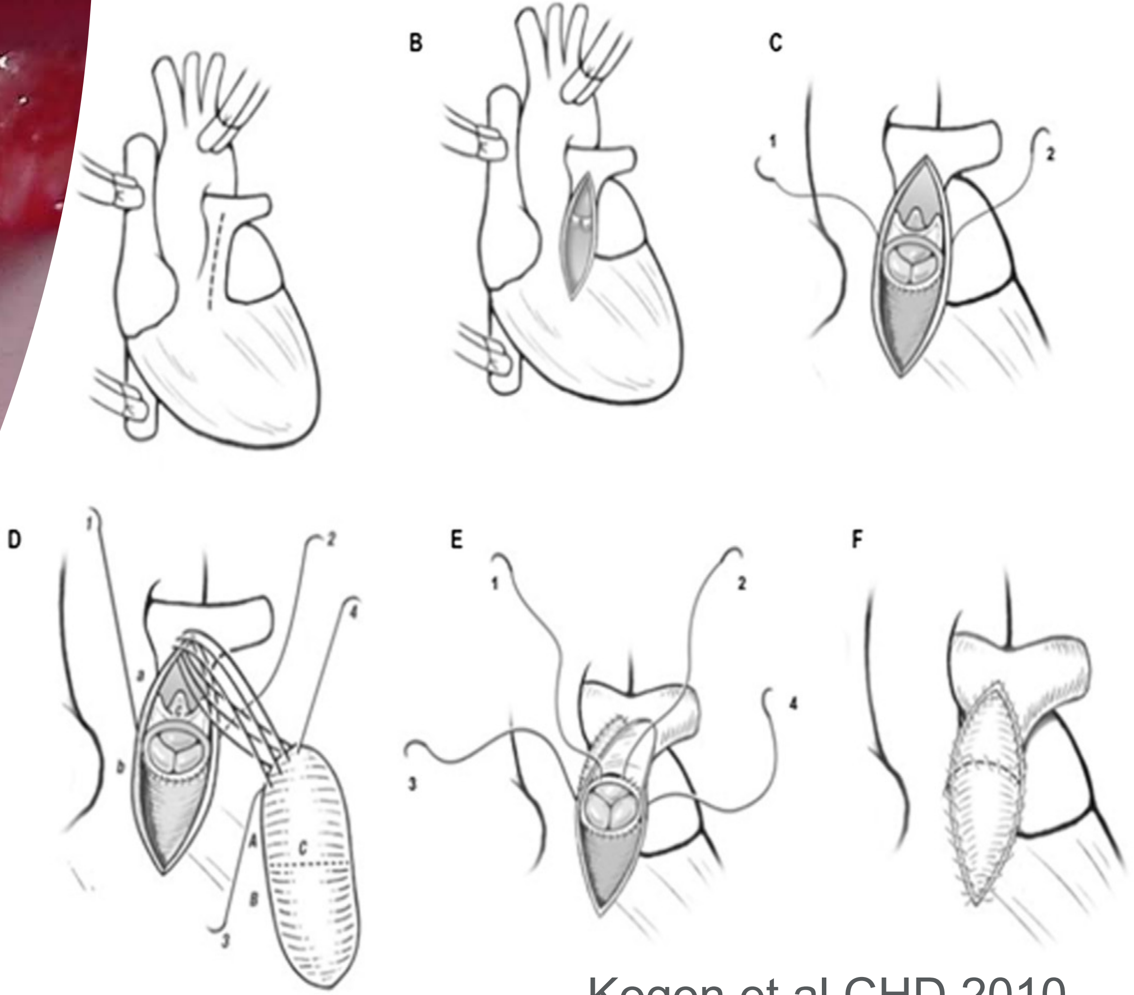
Saxena et al., WJPCHS 2021.

Non-native outflow: truncus arteriosus with RV-PA conduit



Native outflows …like tetralogy





Kogon et al CHD 2010

The Opportunity:

Long-term outcomes in CHD might be substantially better if we had a better valve and conduit.

Innovations

- Getting a replacement there more easily
- Alternative leaflet materials
- Alternative valve designs

New horizons in intervention

Post-Melody Era:

- Smaller sheaths
- Valves less susceptible to infection
- Valve in valve technology
- Banding the landing zone in big annuli

Device development

Traditional implanted bioprostheses now have ‘crack-able’ sewing rings

Supports valve-in-valve concept

For the big annulus:

Alterra pre-stent for Sapien implant (bovine pericardium)

