



1

Transcatheter Interventions in Children and Young Adults

Rodrigo Rios, MD

Minneapolis Heart Institute Foundation
Grand Rounds
11/24/2025

The logo for Children's Minnesota, featuring the word 'Children's' in a serif font with a star above the 'i', and 'MINNESOTA' in a smaller sans-serif font below it.

The logo for The Children's Heart Clinic, featuring a stylized heart icon made of three curved lines and the text 'The Children's Heart Clinic' to its right.

2

Congenital Heart Disease

- Most common congenital disorder
 - 1-2%
 - In general 60% mild, 30% moderate, 10% are complex cases
 - 25% require surgery or catheter based intervention in 1st year of life
 - 97% will survive until adulthood
 - 70% of those alive at 18 years will live to at least 70 years of age
 - Many more adults living with CHD than there are children with CHD
 - From the 1980s to today, the chance of survival to adulthood has increased from 50% to 85% for the most complex CHD, from 70% to 92% for less complex CHD, and from 95% to 99% for the least complex CHD



Children's MINNESOTA

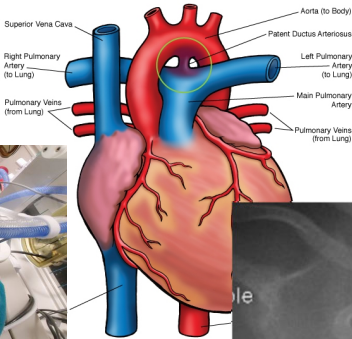
The Children's Heart Clinic

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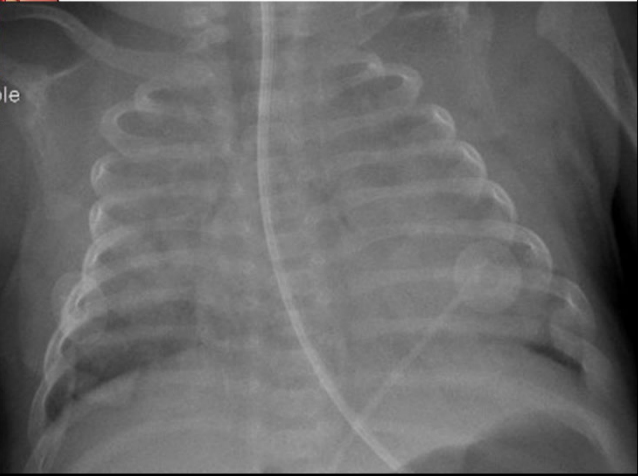
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Patent Ductus Arteriosus (PDA)



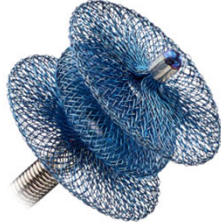
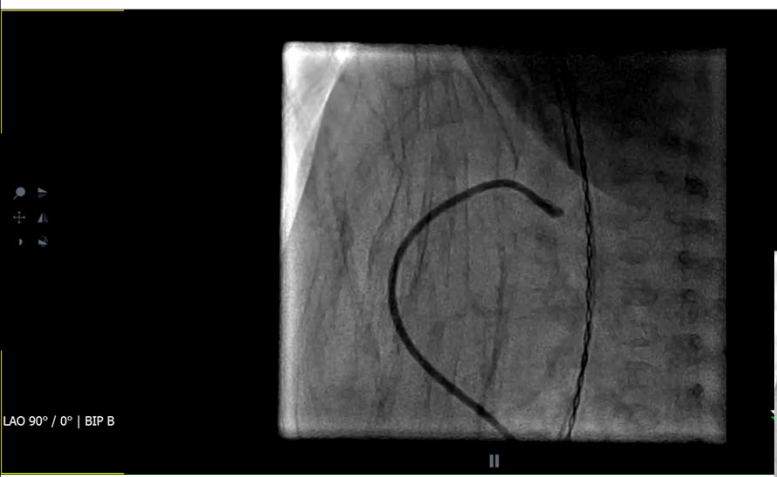




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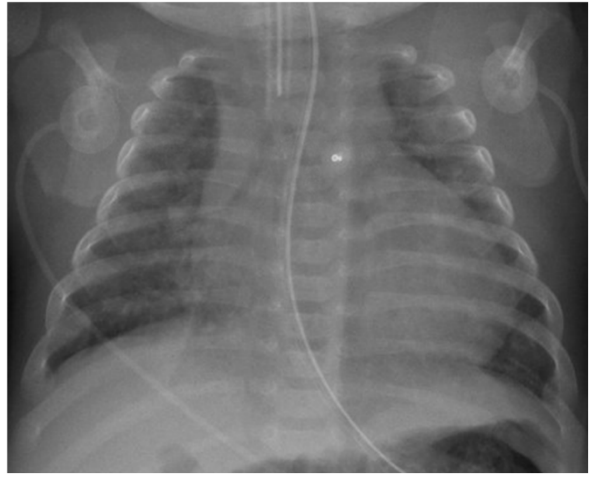
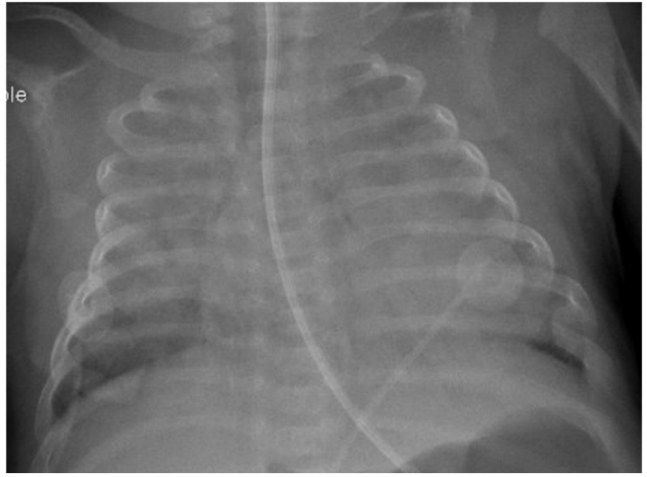
4



- Amplatzer Piccolo Occluder
- FDA approved in 2019 for premature infants ≥ 700 g

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Single Ventricle Heart Disease

- About 8% of CHD
- Survival to adolescence and young adulthood is increasingly common, life expectancy beyond 18 years exceeding 90% among patients whose condition remains stable after the 1st year

Hypoplastic Left Heart Syndrome (HLHS)

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Tricuspid Atresia

Double Inlet Left Ventricle (DILV)

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Stage I Palliation

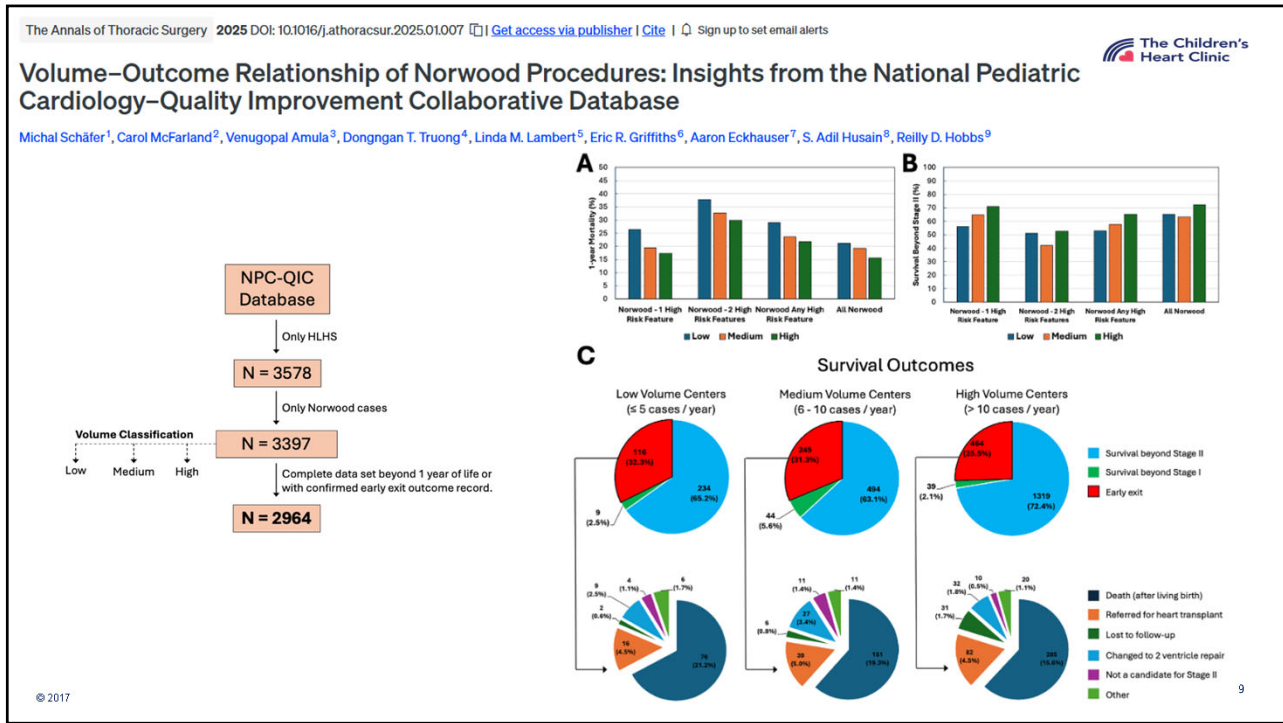
Norwood Procedure (modified BT shunt)

Norwood Procedure (Sano modification)

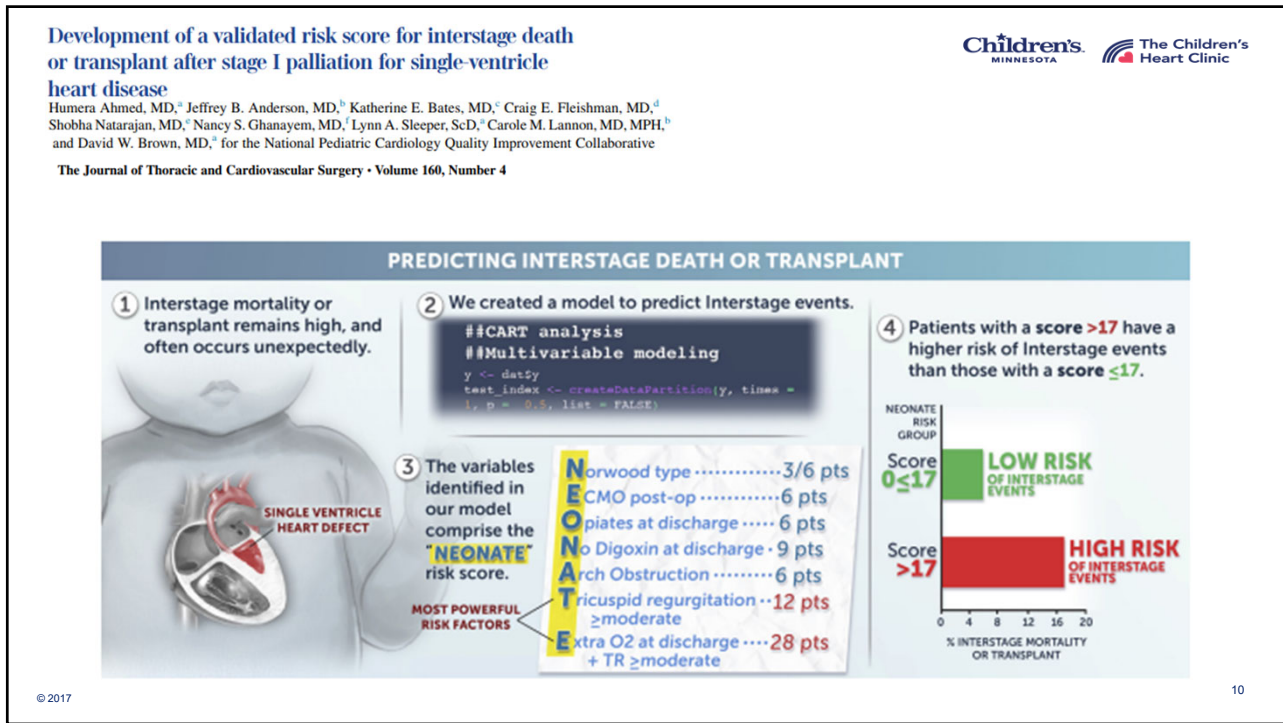
Hybrid Procedure

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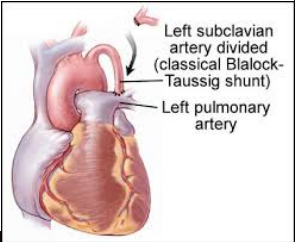


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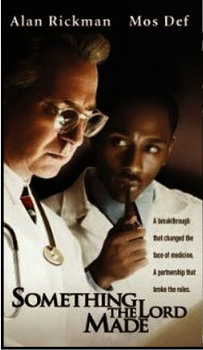
- **Classic Blalock-Taussig-Shunt (BTTS)**
 - Subclavian artery is transected and then sutured to the PA





Dr. Alfred Blalock **Vivien Thomas**

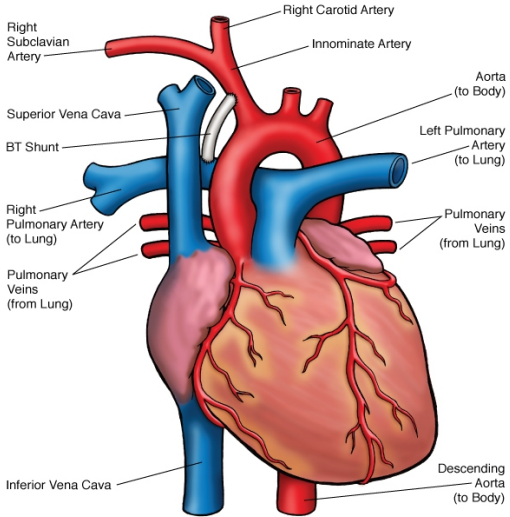
PHOTOS BY THE ALAN MASON CHESNEY MEDICAL ARCHIVES OF THE JOHNS HOPKINS MEDICAL INSTITUTIONS

