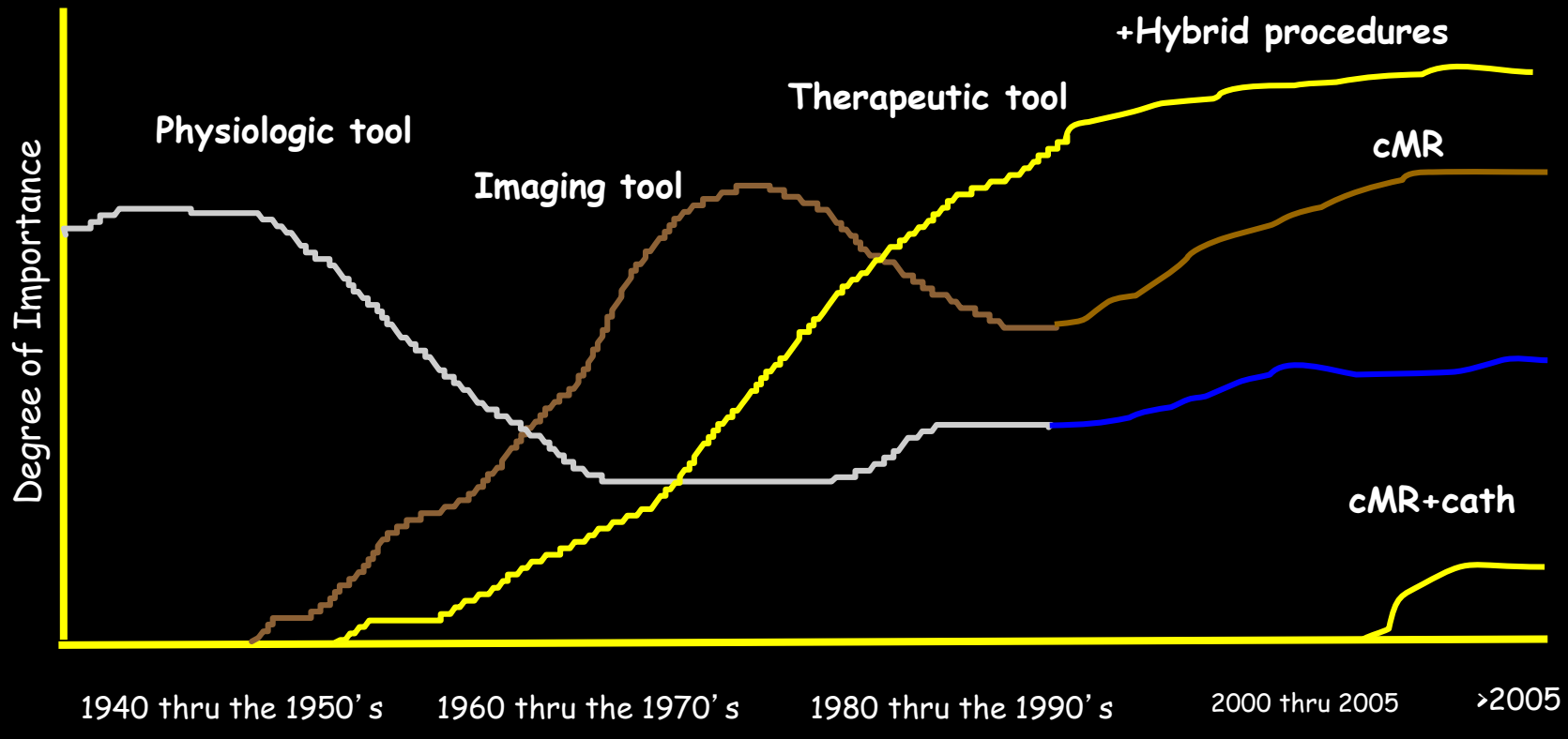
International Symposium on 3D Imaging for Interventional Catheterization in CHD

I Like My MR Scanner Adjacent to My Angio Suite Because……

Lee Benson MD
The Hospital for Sick Children, Toronto

The Changing Role of the Cardiac Catheterization Laboratory



The question to ask is why have a combined unit?

- The 2 imaging technologies are complimentary
- Allows acquisition of pressure & flow variables under consistent physiological conditions
- cMR imaging 2D/3D may facilitate catheter procedures
- Avoid multiple sedation/GA episodes
- Reduces radiation exposure
  - Many diagnostic angiograms can be replaced by cMRAs
  - IMR instead of x-ray guided interventions (?)