Harmony
Porcine pericardial valve

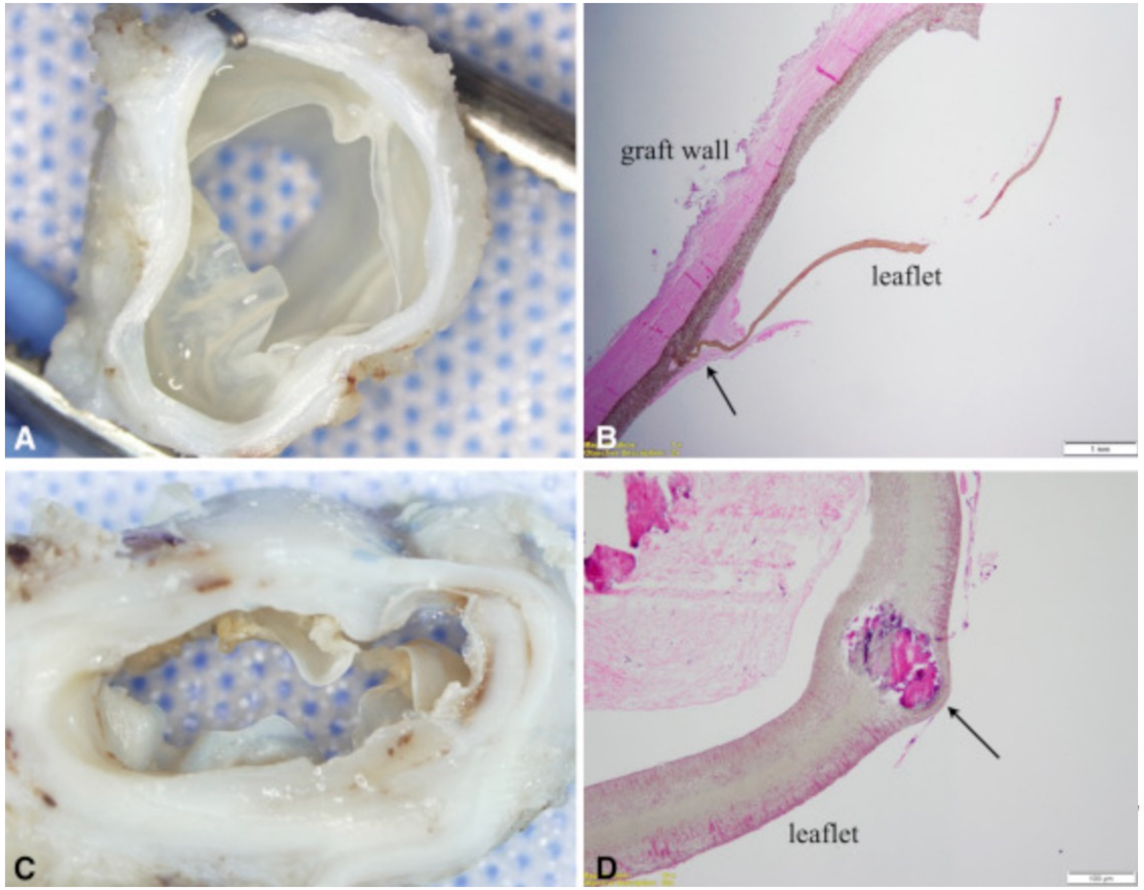
Alternative materials

Getting away from xeno tissue

PTFE (GoreTex) has a long record of stability and non-reactivity in cardiovascular surgery

Hand made valves

- Template based reconstruction with or without bulging sinuses (Miyazaki et al. JTCVS 2018)



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Gore

Gore modified the material for a pulmonary valve conduit, all 20mm

Early results were satisfactory

Development may have been halted

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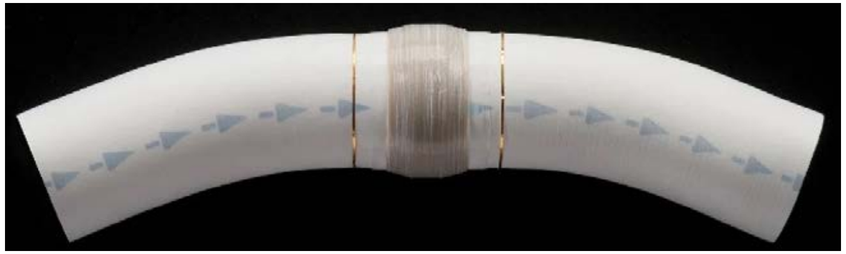
https://doi.org/10.1016/j.athoracsur.2021.10.033

Check for updates

Preliminary Results With a Novel Expanded Polytetrafluoroethylene-based Pulmonary Valved Conduit

Christopher W. Baird, MD, Mariana Chávez, MD, Carl L. Backer, MD, Mark E. Galantowicz, MD, and Pedro J. Del Nido, MD

Department of Cardiac Surgery, Boston Children's Hospital, Harvard Medical School, Boston, Massachusetts; Section of Pediatric Cardiothoracic Surgery, UK HealthCare Kentucky Children's Hospital, University of Kentucky, Lexington, Kentucky; Cardiothoracic Surgery Heart Institute, Cincinnati Children's Hospital Medical Center, Cincinnati, Ohio; and Department of Pediatric Cardiothoracic Surgery, Nationwide Children's Hospital, The Ohio State University College of Medicine, Columbus, Ohio