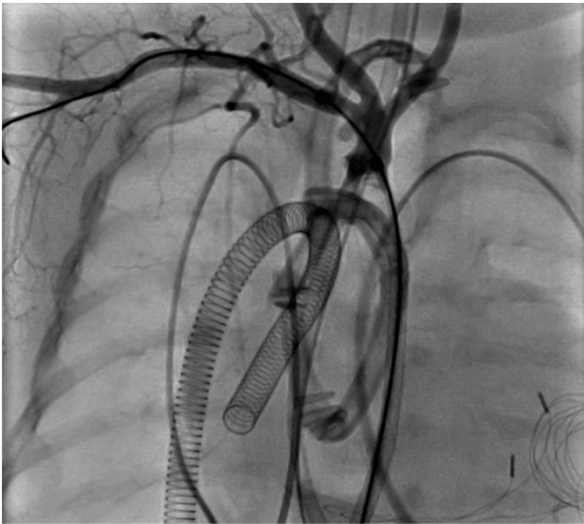


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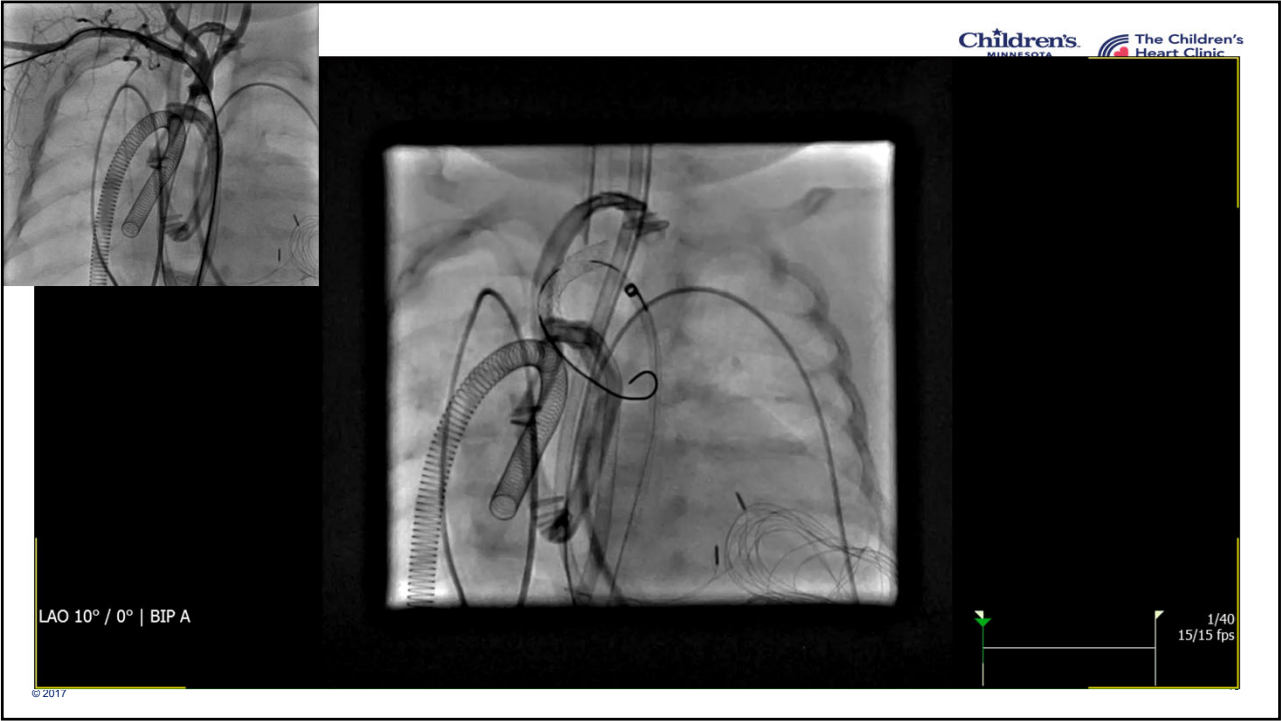
Modified Blalock-Taussig Shunt (MBTS)



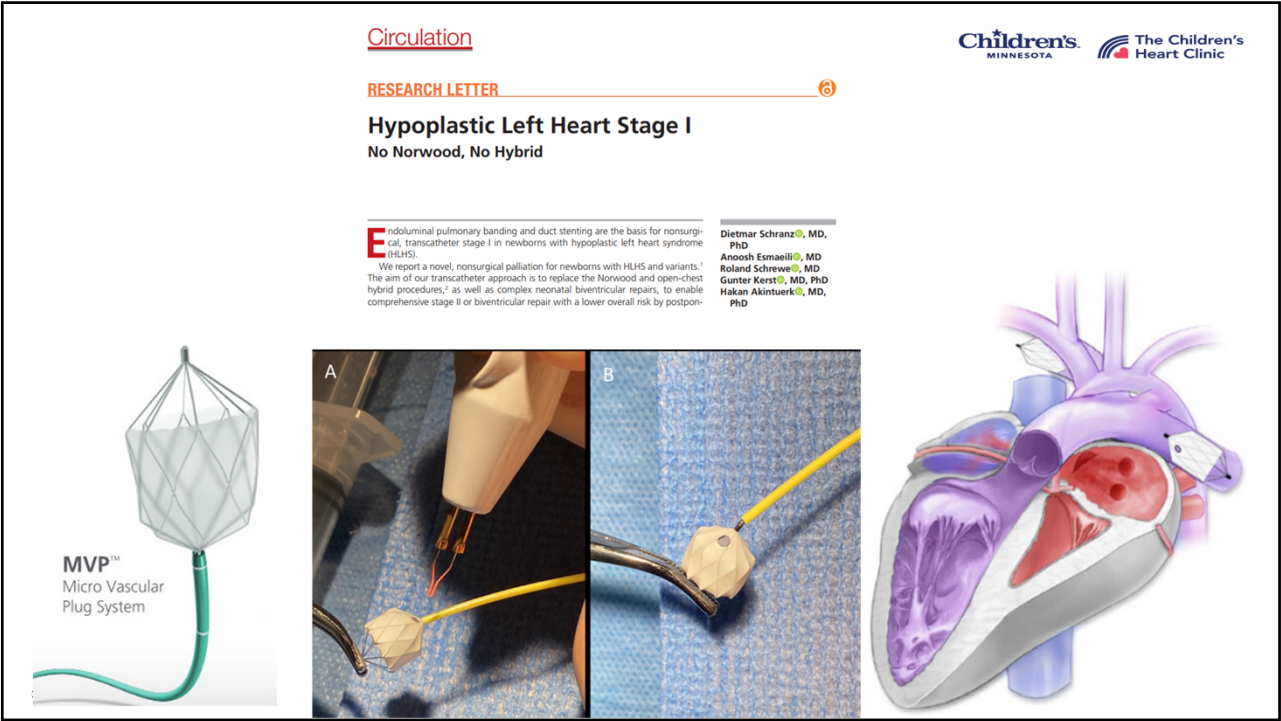


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Congenital Cardiovascular Interventional Study Consortium



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Brief Report – Pulmonary Flow Restrictor (PFR) Registry

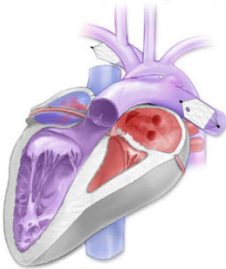
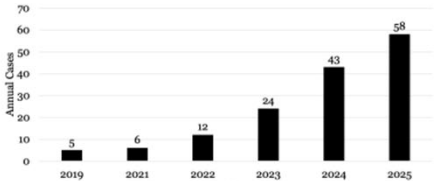
Registry Progress

- Total enrollment: 148 cases
- Participating centers: 17
- Study cohort analyzed: 132 patients (BL branch PAs n=126, Single PA branch n=6)

Initial indications for PFR Implantation (n=132)

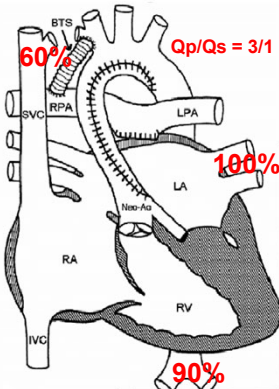
- Bridge to single ventricle palliation: n=50, 38%
- Bridge to biventricular repair: n=65, 49%
- Bridge to transplant: n=10, 8%
- Palliative purpose: n=7, 5%

Figure. Number of enrolled cases per year. Year 2025 has the largest number of enrollments.



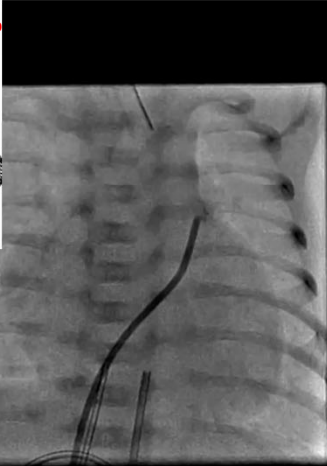
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Hypoplastic Left Heart Syndrome (HLHS)

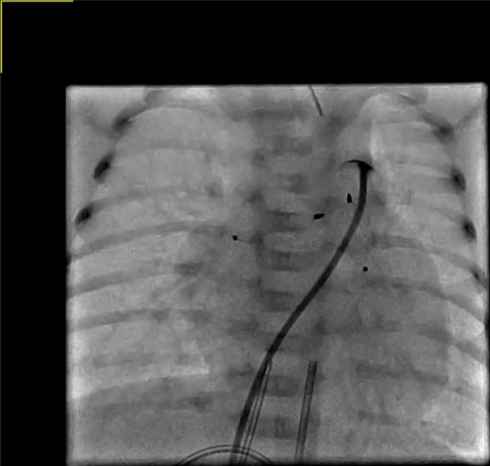


Pulmonary Flow Restrictors

- 2.08 kg, 6 days old



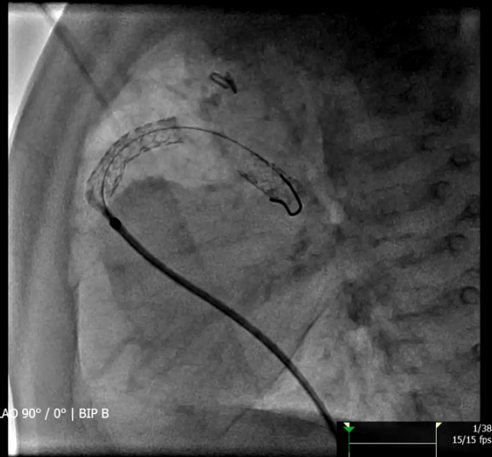
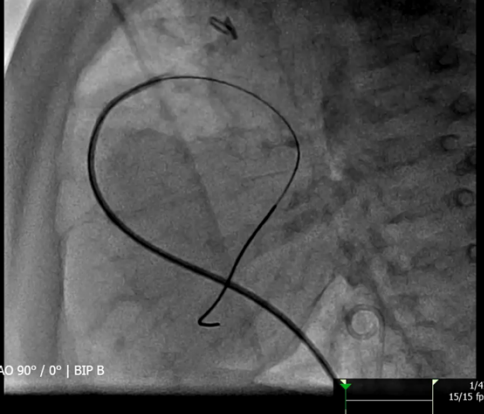
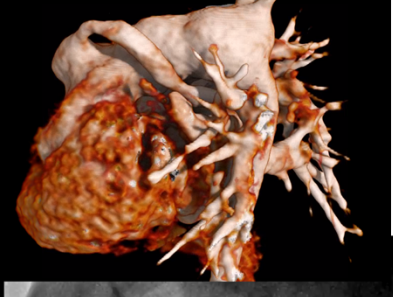
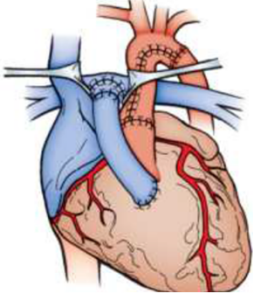
0° / 0° | BIP A
1/54
15/15 fps



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15/15 fps

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- Underwent Norwood with Sano shunt at 5 weeks old, 2.5 kg
- Sano stents at 4 months old, 5.5 kg

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LAO 90° / 0° | BIP B

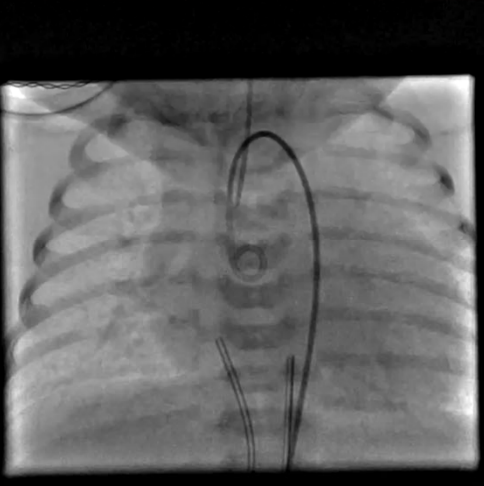
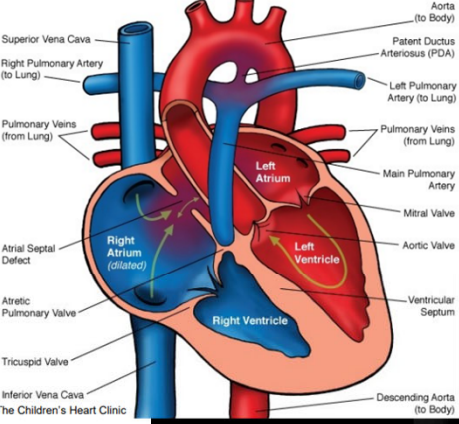
1/47 15/15 fps

LAO 90° / 0° | BIP B

1/38 15/15 fps

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**Pulmonary Atresia
Intact Ventricular Septum (IVS)**



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0° / 0° | BIP A

1/94 15/15 fps

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Pulmonary Atresia Intact Ventricular Septum (IVS)

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15/15 fps

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Pulmonary Atresia Intact Ventricular Septum (IVS)

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5/5 fps

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Pulmonary Atresia Intact Ventricular Septum (IVS)