Combined UNIT
System Requirements

cMR unit

Biplane/monoplane catheterization unit

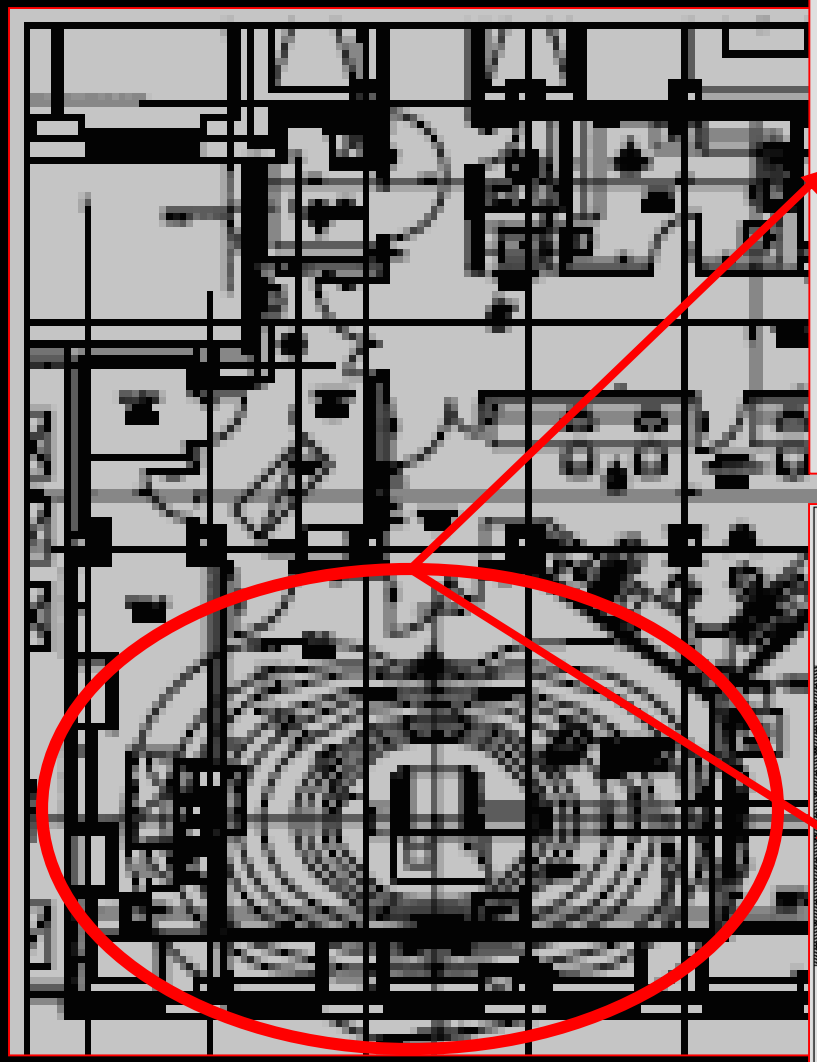
Sliding door with RF & X-ray shielding

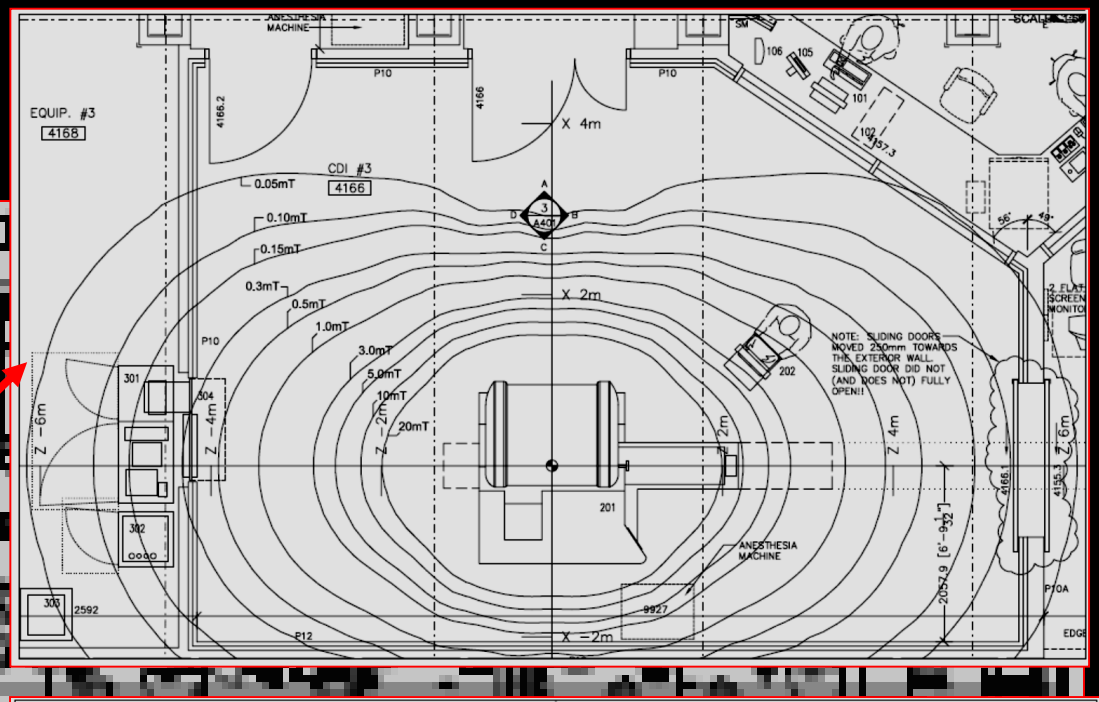
Transportation mechanism

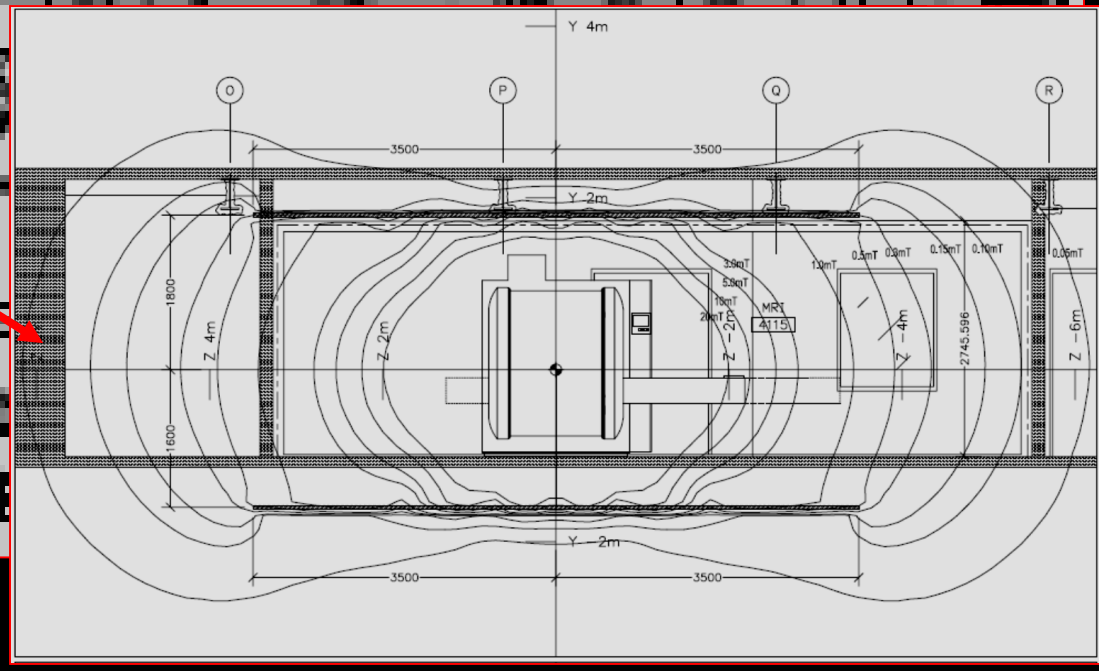
- Separate trolley
- Extended tables with rollers