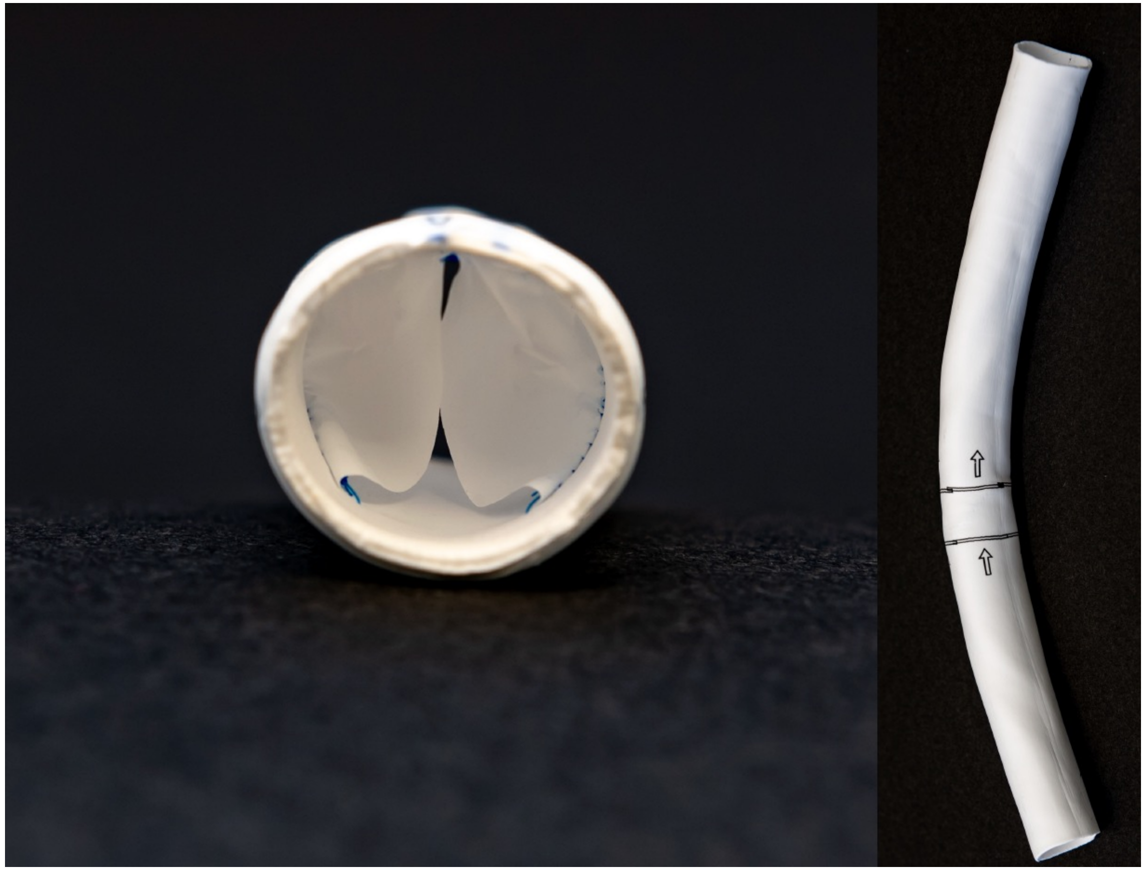


Masa Valve (PECA labs – UPMC)

Bi-leaflet valve contained within curvature with a gap area at the bottom in the 'low flow' zone

Modified PTFE – single layer construction. Apparently little neo-intima with preserved valve function.

In early feasibility trials, FDA approved for humanitarian use.

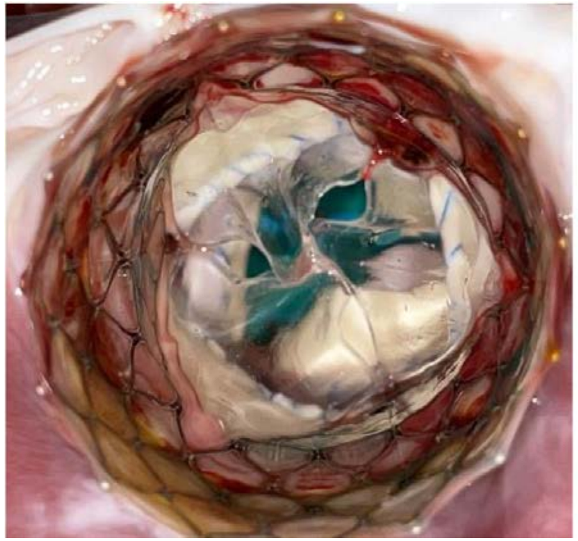


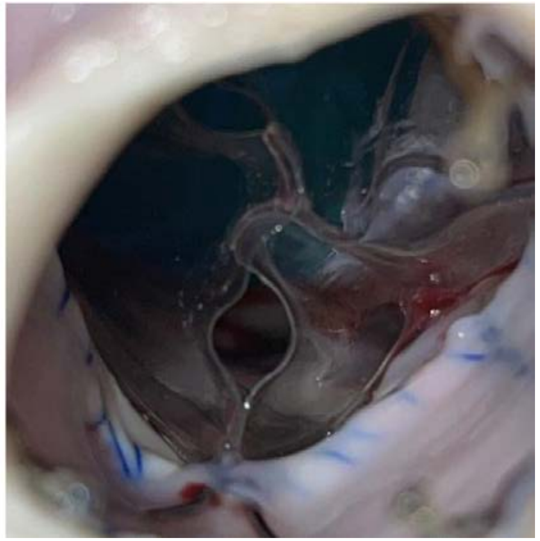
ClinicalTrials.gov Identifier: NCT05452720

Foldax – polymeric leaflet tissue

Early experience reported in adult aortic valve replacement
(JACC Cardiovascular Interventions 2021)