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15/15 fps

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Stage II – Bidirectional Glenn

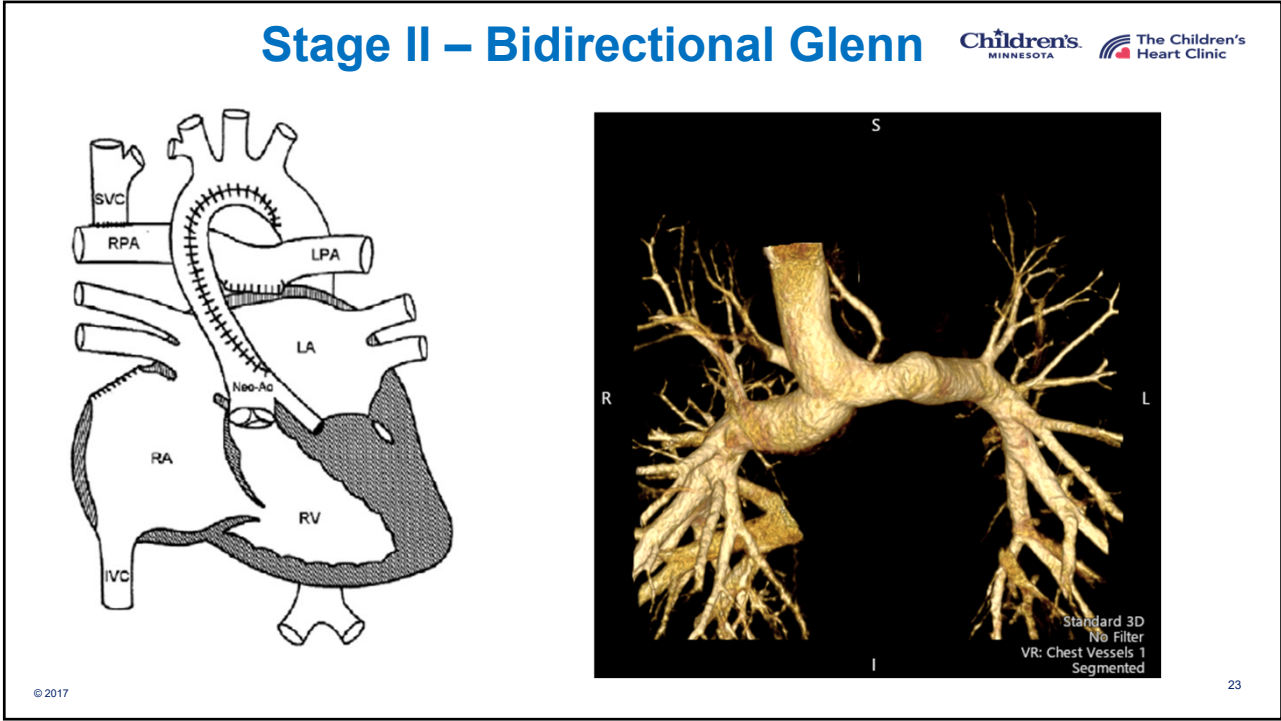
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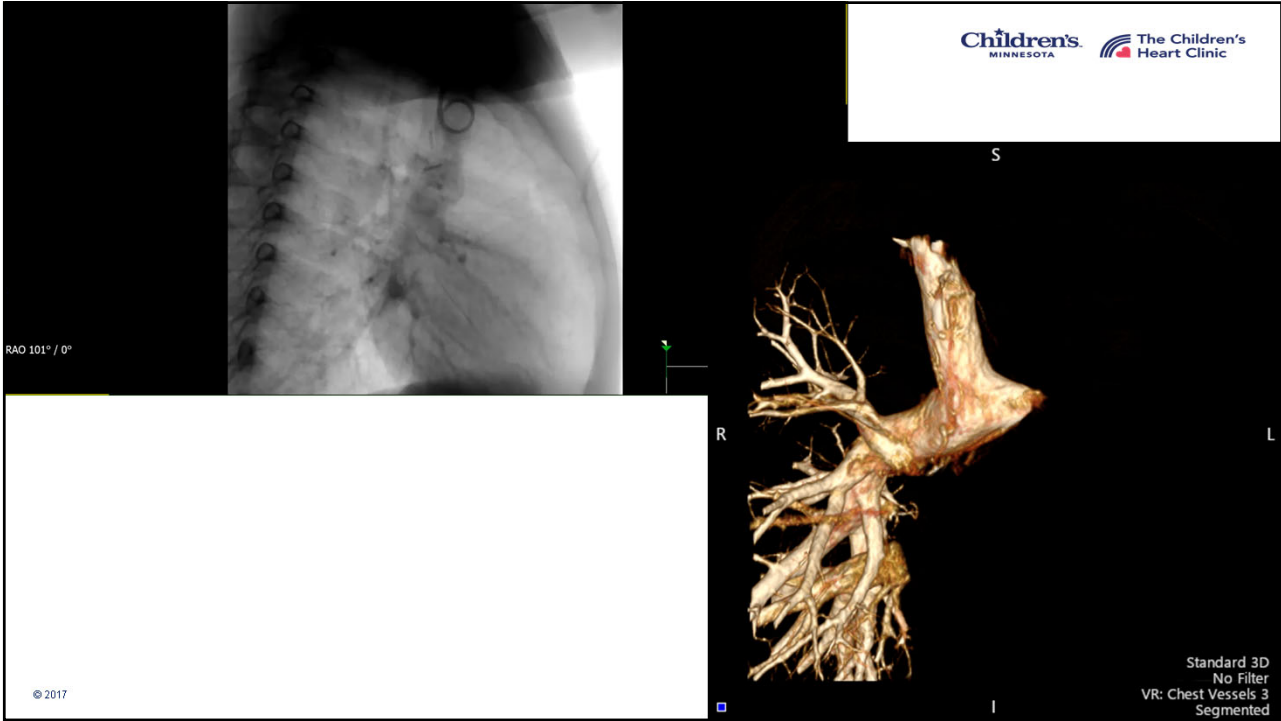
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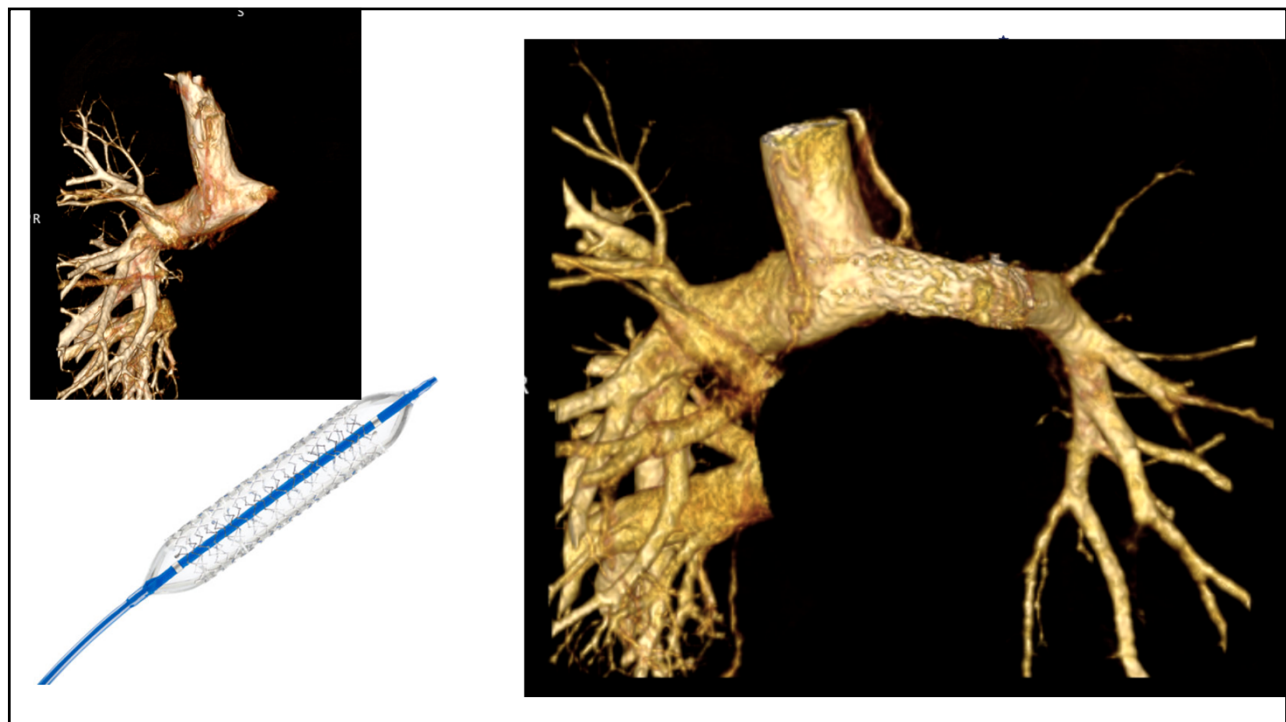
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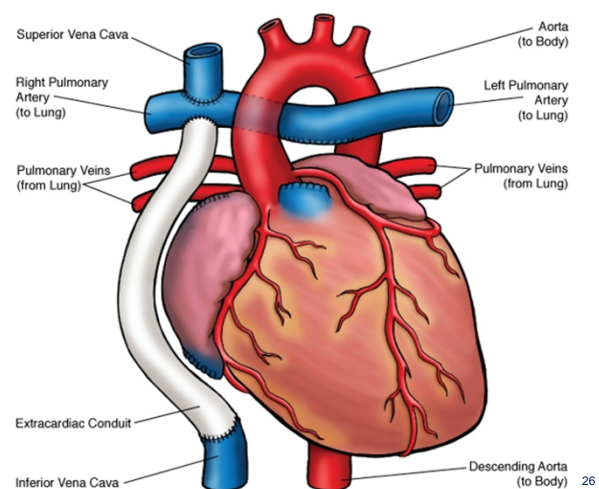
25

Stage III - Fontan

Surveillance cardiac catheterization every 10 years.

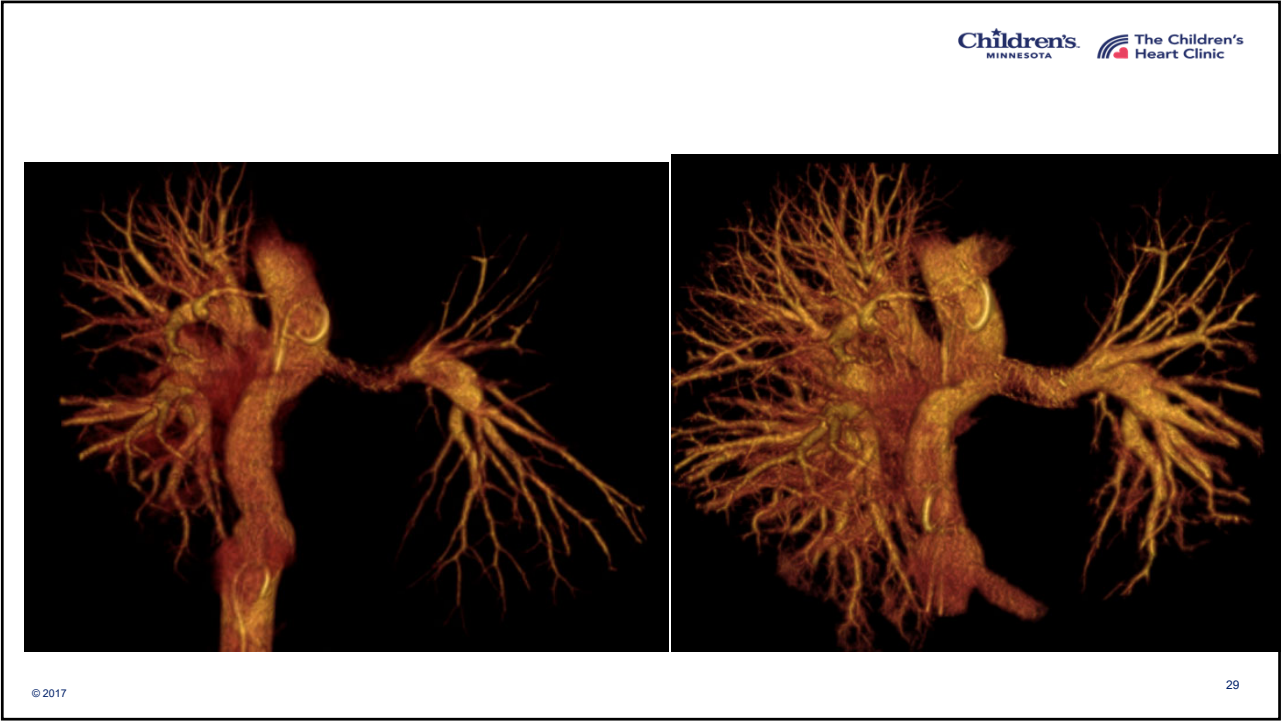
Patel N.D. et al (2020) Routine surveillance catheterization is useful in guiding management of stable Fontan patients. *Pediatric Cardiology*.