CDIU physical plant integration

Gauss lines
Noise reduction





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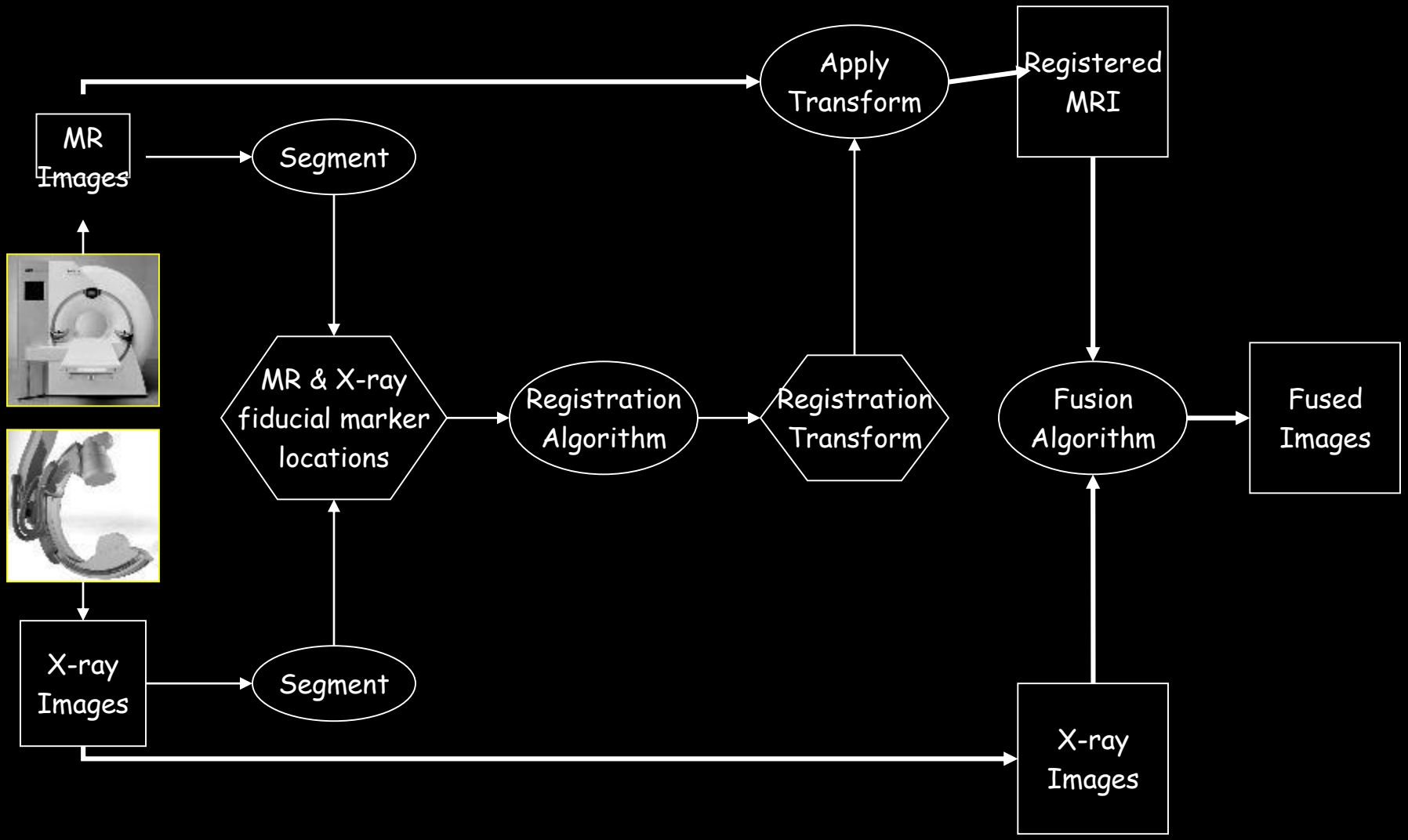
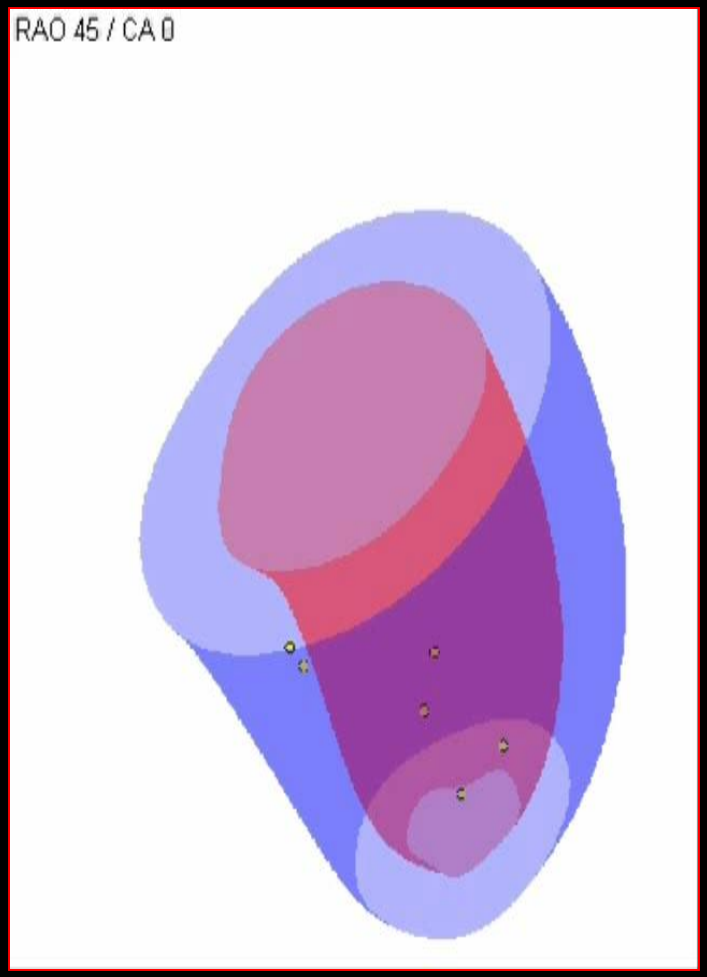
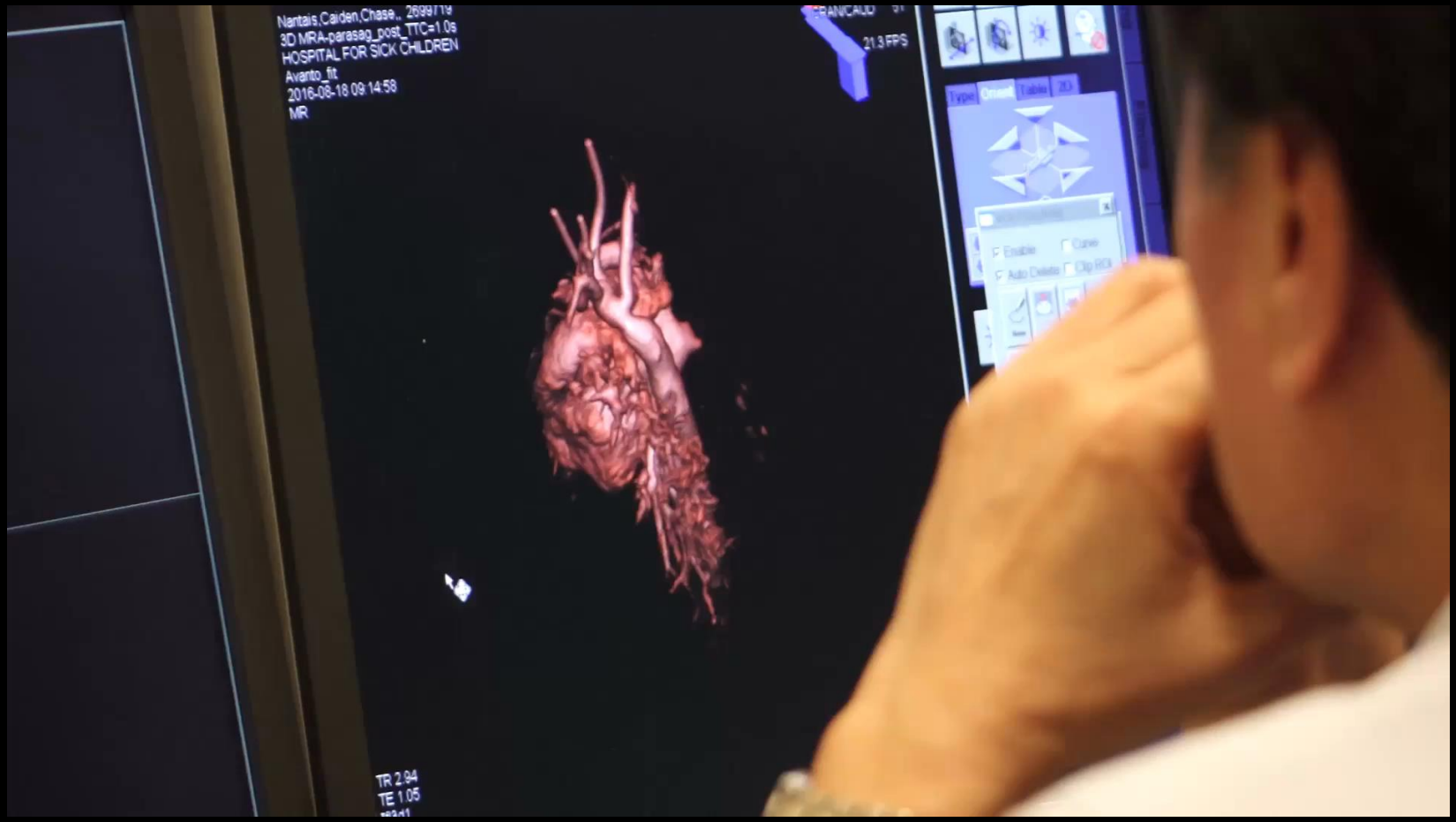
cMR data may help facilitate catheter procedures