New class of leaflet material – possible sea change





90-day animal study – Source: Foldax.com

ClinicalTrials.gov Identifier: NCT03851068

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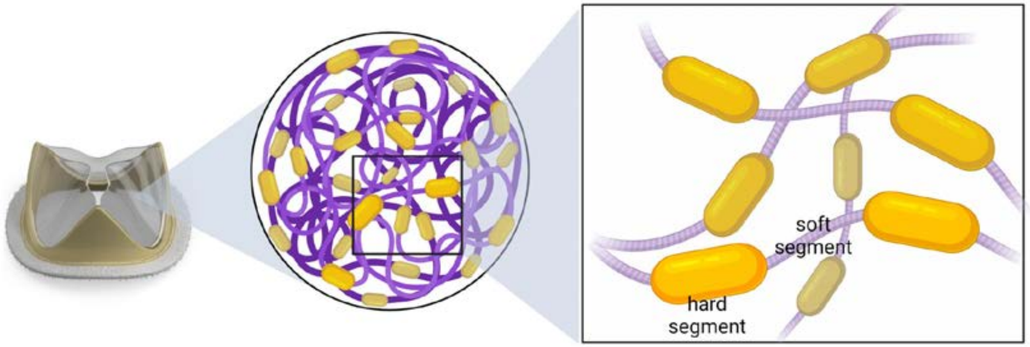
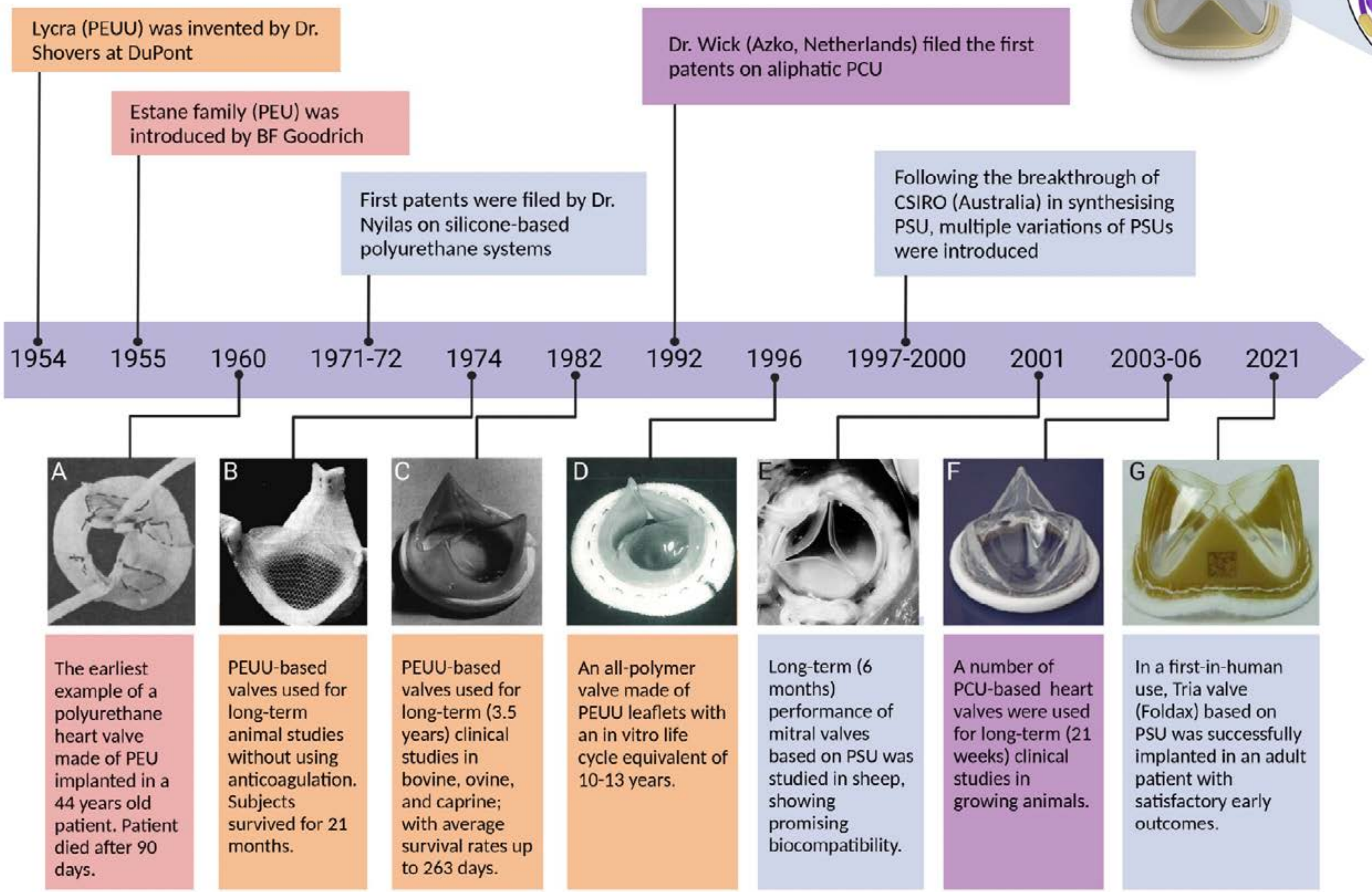
Nothing new!