- Retrospective review of 63 patients
- 57 underwent liver biopsy, all but one had fibrosis
- PDE5 inhibitors initiated in 9
- 39.7% had intervention, Stents in 19



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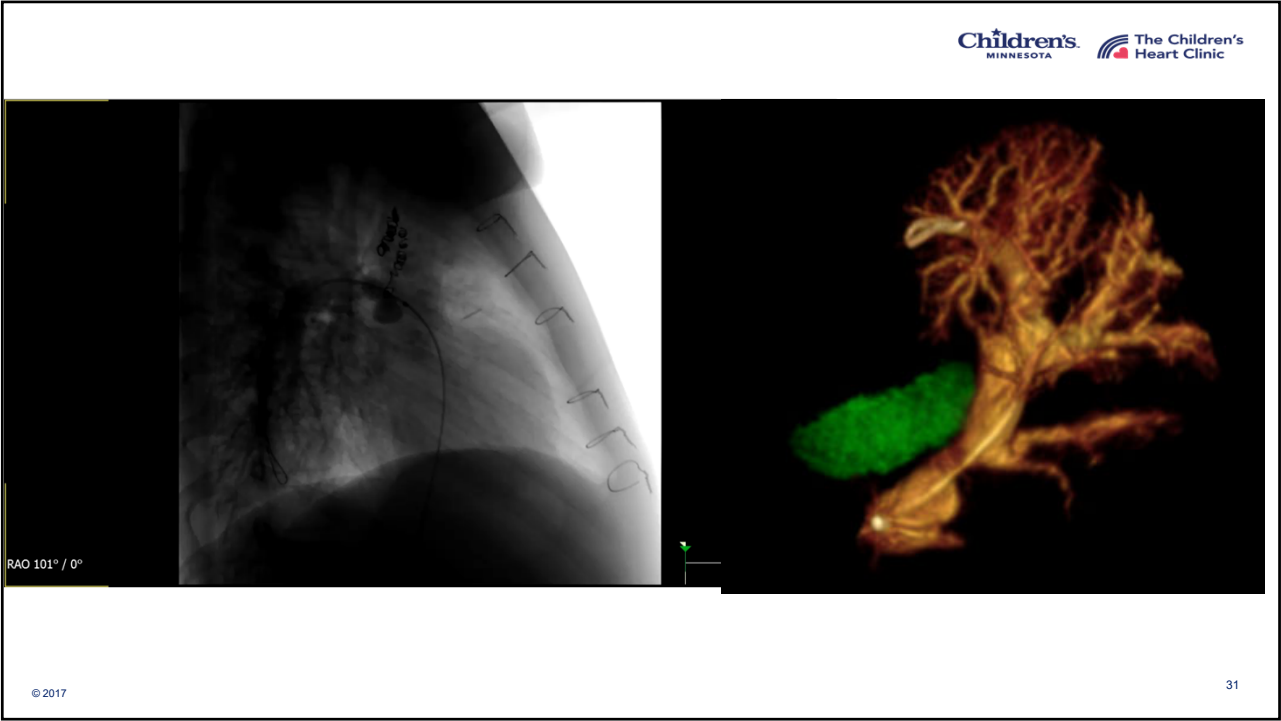
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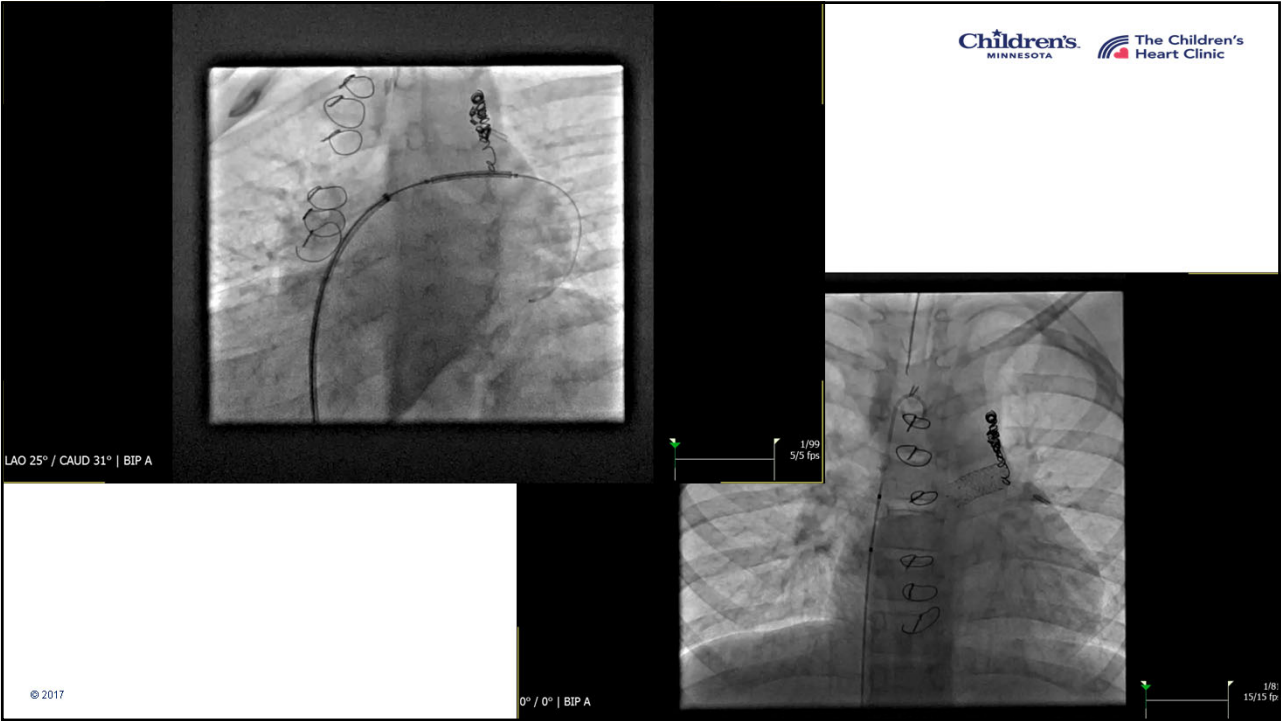
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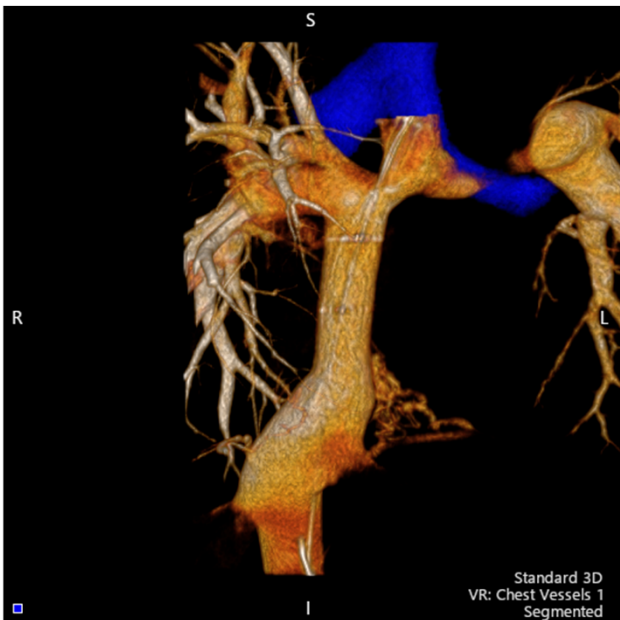
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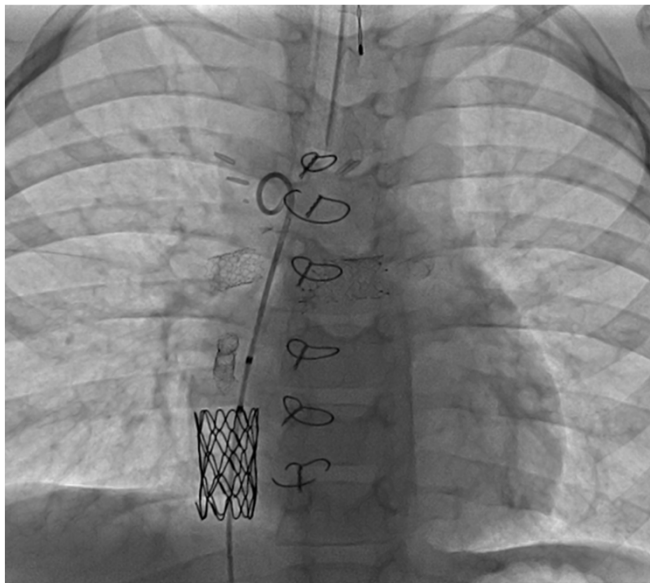
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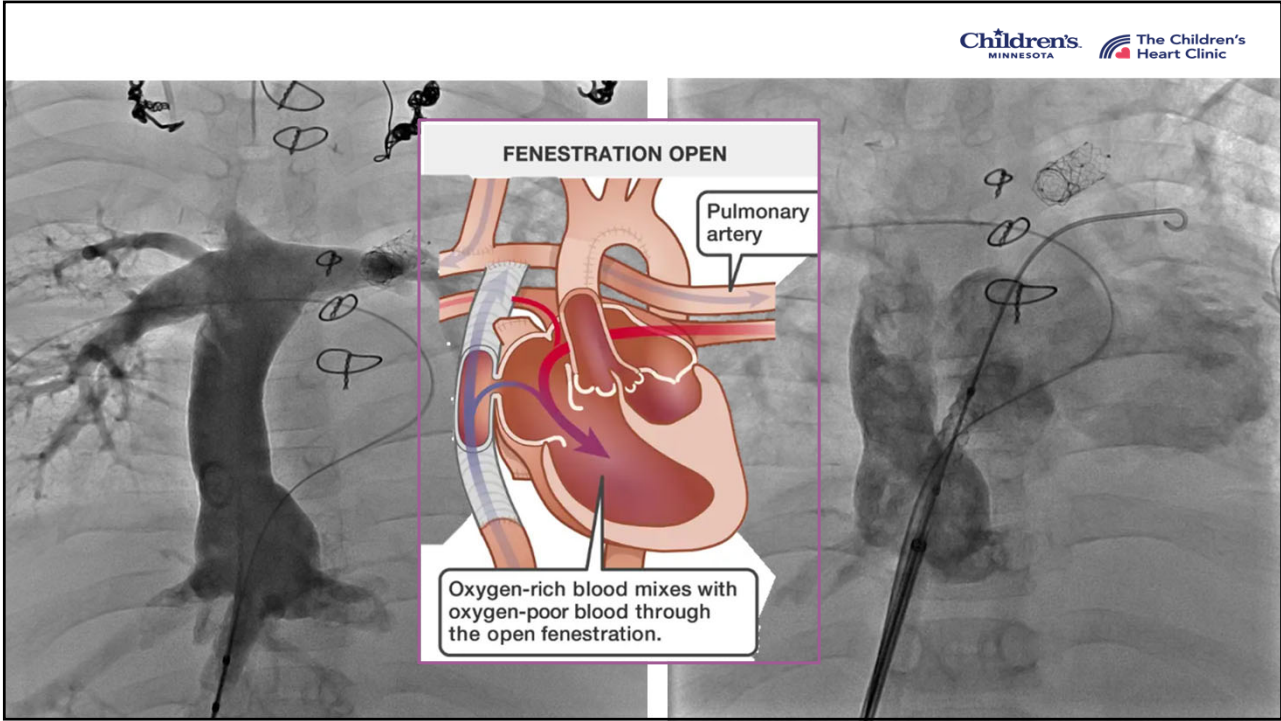
32



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Notable Late Complications

Plastic Bronchitis

< 5% Fontan Patients

Bronchial protein loss

- Lymphatic leak
- Fibrinous bronchial casts

Airway obstruction

- Wheezing



Protein Losing Enteropathy (PLE)

5-12% Fontan patients

Intestinal protein loss

- Lymphatic leak
- Diarrhea, abd pain/fullness, effusions, ascites (abd fluid)

Due to poor gut perfusion

- Venous congestion/lymphatic overload

AV valve failure

~50% patients at age 25

Less if mitral valve morphology

Higher risk if valve operation performed at time of Fontan³⁶

© 2017
Rychik J, Goldberg, D. Late Consequences of the Fontan Operation. *Circulation*. 2014;130:1525-1528.

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Transcatheter Pulmonary Valve Replacement

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Tetralogy of Fallot

Aortic Stenosis - Valvar

Ross Procedure

Balloon Expandable Valves

Self-expanding Valves

Self-expanding Presept

Transcatheter Pulmonary Valve Replacement: A Review of Current Valve Technologies
Neil D. Patel, MD^{1,2}, Daniel S. Levi, MD³, John P. Cheatham, MD⁴, Shaked A. Qureshi, MD⁵, Shabana Shahmoradian, MBBS⁶, Evan M. Zahn, MD⁷
Journal of the Society for Cardiovascular Angiography & Interventions 1 (2022) 100452

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Medtronic Melody Valve

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- First transcatheter valve implanted in a human in 2000 by Dr. Philip Bonhoeffer.
 - First to be FDA approved in 2010
- Valved bovine jugular vein sewn into a platinum-iridium stent
 - Veins are either 16 or 18 mm in diameter and are designated as TPV 20 and TPV 22, respectively.