Real-time X-ray FUSED with cMRI



Real-time X-ray FUSED with MRI

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3D MRA-parasag_post_TTC=1.0s
HOSPITAL FOR SICK CHILDREN
Avanto_fit
2016-08-18 09:14:58
MR
21.3 FPS
TR 2.94
TE 1.05

Combined procedures

(36 in 2015, 62 so far 2016)

Before diagnostic catheterization

prior to a Fontan operation
assessment of APC's
CA anomaly after re-implantation –ALCAPA; ARCAPA
after a Fontan operation
PAH study (multiple sources PBF)
anatomical assessment

Before &/or after catheter interventions

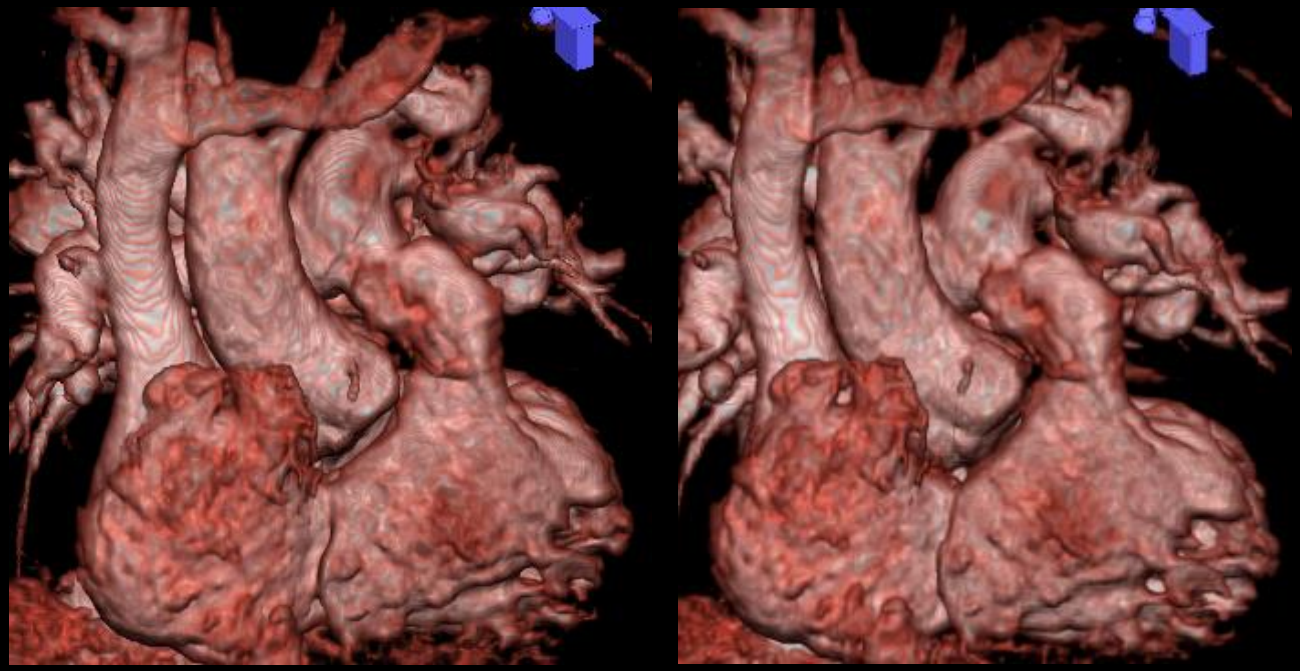
RV-PA conduits
branch PAS
BCPS
a prior hybrid procedure – HLHS

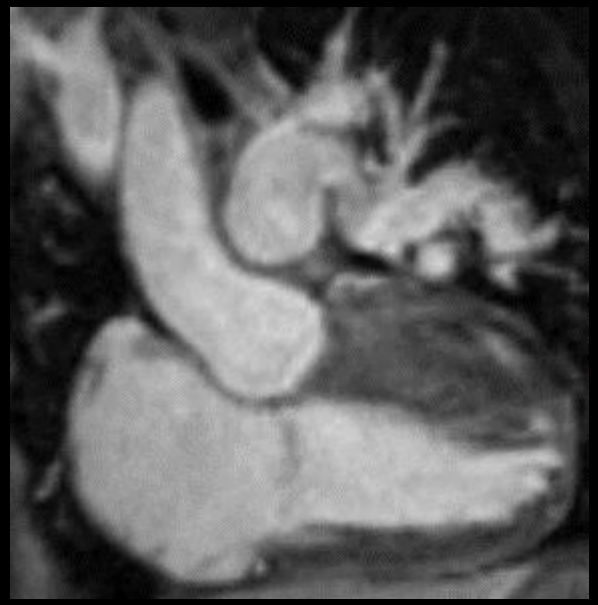
Ventricular performance, anatomy (volumes)

endomyocardial biopsy (tumor)
combined with brain MRI
prior to a hybrid stage II

Research studies

cMR data may help facilitate catheter procedures





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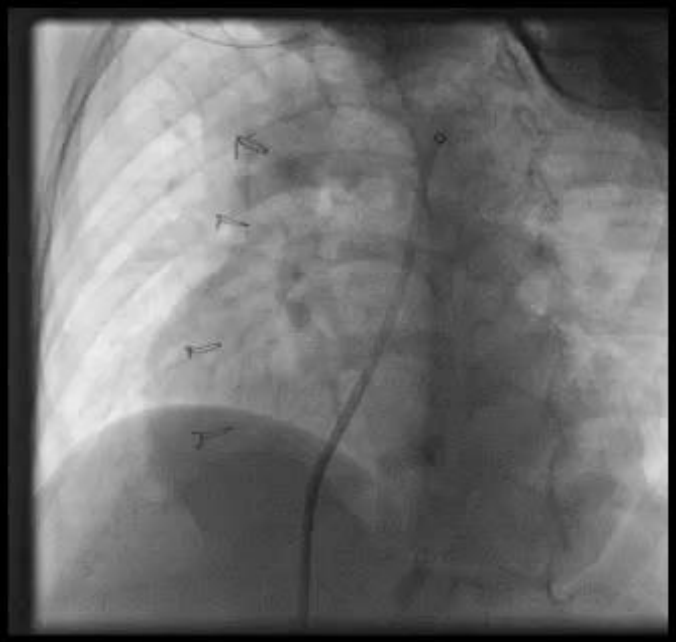