Crago et al. 2022 Materials Today Communications

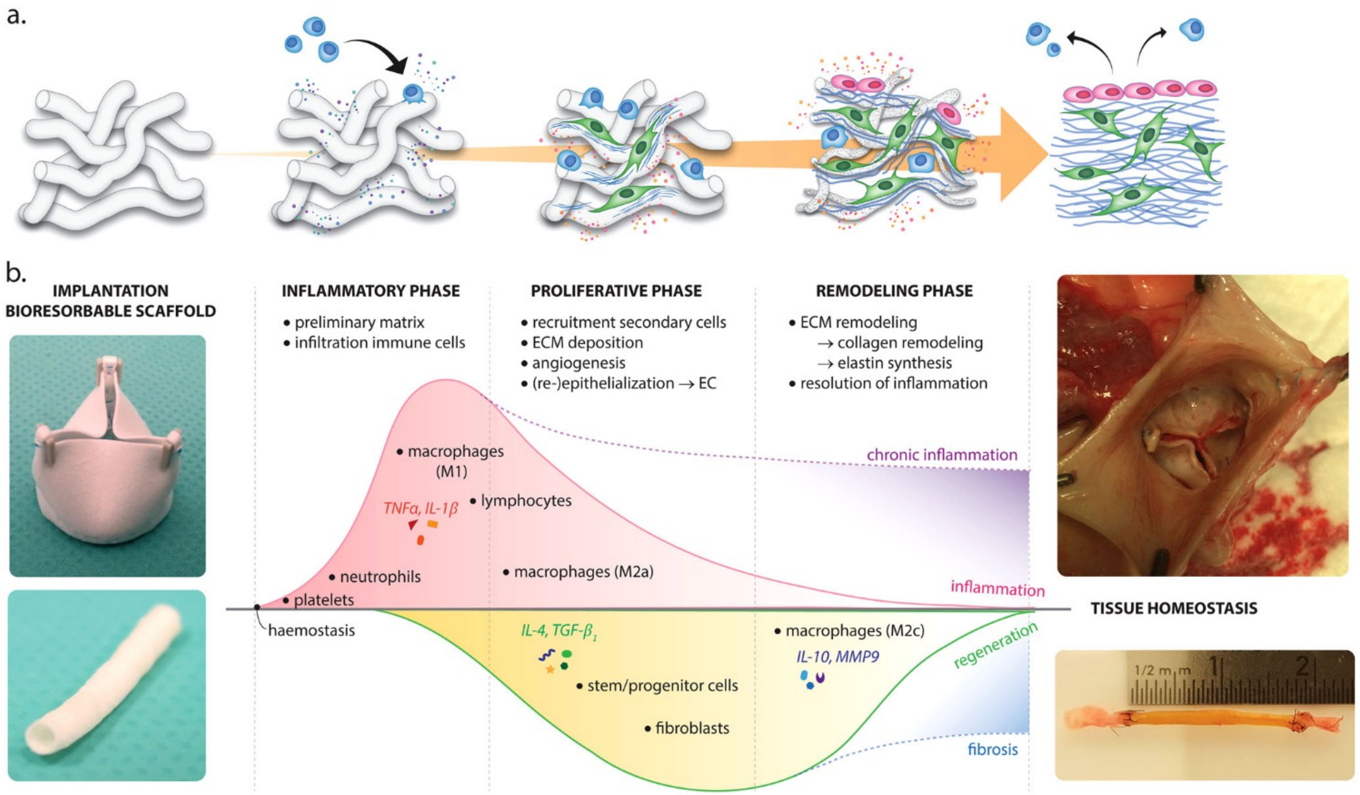
Sydney Valve Bioengineering Group

Tissue engineering approaches

A degradable polymer allowing autologous tissue ingrowth: (Xeltis).

- Remains an attractive concept, particularly for the conduit
- Concept may not work for valve leaflets

Host inflammatory response is variable



Wissing ….Smits 2017 npjregenmed

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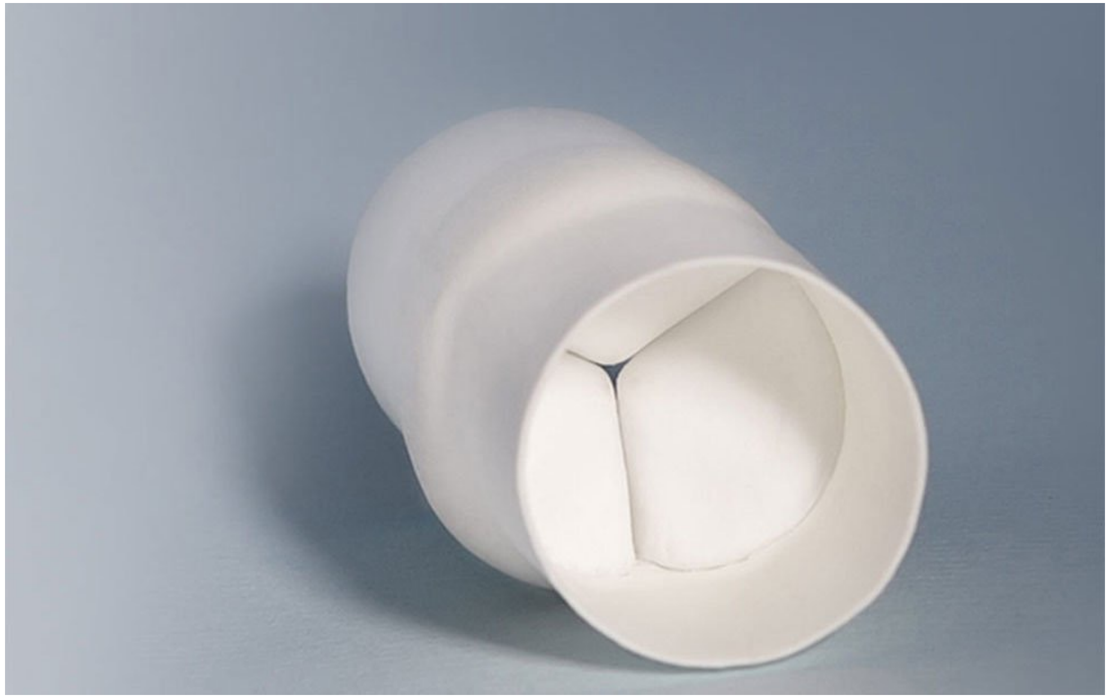
Xeltis Devices



frontiers in Cardiovascular Medicine

A Novel Restorative Pulmonary Valve Conduit: Early Outcomes of Two Clinical Trials

David L. Morales[1], Cynthia Herrington[2], Emile A. Bacha[3], Victor O. Morell[4], Zsolt Prodán[5], Tomasz Mroczek[6], Sivakumar Sivalingam[7], Martijn Cox[8], Gerardus Bennink[9]* and Federico M. Asch[10]