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Variations in Right Ventricular Outflow Tract Morphology Following Repair of Congenital Heart Disease: Implications for Percutaneous Pulmonary Valve Implantation

Silvia Schievano,¹ Louise Coats,¹ Francesco Miglilavacca,² Wendy Norman,¹ Alessandra Frigiola,¹ John Deanfield,¹ Philipp Bonhoeffer,¹ and Andrew M. Taylor¹



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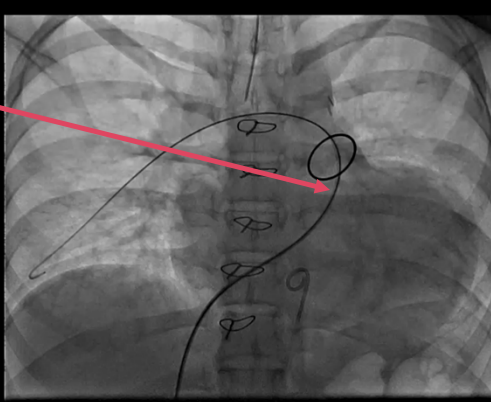
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17 year old F with a history of TOF with pulmonary atresia

Insufficient and Stenotic 22 mm RV-PA conduit

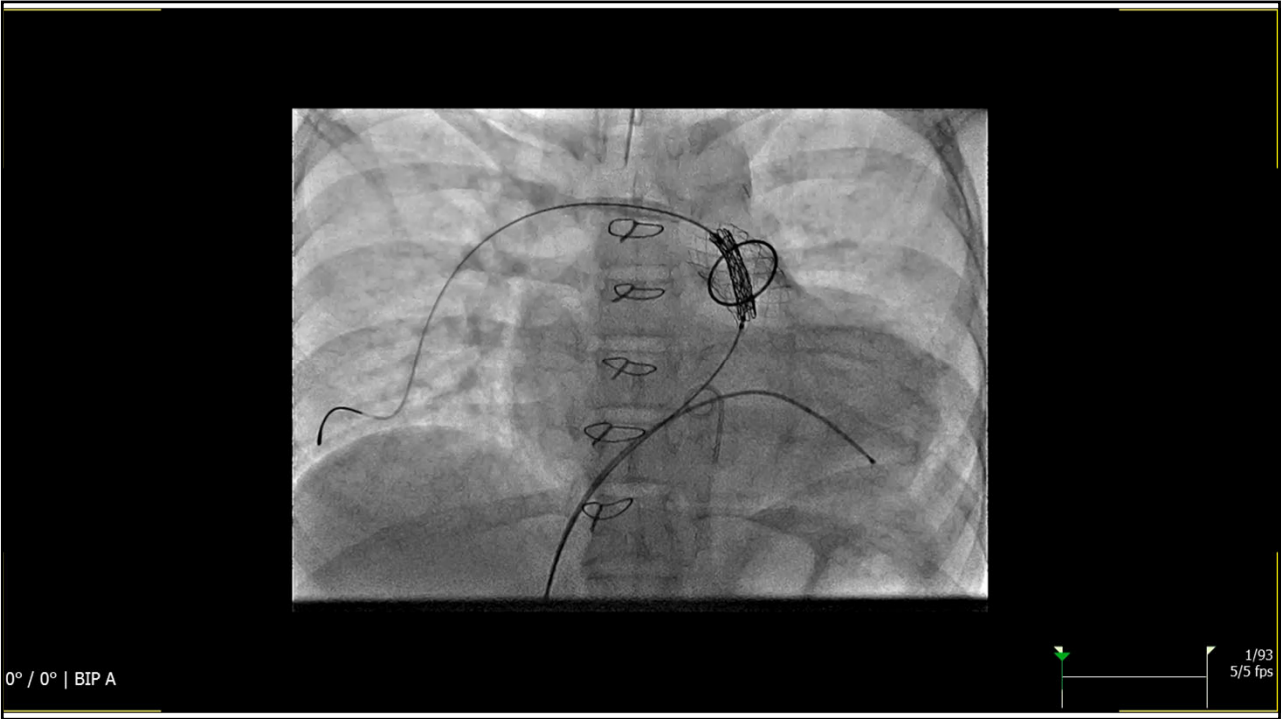


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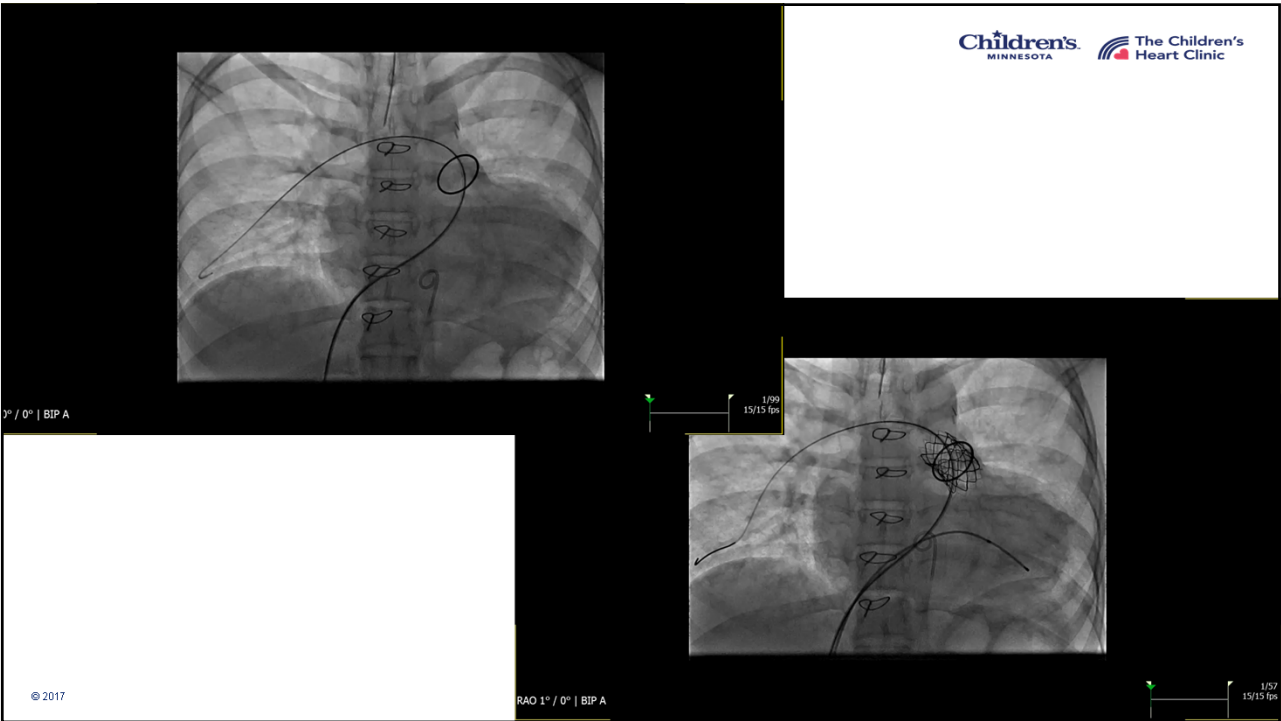
0° / 0° | BIP A

1/9
15/15 fp

40

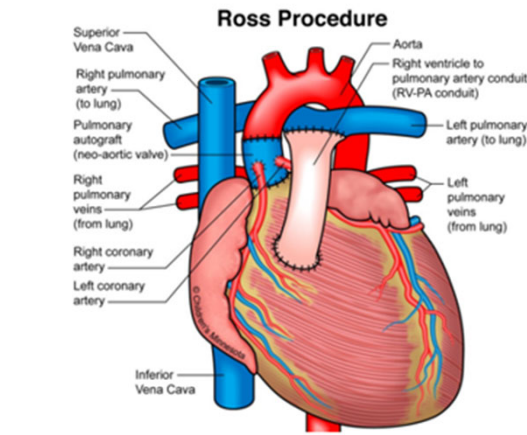


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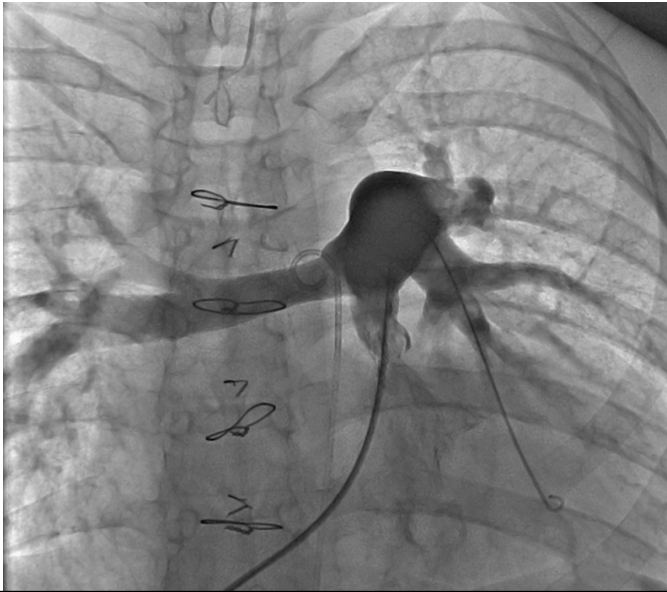


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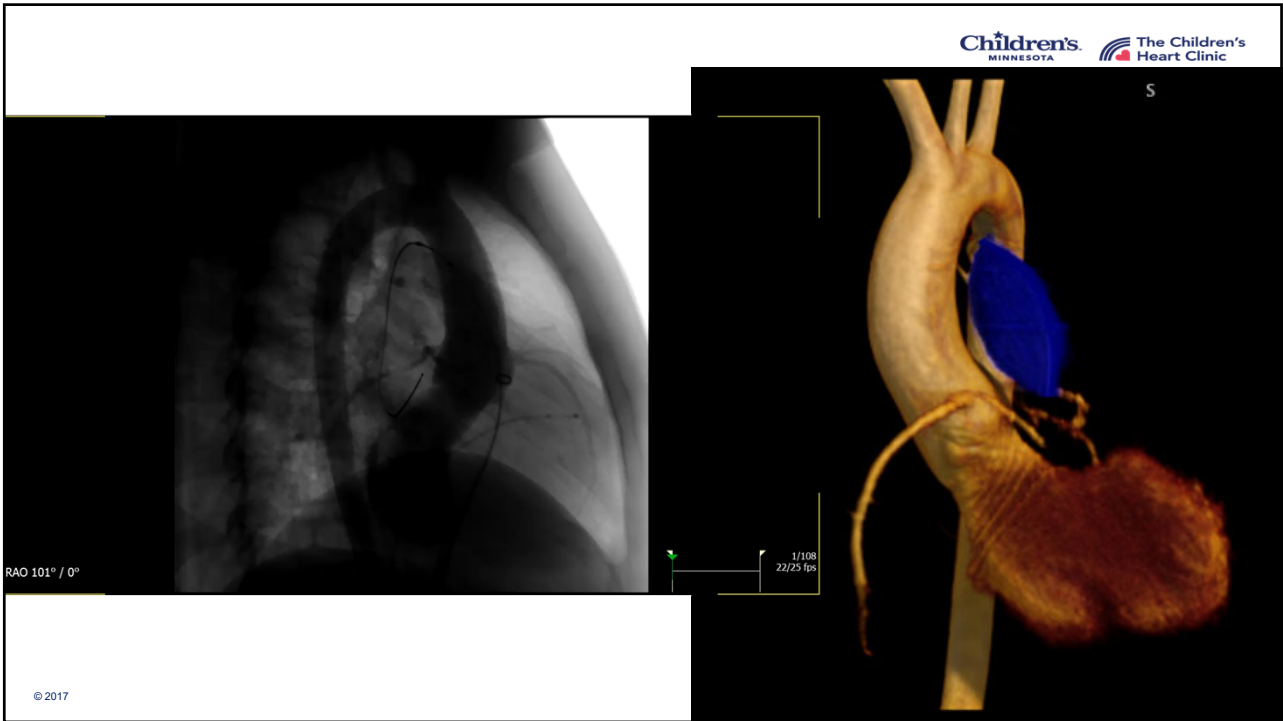
- 22 year old male with a history of aortic valve stenosis status post Ross procedure