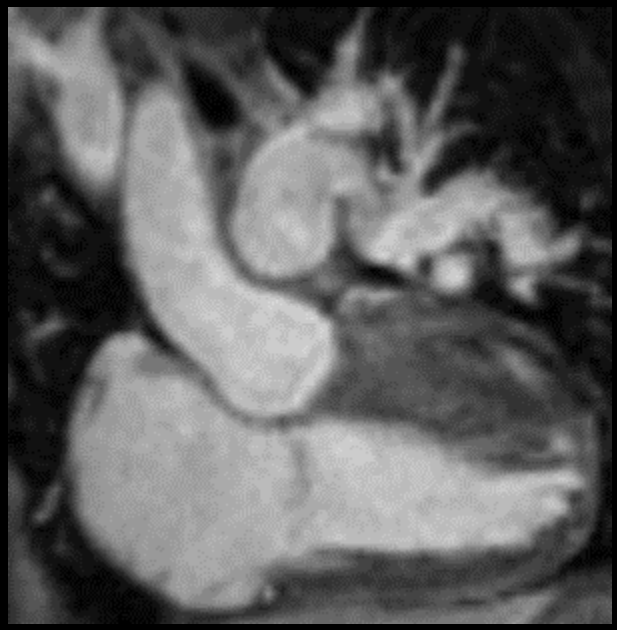

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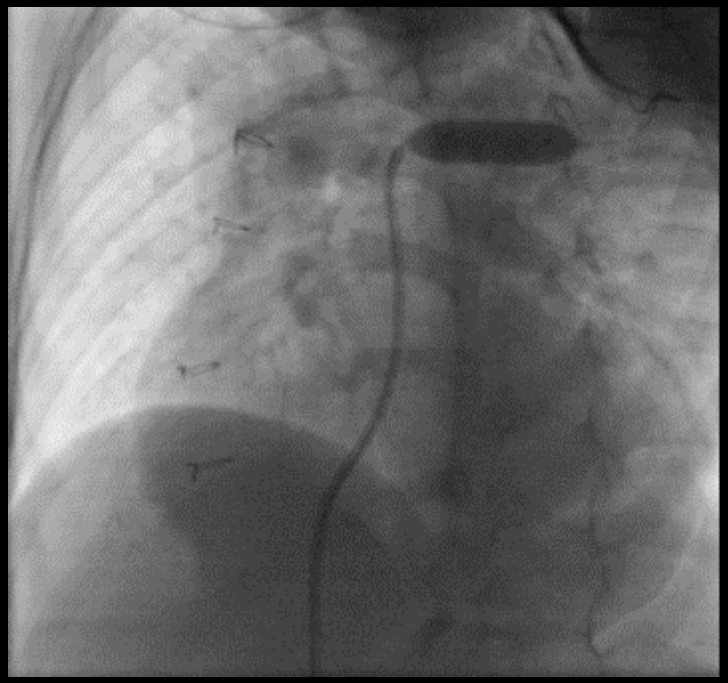
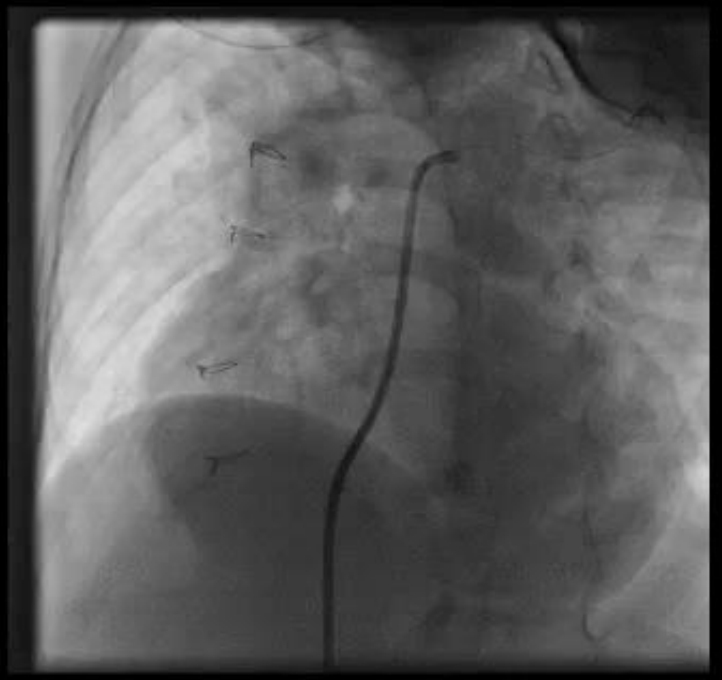
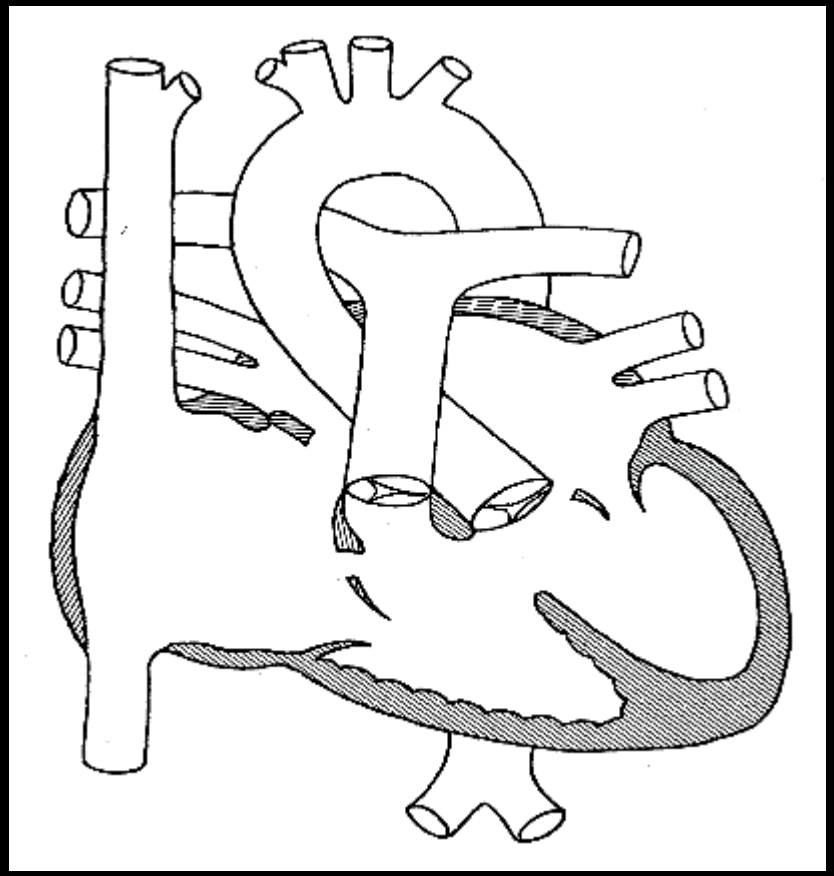
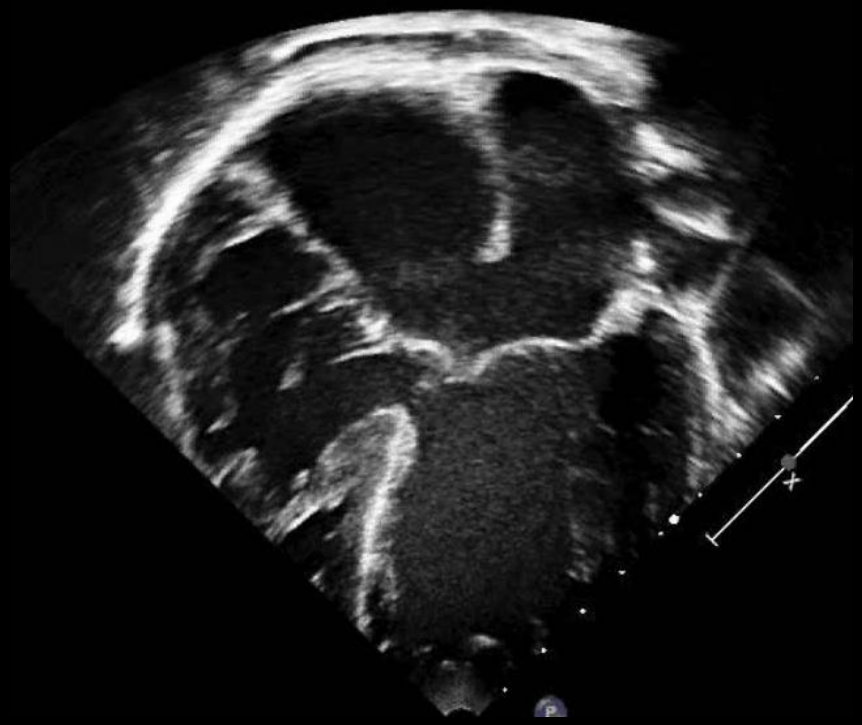




Can cMR help with hemodynamic assessments?