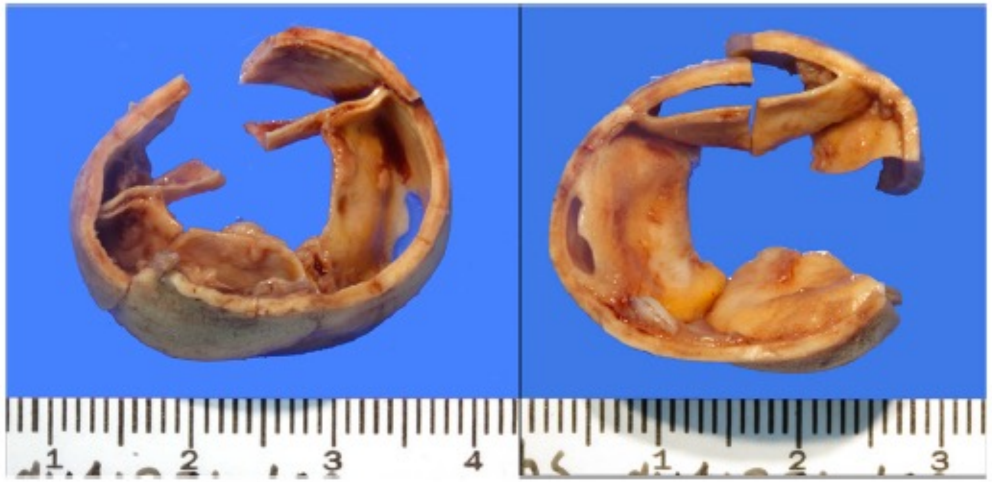


FIGURE 3 | Downstream (left hand panel, looking from the side of the pulmonary trunk, and upstream (looking from the RV side, right hand panel) of the explanted conduit. The leaflets are well-preserved, with mild commissural fusion at the base. The lumen of the conduit is also smooth, without evidence of excessive tissue proliferation or potential obstruction.

PMID: 33748192 DOI: 10.3389/fcvm.2020.583360

New approaches

Pulmonary regurgitation after pulmonary valvectomy in tetralogy of Fallot

Risk of condition – symptoms occur late but consequences are severe

Risk of intervention – low risk of dying but important morbidity

Expected benefit - ‘protecting’ the RV from deteriorating function

- Timing the intervention is difficult

Valente and Geva Circ Imaging 2018

Implanting a valve before the RV dilates:

Autus Valve

- Built for native outflows
- Surgically implanted, with serial dilation
- 3 implanting sites in the US

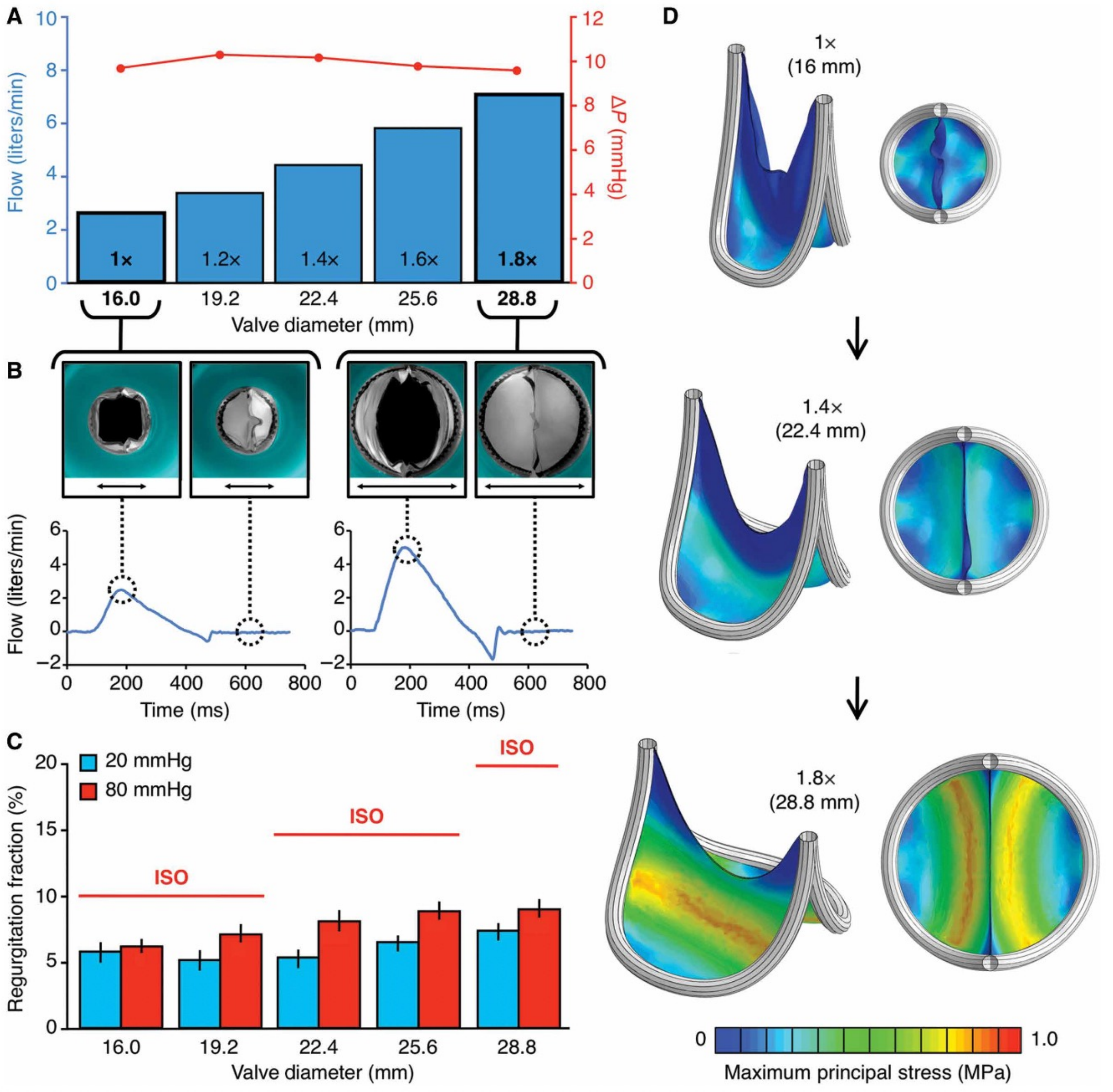
ClinicalTrials.gov Identifier: NCT05006404