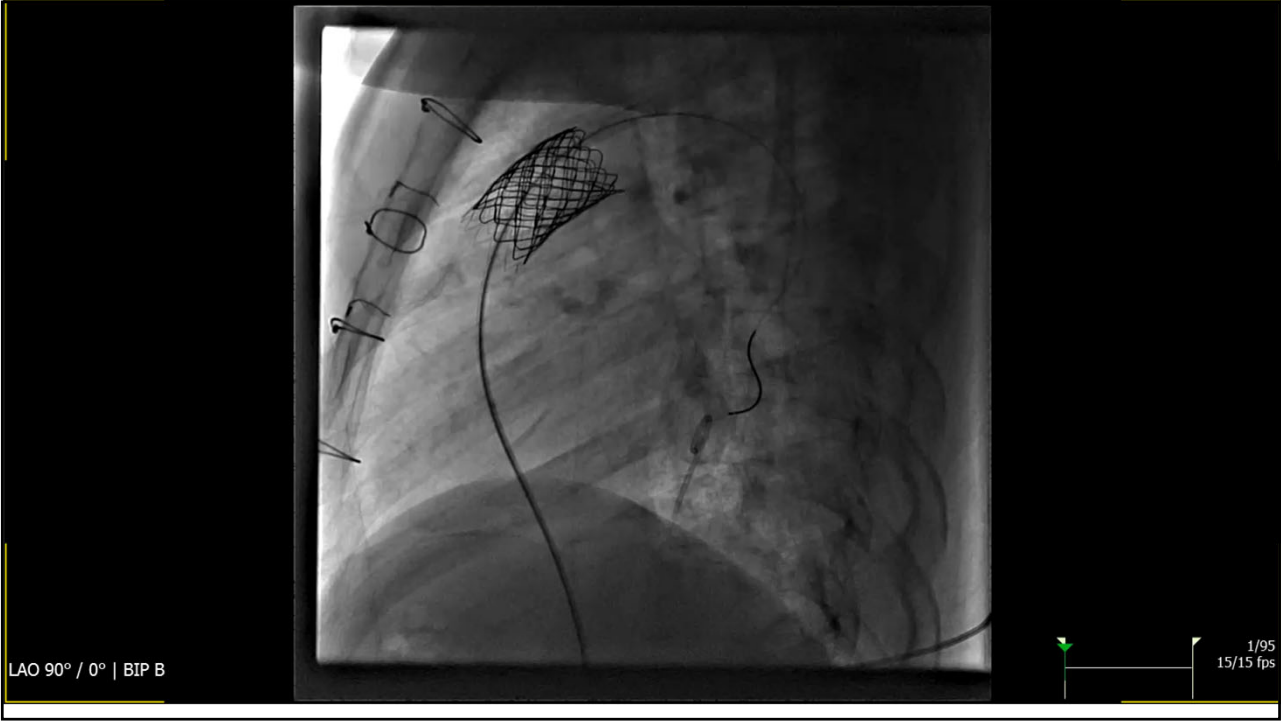
Stenotic 24 mm RV-PA conduit



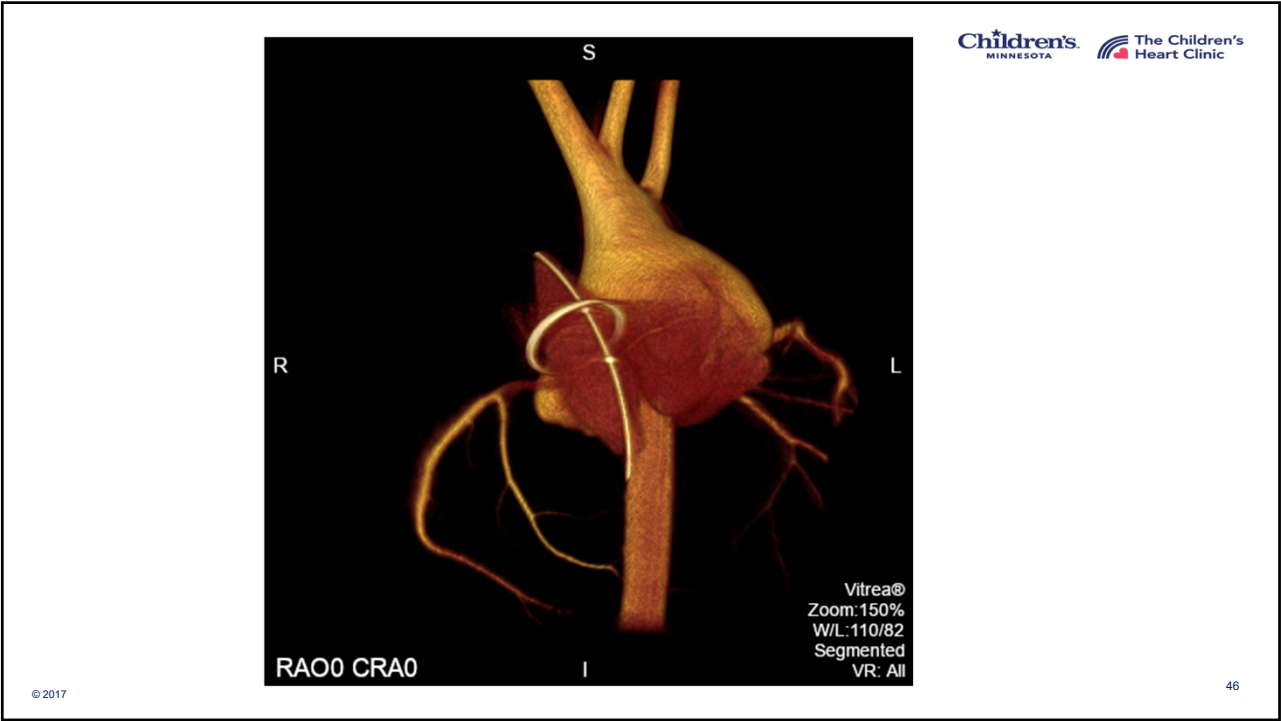
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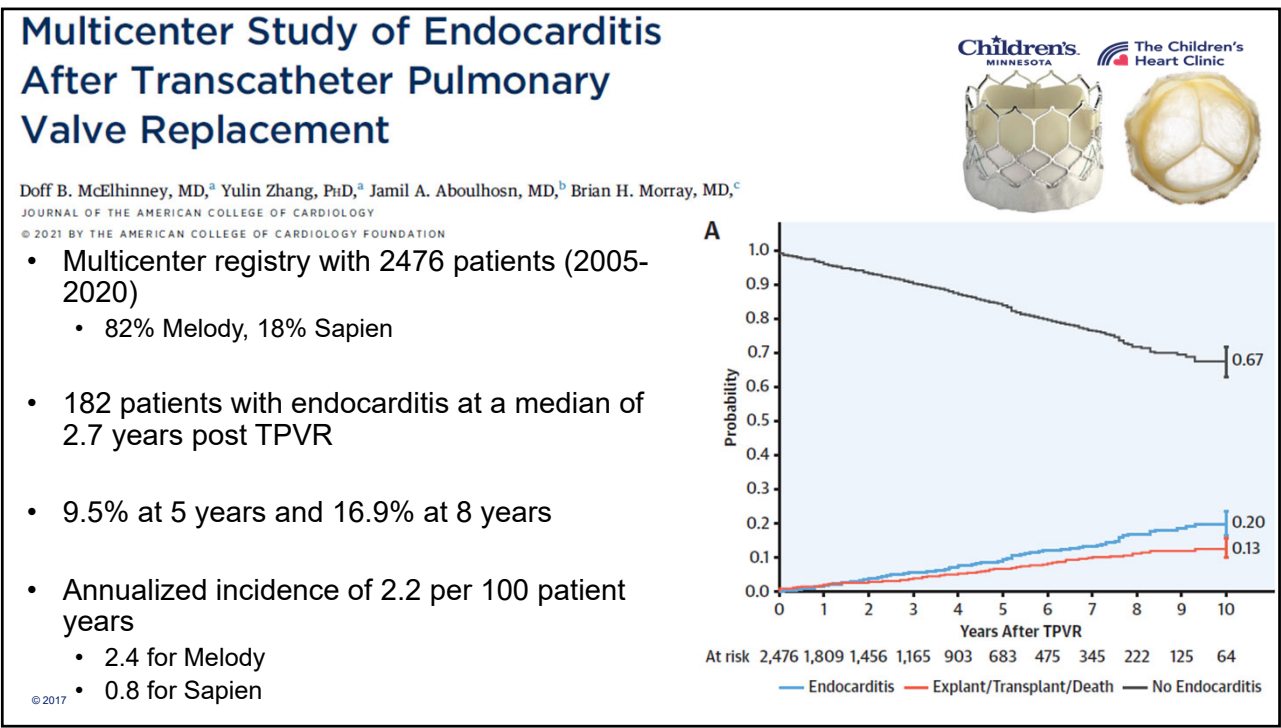
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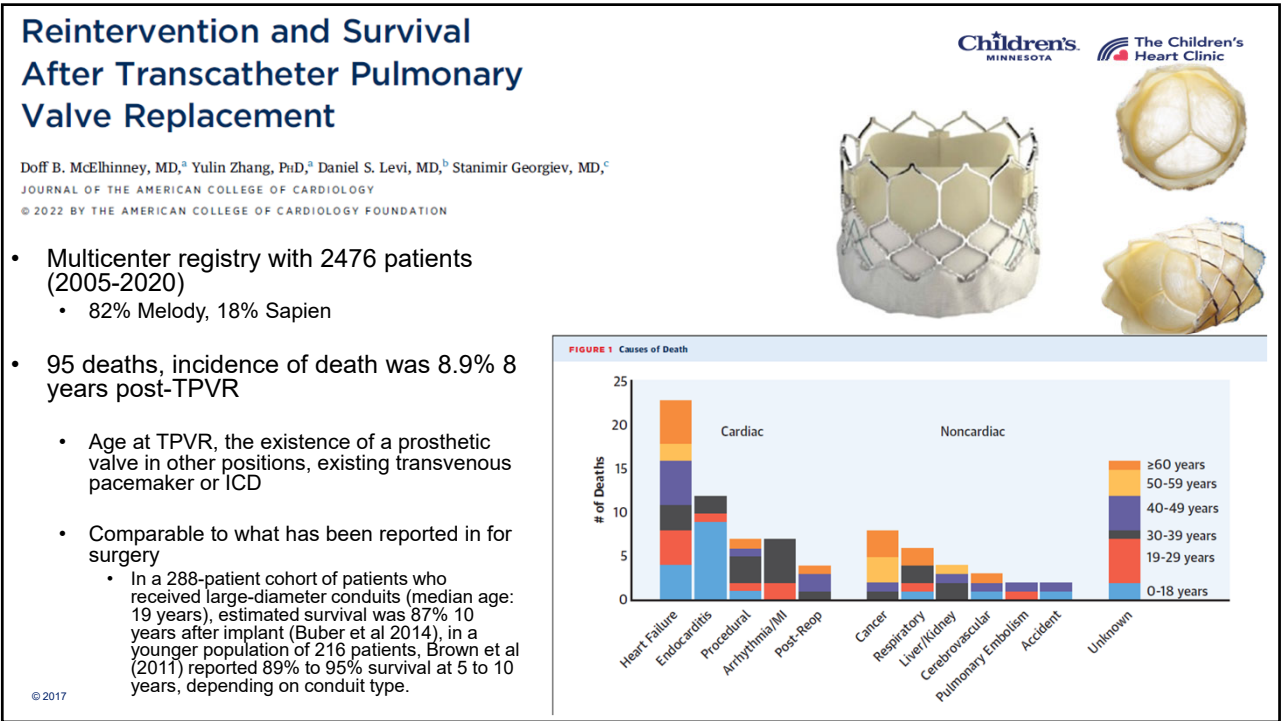
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Reintervention and Survival After Transcatheter Pulmonary Valve Replacement

Doff B. McElhinney, MD,^a Yulin Zhang, PhD,^a Daniel S. Levi, MD,^b Stanimir Georgiev, MD,^c

- A total of 258 patients underwent reintervention
 - Survival and freedom from reintervention are generally comparable to outcomes of surgical valve replacement
 - Incidence of any reintervention was 25.1% at 8 years
 - TPV explant and surgical valve replacement 14.4% at 8 years
 - 50% primary indication of TPV obstruction without endocarditis
 - Over 30% were endocarditis
 - 7% for PI or mixed PS/PI

© 2017 About ½ first reintervention were transcatheter

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Probability

Years after TPVR

At risk 2476 1908 1462 1163 904 677 470 330 210 111 54

— No reintervention
— Angioplasty only
— Second TPV
— Surgical Reintervention
— Death

All

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Medtronic Harmony Valve

First FDA-approved transcatheter valve specifically designed to treat severe pulmonary regurgitation in patients with a native or surgically-repaired right ventricular outflow tract.

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Harmony™ TPV 22		Harmony™ TPV 25	
Harmony TPV 22 PA section	Anatomical Size (perimeter-derived diameter)	Harmony TPV 25 PA section	Anatomical Size (perimeter-derived diameter)
Outflow — Distal PA/Bifurcation	22–28 mm	Outflow — Distal PA/Bifurcation	25–38 mm
Valve Housing	> 22 mm	Valve Housing	> 25 mm
Inflow — Proximal PA/RVOT	23–39 mm	Inflow — Proximal PA/RVOT	32–48 mm

© 2017

- Knitted PET cloth covering with nitinol wire frame sewn into it
- Leaflets are porcine pericardium

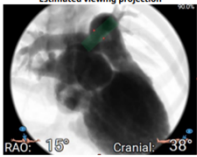
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Medtronic Harmony Valve

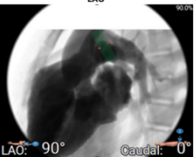
- Candidacy is determined based on CTA with post processing

Estimated viewing projection



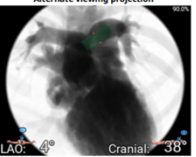
RAO: 16° Cranial: 38°

LAO



LAO: 90° Cranial: 0°

Alternate viewing projection

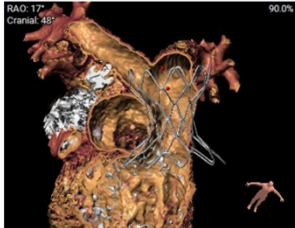


LAO: 6° Cranial: 38°

AP Angio

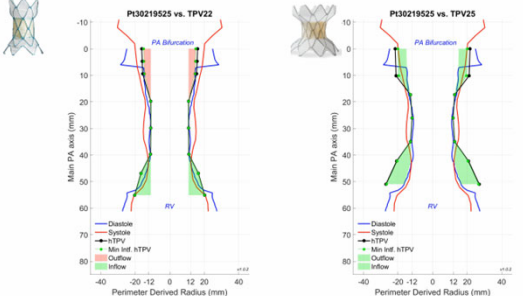


RAO: 0° Cranial: 0°

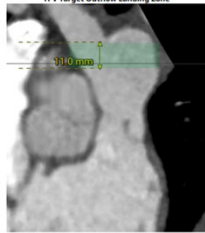


RAO: 17° Cranial: 45°

Perimeter Plot



TPV Target Outflow Landing Zone

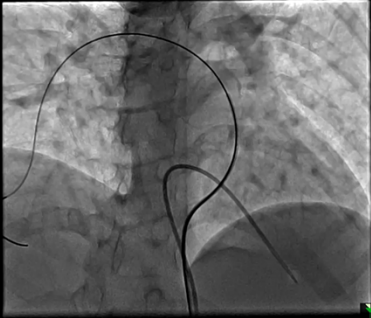


11 mm landing zone begins at the roof of the bifurcation

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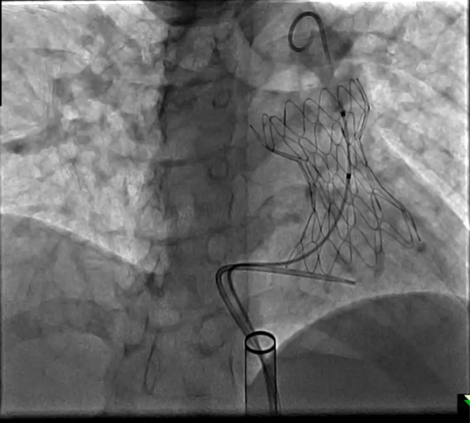
55

Medtronic Harmony Valve



RAO 15° / CRAN 38° | BIP A

1/113 13/13 fps



RAO 15° / CRAN 38° | BIP A

1/75 15/15 fps

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Early Outcomes From a Multicenter Transcatheter Self-Expanding Pulmonary Valve Replacement Registry

Brvan H. Goldstein, MD,^a Doff B. McElhinney, MD,^b Matthew J. Gillespie, MD,^c Jamil A. Aboulhosn, MD,^d
JOURNAL OF THE AMERICAN COLLEGE OF CARDIOLOGY
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- 243 patients from 11 centers through 4/30/22
 - Freedom from PR, PS, RVOT intervention
 - 99% at 1 year and 96% at 2 years
 - Endocarditis in 6 patients at a median of 11 mo
 - 2 medical therapy, 2 explantation, 2 deaths
 - 6 RVOT re-interventions
 - 5 deaths

Freedom from PR, Stenosis, and RVOT Reintervention/Explant (%)

Time Post TPV Implant (Months)

Number at Risk

Time (Months)	0	4	8	12	16	20	24	28	32	36
Number at Risk	233	216	176	133	89	45	30	17	13	11

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Edwards Alterra Adaptive Prestent System

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- Designed to remodel RVOT for suitable landing zone for 29 mm Sapien 3
 - FDA approved in 2021 for patients with severe PI
- Self-expanding, radiopaque, nitinol frame
- Symmetrical frame design with the inflow and outflow diameters equal to 40 mm and the central section measures 27 mm