Cardiac catheterization in patients with known PAH

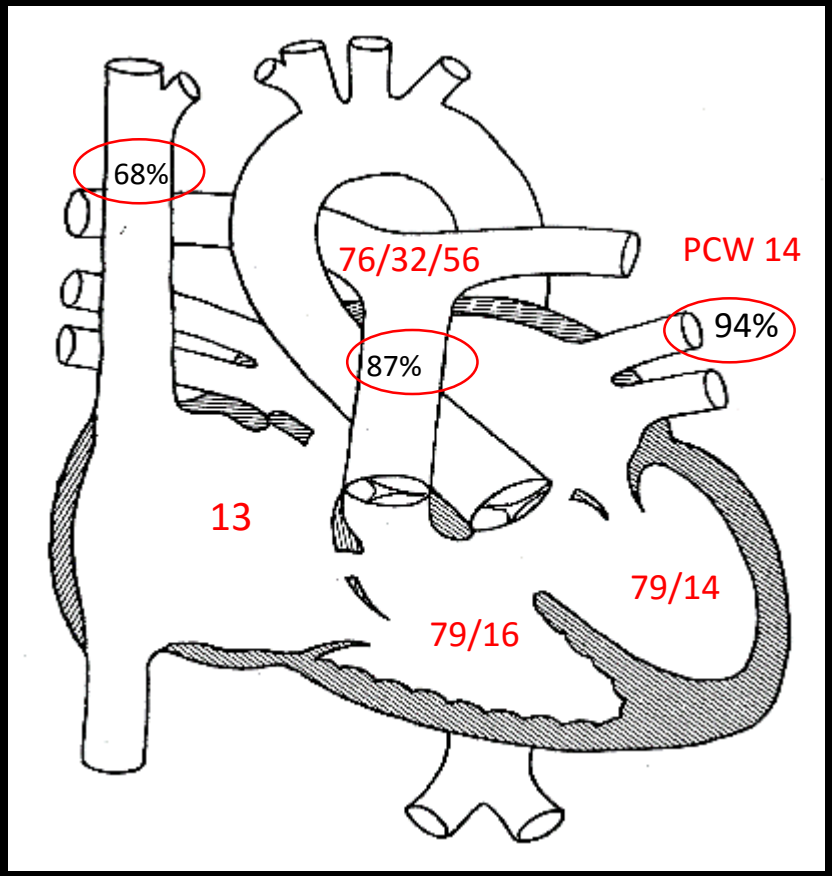


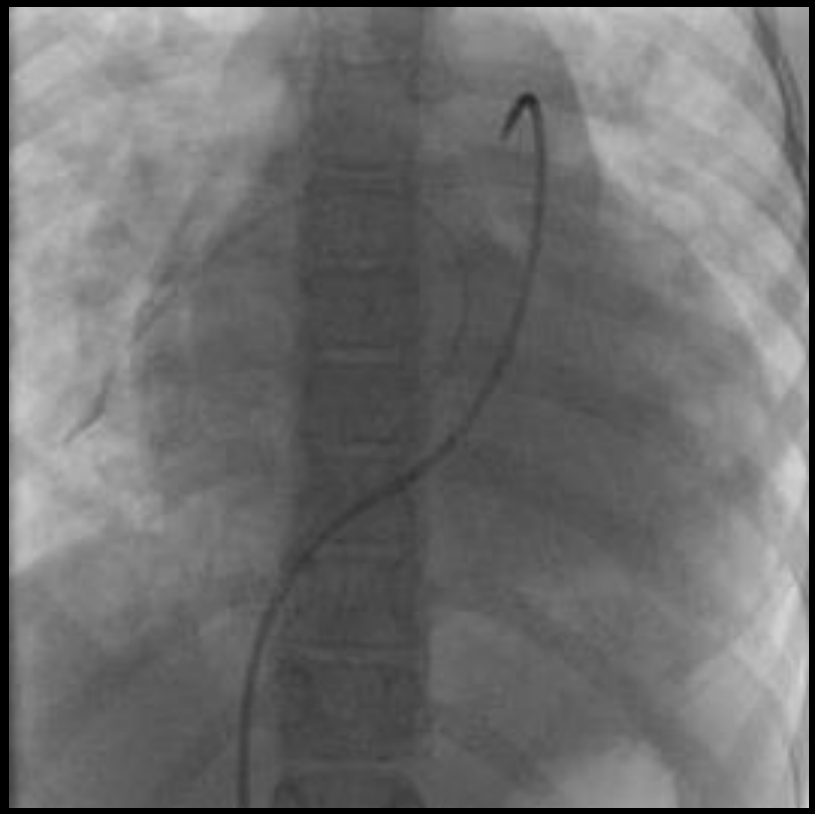


12 year old AVSD..is she operable?

Can cMR help with hemodynamic assessments?

Cardiac catheterization in patients with known PAH

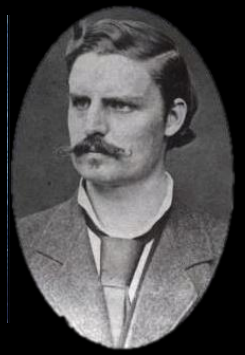




12 year old AVSD..is she operable?

Cardiac catheterization in patients with known PAH

Based on Fick principle



Adolf Gaston Fick

$$\text{Pulmonary blood flow} = \frac{VO_2}{\text{Pulmonary AV-}O_2\text{ content difference}}$$

Pulmonary vascular resistance:

$$\frac{\text{mean PAP - mean LAP (or mean PCWP)}}{\text{PBF}}$$

Wood units (mmHg/l/min)

Not Tiger Woods

Cardiac catheterization in patients with known PAH

That's pretty easy

Cardiac catheterization in patients with known PAH

Any invasive catheterization has risks, especially in patients with PVD.

However, with the currently available techniques & materials, including non-ionic contrast media, the risks are relatively low.

- What are the pitfalls in the calculation of PVR?

Common sources of errors

- Use of inappropriate value/sample for "mixed venous" blood
- Failure to calculate dissolved O_2 when using enriched gas (for example, 100% O_2)

Cardiac catheterization in patients with known PAH

Common sources of errors

- Assumed O_2 consumption is notoriously unreliable
- Unfamiliarity with O_2 consumption measurement technique—leads to unpredictable/unreliable results

The LaFarge & Miettinen table has been largely used for the assumed O_2 consumption, but in young (infants) it tends to give higher O_2 consumption values resulting in optimistic results (lower values) for PVR.