SCIENCE TRANSLATIONAL MEDICINE | RESEARCH ARTICLE

CARDIOLOGY

A geometrically adaptable heart valve replacement

Sophie C. Hofferberth[1]*, Mossab Y. Saeed[1], Lara Tomholt[2,3], Matheus C. Fernandes[2,4], Christopher J. Payne[1], Karl Price[1], Gerald R. Marx[5], Jesse J. Esch[5], David W. Brown[5], Jonathan Brown[6], Peter E. Hammer[1], Richard W. Bianco[7], James C. Weaver[2], Elazer R. Edelman[6,8], Pedro J. del Nido[1]*



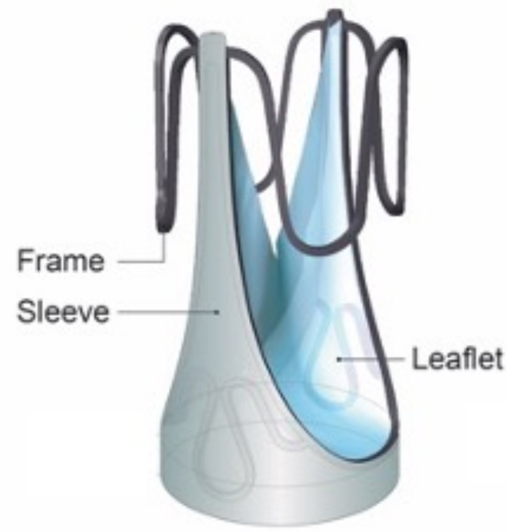
AUTUS VALVE - TECHNOLOGY OVERVIEW

- **Balloon-expandable surgical pulmonary valve implant**
  - Manufactured at single size

- **Novel biomimetic bileaflet design**
  - Functions over wide range of diameters

- **Size-adjustable**
  - Pre-implant (in OR): Match valve diameter to patient body surface area
  - Post-implant (Transcatheter): Accommodate patient growth

- **Fully synthetic**
  - Sleeve - ePTFE
  - Leaflets - ePTFE
    - Low mass, flexible
    - Chemically inert, biocompatible
    - **Long history of clinical use in pulmonary position - pediatric patients**[1,2,3]



Nominal diameter: 12.7 mm

Max. functional diameter: 22 mm

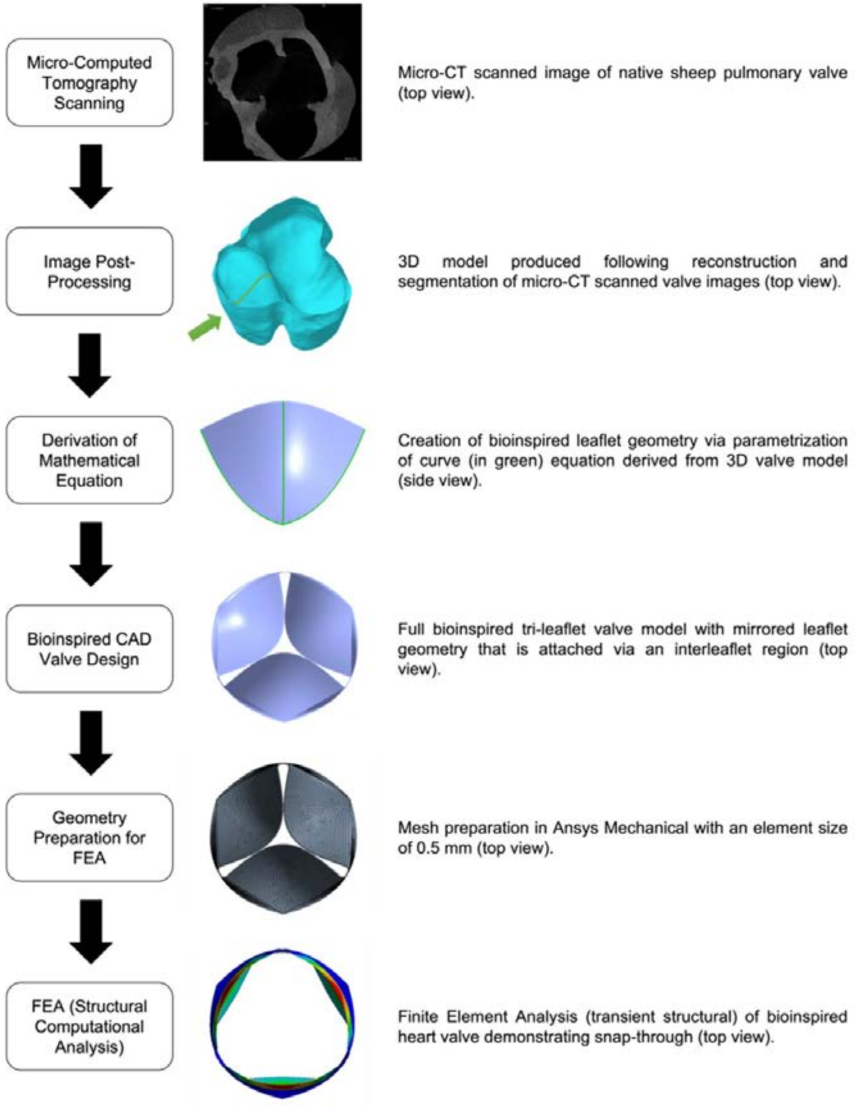
[1]Miyazaki et al, J Thorac Cardiovasc Surg 2018;155:2567-76
[2]M. Kumar et al, Semin Thorac Cardiovasc Surg 2016; 28,463-470.
[3]Quintessenza et al, World J Pediatr Congenit Heart Surg 2010: **1**, 20-27