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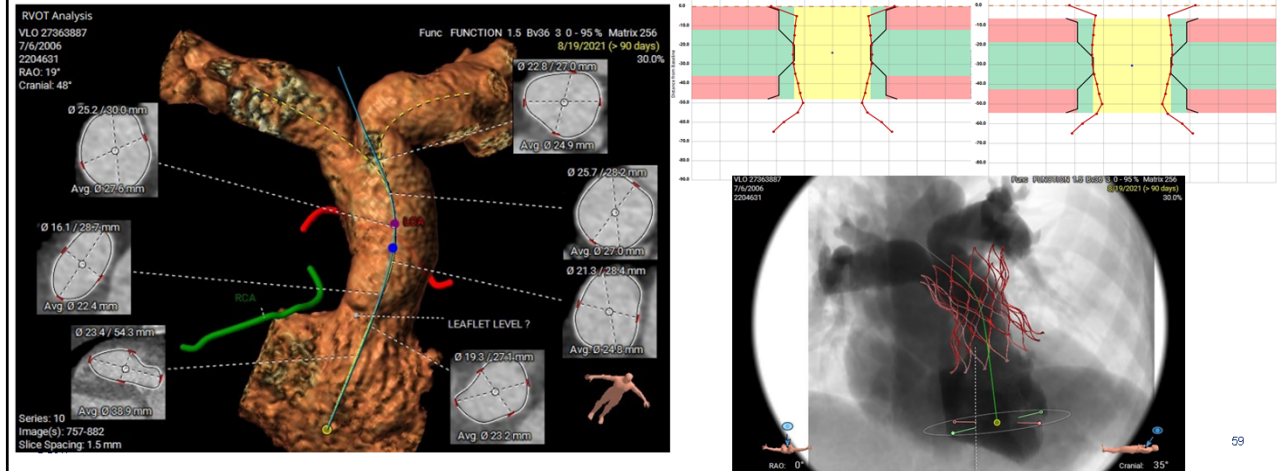
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58

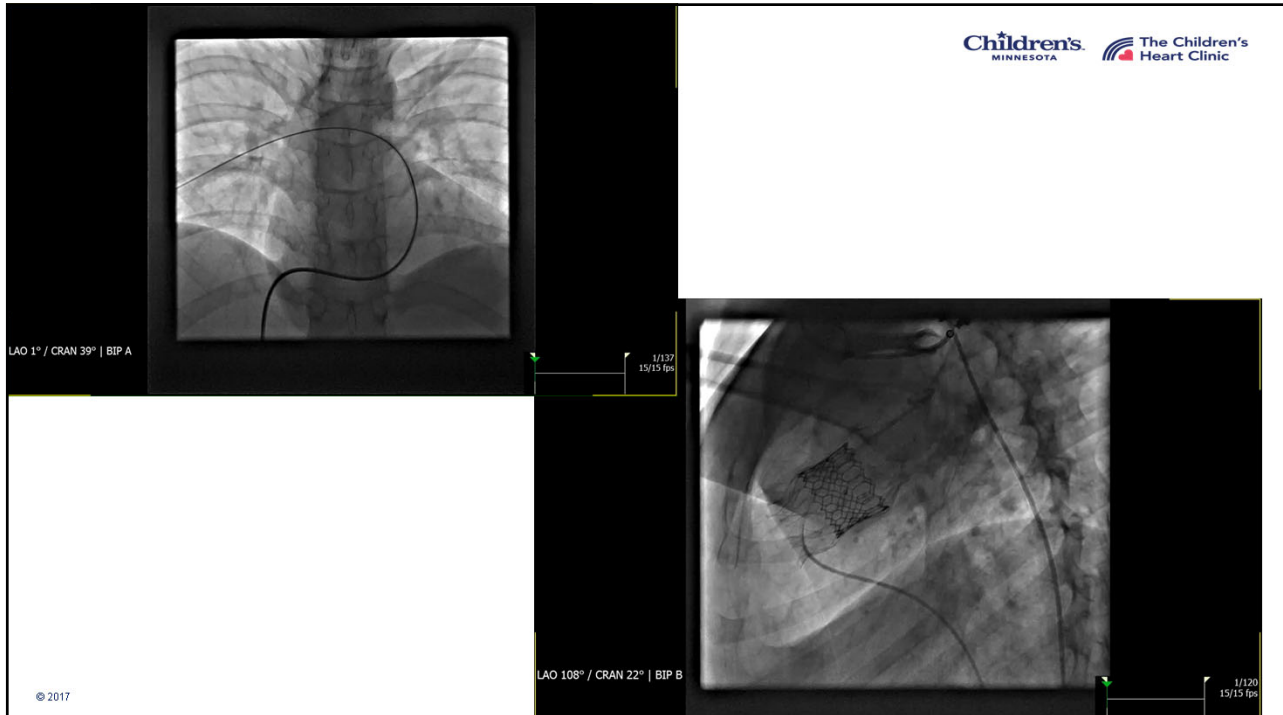
Edwards Alterra Adaptive Prestent System



- Candidacy is determined based on CTA with reconstructions
- Landing zone diameter between 27 and 38 mm with a minimum length 35 mm



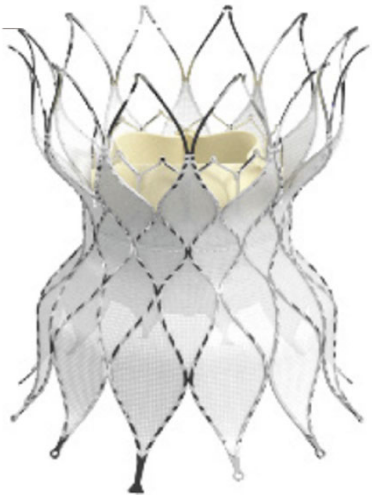
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Edwards Alterra Adaptive Prestent System

- 1 year data, 60 patients
- 33% with transient arrhythmias but none after 30 days
- 16.7% with new or worsened TR
 - Likely secondary to Commander delivery system which has been replaced with new covered design
- Improved PR and RV EDV



Zahn E, Dimas V, Babaliaros V, Kim D, Um S, Morgan G. Transcatheter pulmonary valve implantation with the Alterra adaptive Prestent and SAPIEN 3 transcatheter heart valve: one-year outcomes of the ALTERRA pivotal trial. *Pediatr Cardiol.* 2021; 42(8):1910-1911.

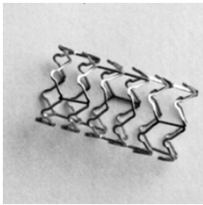
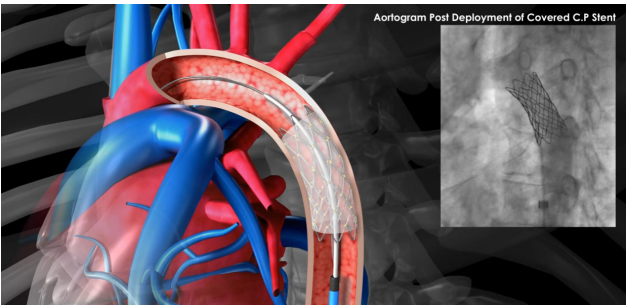
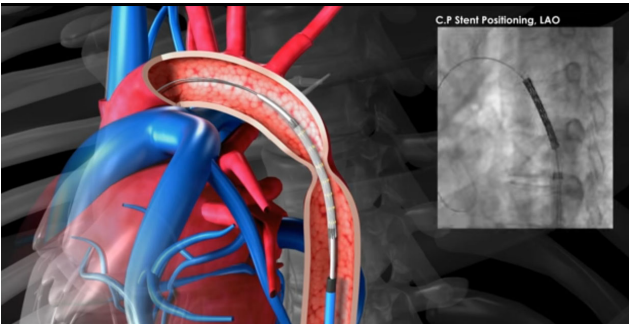
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Coarctation of the Aorta

- 5-8% of congenital heart disease
- Stenting is an option in native and post-surgical residual coarctation

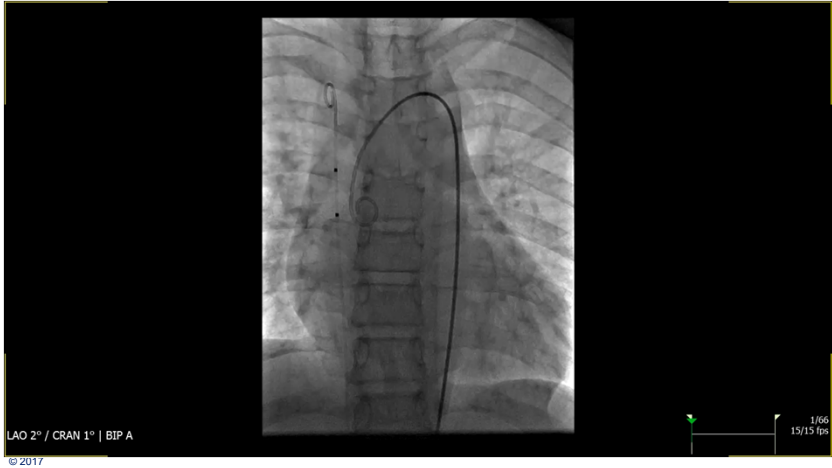


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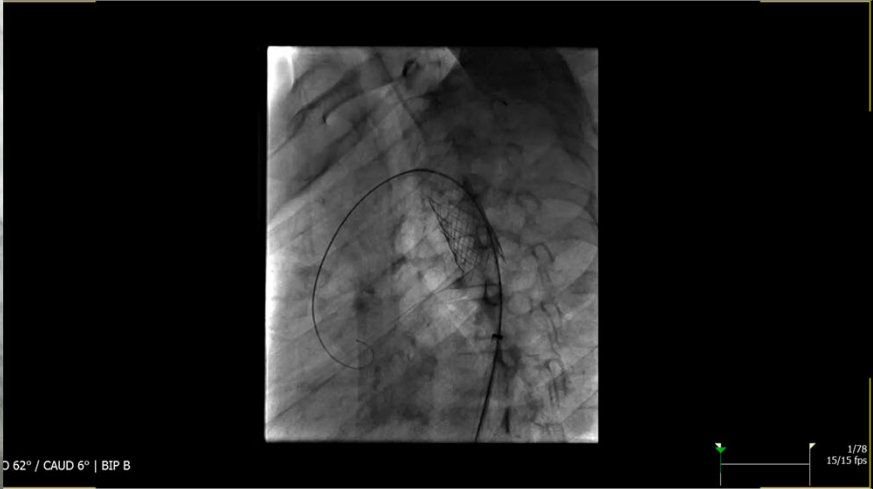
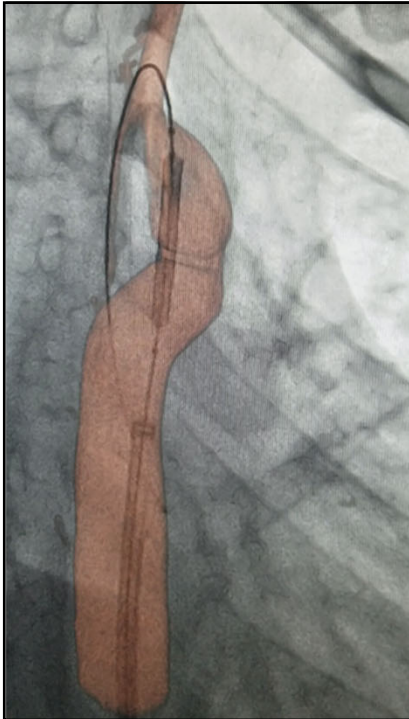
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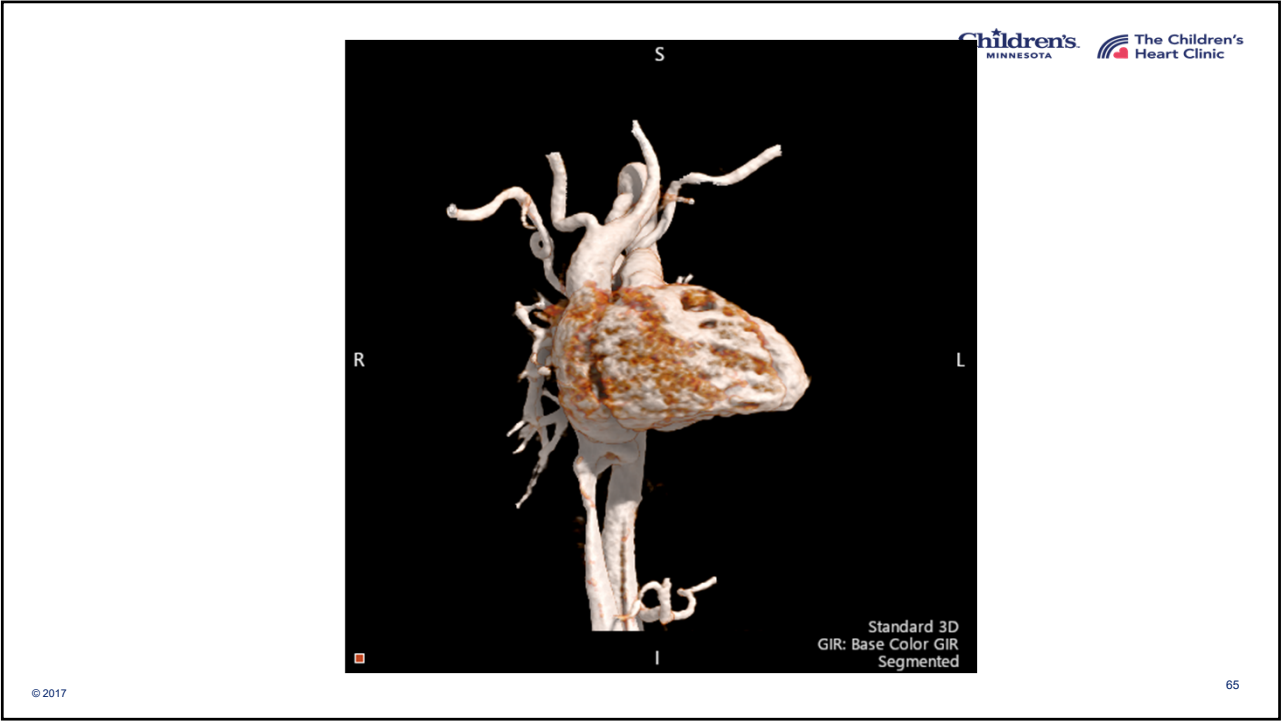
- 17 yo status post surgical coarctation repair at 9 months of age