Calculations based on assumed O_2 consumption is a real problem in cyanotic patients (measured values >assumed ones).

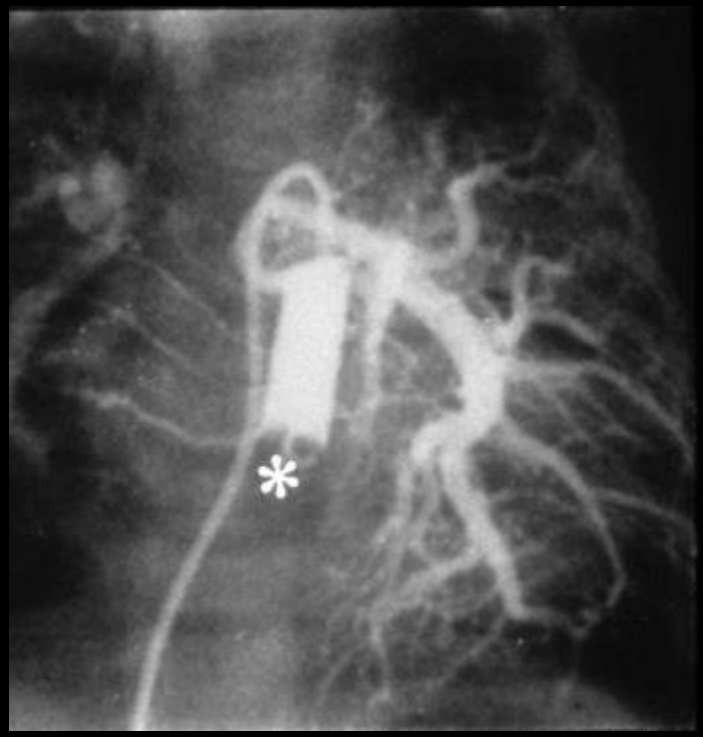
Cardiac catheterization in patients with known PAH

If assumed, use the range of values.

infants:	130 (<3mon) - 170 ml/min/m^2
2 -5 years:	150 - 200 ml/min/m^2
adolescents:	120 - 180 ml/min/m^2
adult females:	100 ml/min/m^2
adult males:	110 – 120 ml/min/m^2

Cardiac catheterization in patients with known PAH

Patients with multiple sources of PBF (i.e. MAPCAs) or discontinuous PA's pose a very special problem.



Novel Method of Quantifying Pulmonary Vascular Resistance by Use of Simultaneous Invasive Pressure Monitoring and Phase-Contrast Magnetic Resonance Flow

Muthurangu et al Circ 110:2004

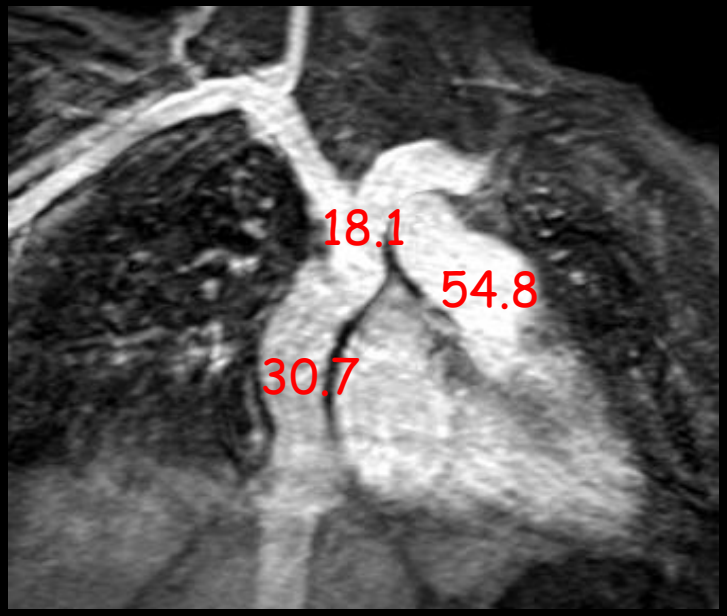
Phase-Contrast Magnetic Resonance Quantification of Normal Pulmonary Venous Return

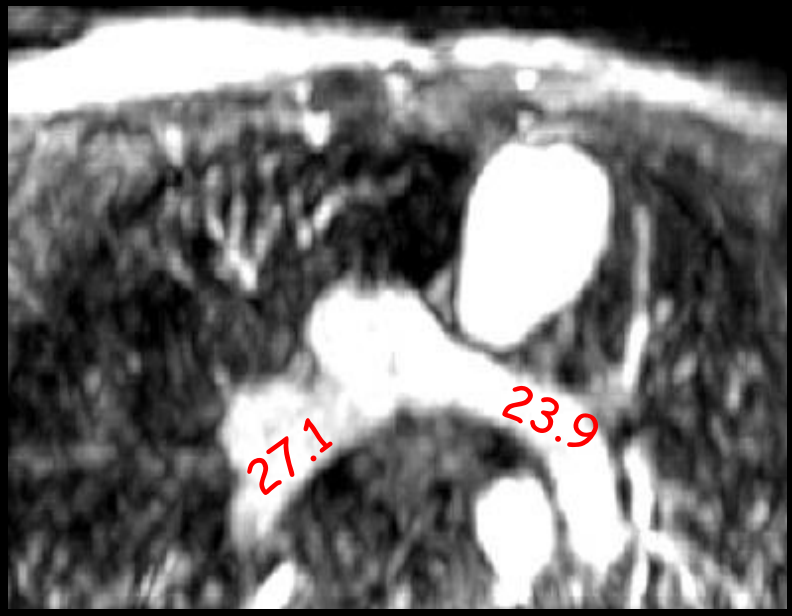
Goo et al JMRI 29:2009

Cardiovascular Magnetic Resonance catheterization derived pulmonary vascular resistance and medium-term outcomes in congenital heart disease