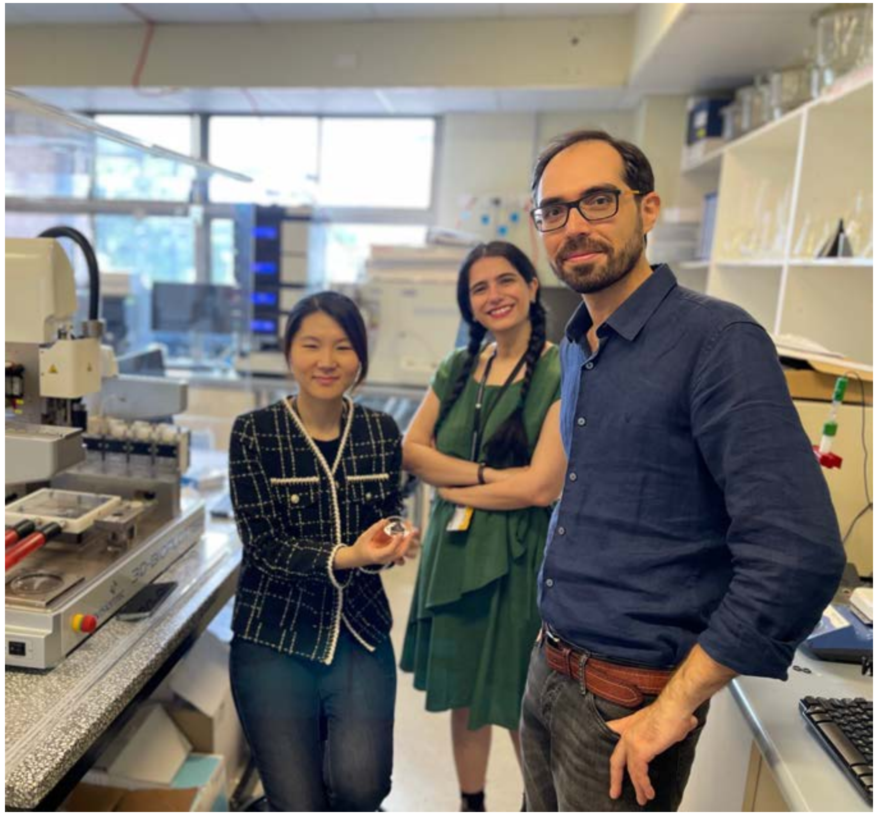
CAUTION: Investigational device. Limited by Federal (United States) law to investigational use.

Bringing it all together

Imaging, design, testing, manufacturing

Mathematically defining leaflet curvature





Lee J Biomech Eng 2022

Sydney Valve Bioengineering Group

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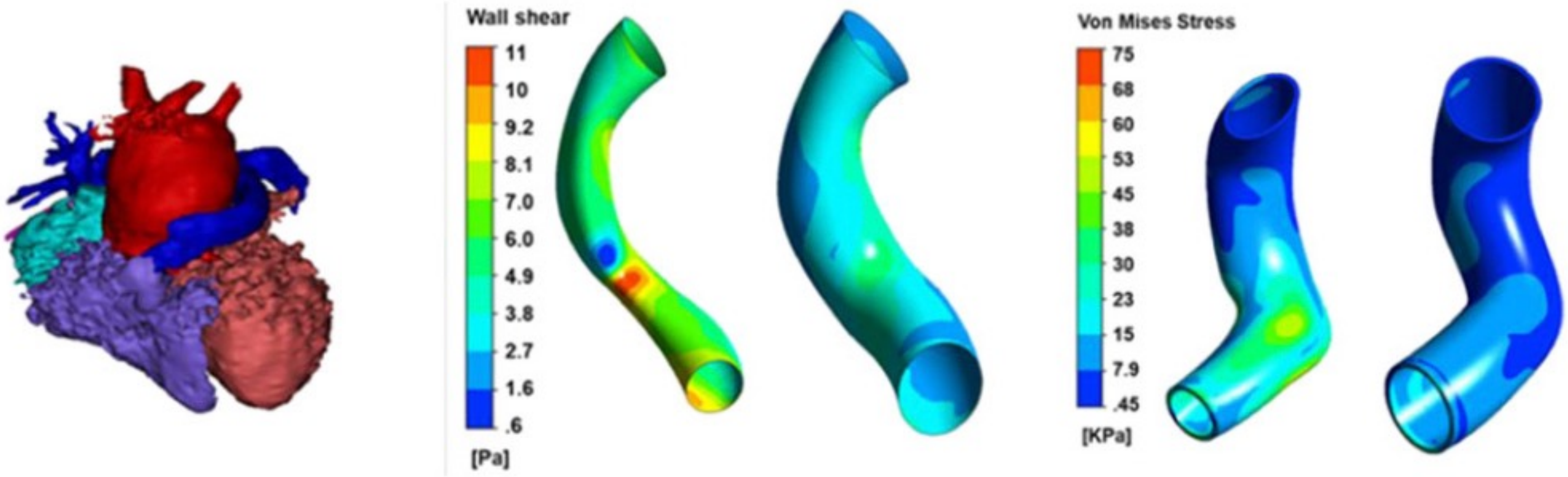
Personalize: 3D modelling, fluid dynamic assessment



(a) scan data (b) wall shear stress (c) von Mises stress

Digital Twin Development – Coorey et al. Nature Digital Medicine 2022
Sydney Valve Bioengineering Group

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Essentials

Personalize

Combine surgical and catheter-based approaches

Improve materials and valve designs

Reduce the burden of an RV-PA connection