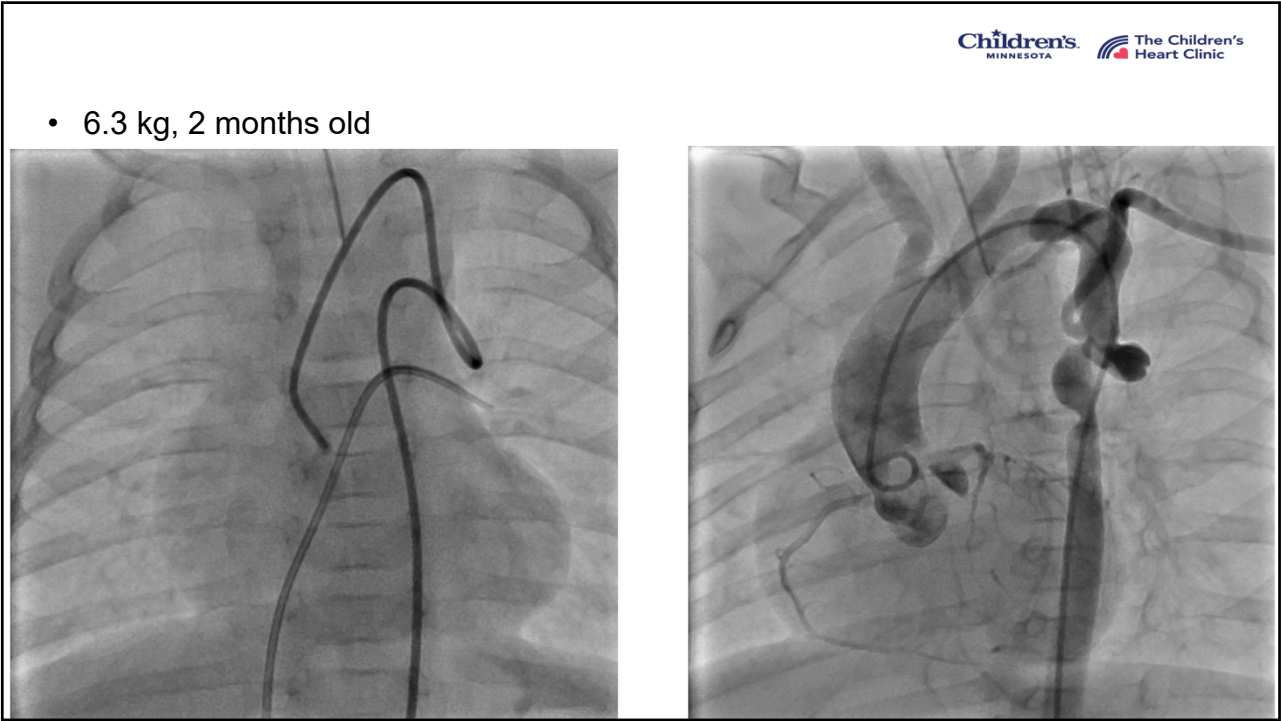
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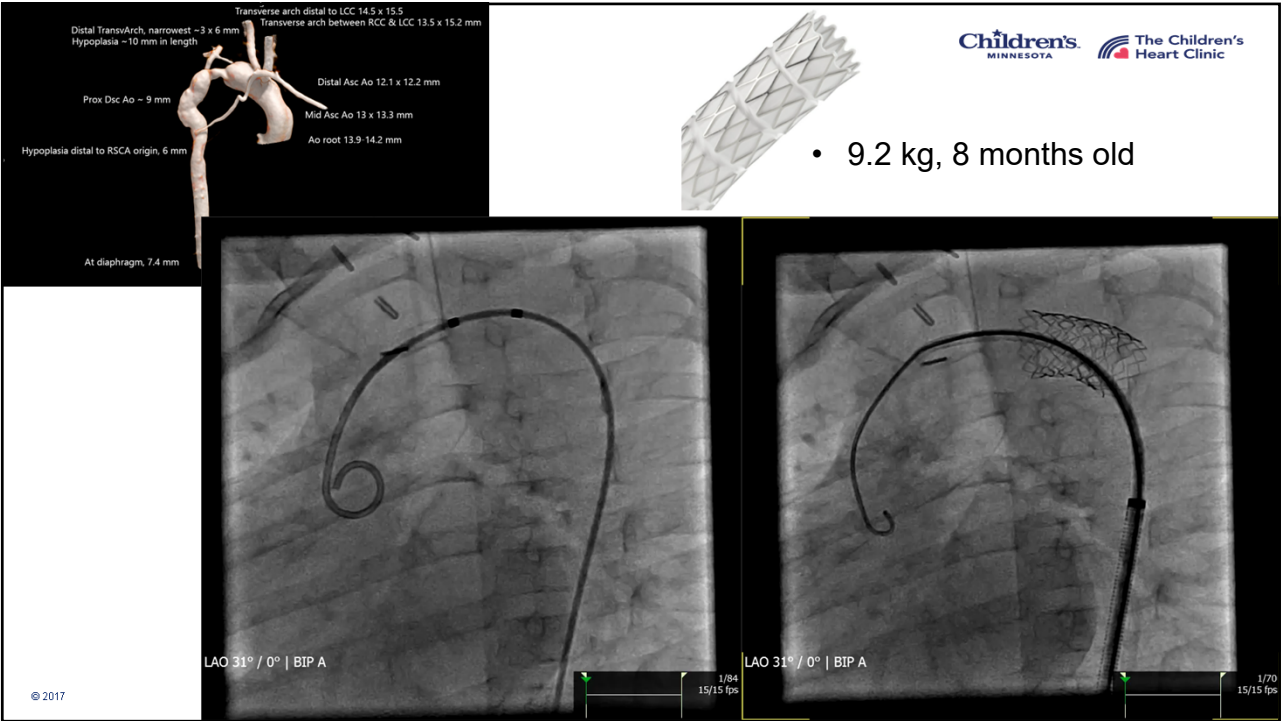
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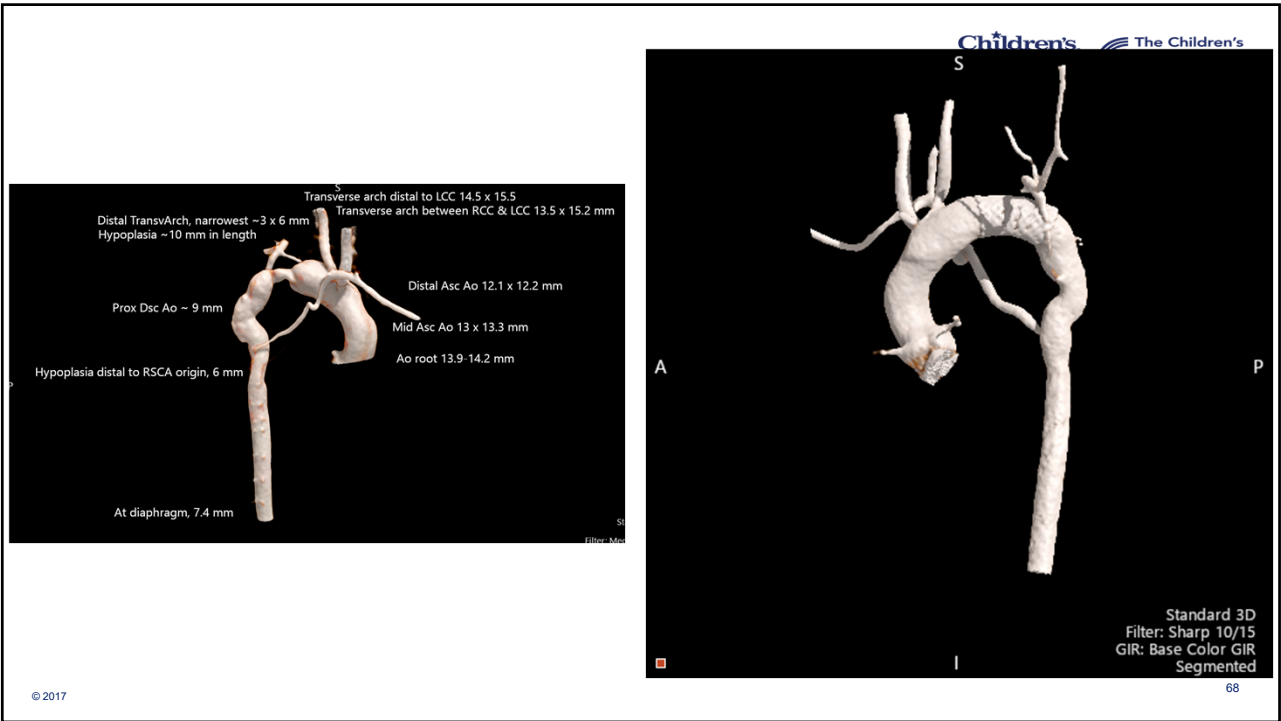
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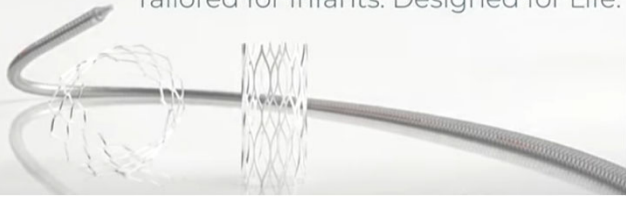
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Minima™ Stent System

Tailored for Infants. Designed for Life.





First-of-its-kind stent system FDA approved in 2024 for treating vascular stenosis in neonates and infants > 1.5 kg



< 2 mm

Premounted, front-loaded stent suitable for infant vessel access (4 Fr).



5.1 - 8.5 mm

Initial implant range tailored for infant sized vessels.



≤ 24 mm

Minima is designed for planned re-expansions up to adult sizes.*

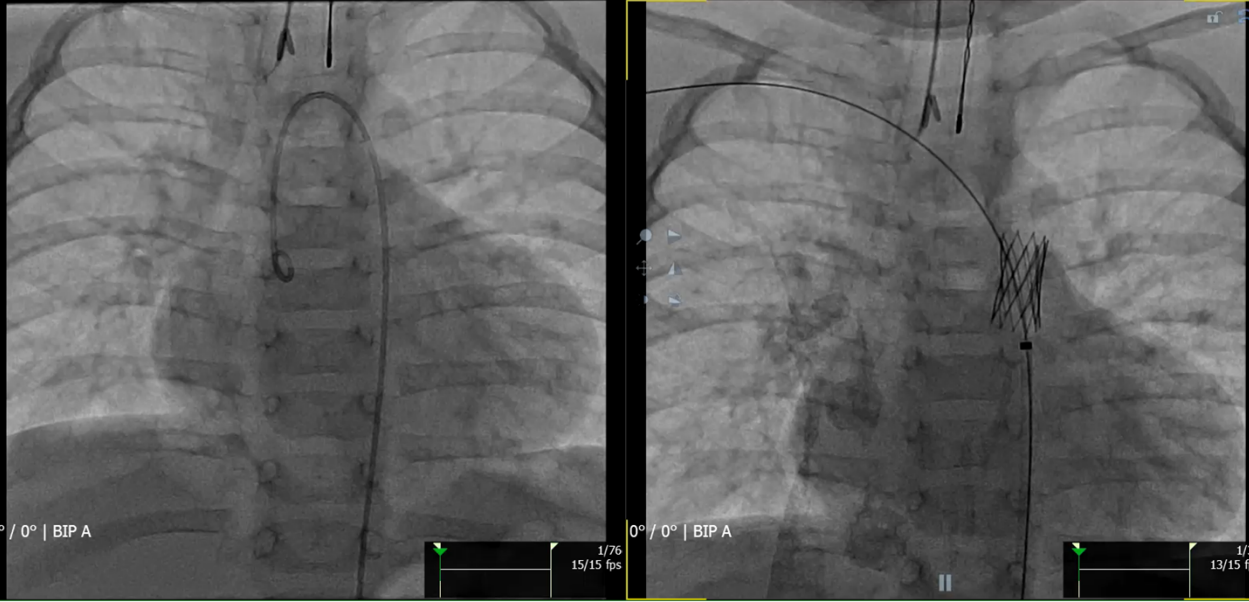
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- Post coarctation repair
- 10 months old, 10 kg





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2018 AHA/ACC Guideline for the Management of Adults With Congenital Heart Disease: A Report of the American College of Cardiology/American Heart Association Task Force on Clinical Practice Guidelines

As patients with ACHD grow beyond the pediatric age group, continued access to specialized cardiovascular care presents several challenges:

- Lack of guided transfer from pediatric to adult care;
- Insufficient availability of ACHD programs;
- Inadequate insurance coverage;
- Deficient education of patients and caregivers regarding ACHD;
- Inadequate resources for patients with cognitive or psychosocial impairment;
- Lack of comprehensive case management; and
- Different needs for evaluation and management compared with adults with acquired cardiovascular disease.

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Patients with complex CHD have generally better outcomes when cared for in an integrated, collaborative, and multidisciplinary program

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Table 5. Key Personnel and Services Recommended for ACHD Programs	Services
Personnel	Echocardiography, including TEE and intraoperative TEE*
ACHD board-eligible/board-certified cardiologists	CHD diagnostic and interventional catheterization*
Congenital cardiac surgeons	CHD electrophysiology/pacing/ICD implantation*:
Nurses/physician assistants/nurse practitioners	Exercise testing
Cardiac anesthesiologists with CHD training/expertise	Echocardiographic
Multidisciplinary teams:	Radionuclide
High-risk obstetrics	Cardiopulmonary
Pulmonary hypertension	Cardiac imaging/radiology*:
HF/transplant	CMR
Genetics	CCT
Hepatology	Nuclear medicine
Cardiac pathology	Information technology:
Rehabilitation services	Data collection
Social services	Database support
Psychological services	Quality assessment review/protocols
Financial counselors	

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Thank You!

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