Pushparajah et al JMRI 2015

Cardiac catheterization in patients with known PAH





Flow volumes in ml/beat

$$Q_P = Q_{PV} = Q_{AA}$$

$$Q_S = Q_{SVC} + Q_{IVC} = Q_{PA}$$

$$Q_{APC} = Q_{PV} - Q_{PA}$$

$$= Q_{AA} - (Q_{SVC} + Q_{IVC})$$

$$= Q_{AA} - Q_{PA}$$

Cardiac catheterization in patients with known PAH

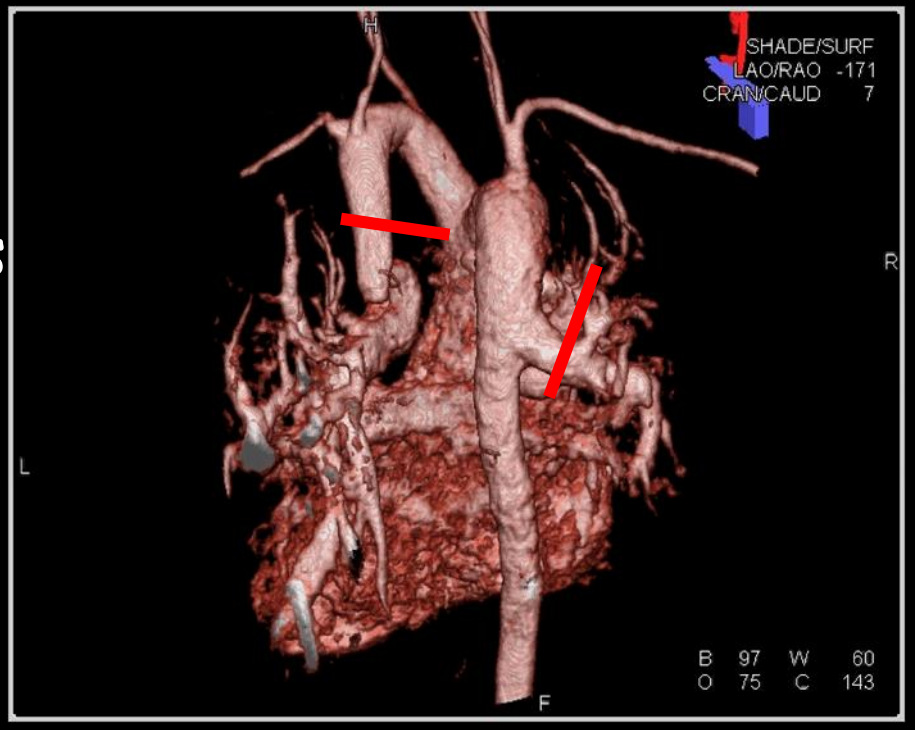
14 year boy

unrepaired PA/VSD, MAPCAs

unrestrictive VSD

O_2 saturation 88%

moderately limited



Cardiac catheterization in patients with known PAH

MRI

Qs =SVC+DAO flows	= 2.40 l/min/m^2
Qp = pulmonary vein flow	= 6.20 l/min/m^2
Qp/Qs = 2.58	

r-MAPCAs: *inaccurate*

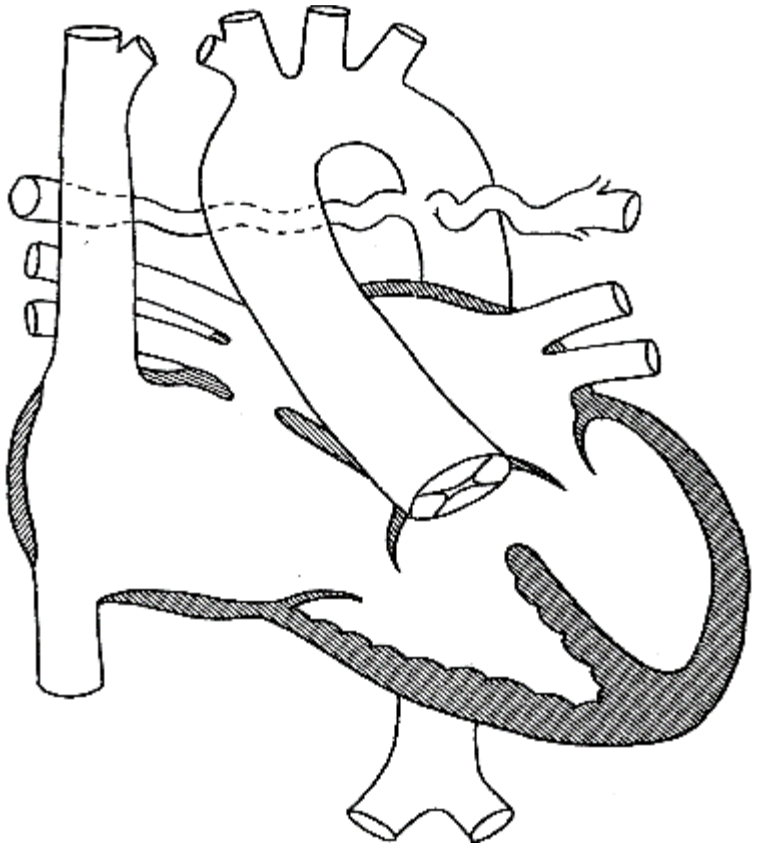
right pulmonary veins:	= 2.16 l/min/m^2
l-MAPCA	= 3.61 l/min/m^2

Cath

r-mAP	= 61mmHg
wedge	= 15mmHg
l-mAP	= 17mmHg

Total resistance=$(R_1 * R_2)/R_1+R_2$

Cardiac catheterization in patients with known PAH

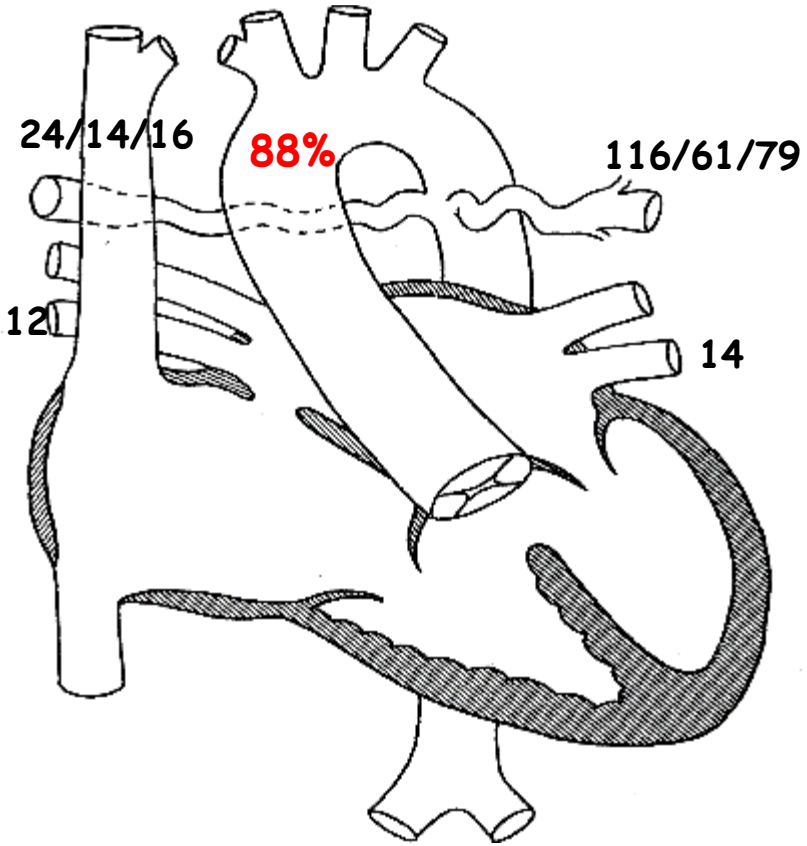


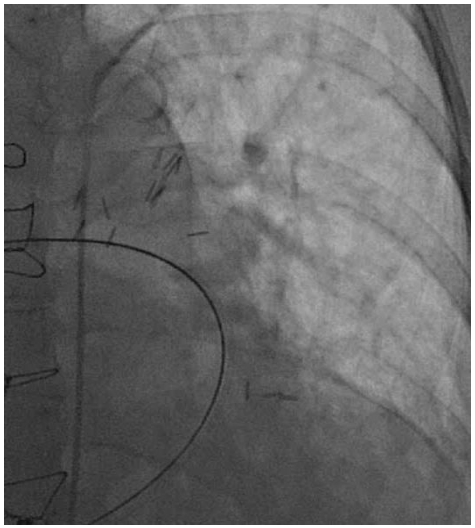
41 year old
Increasing cyanosis with effort
RA O_2 saturation 80% in 15 l O_2

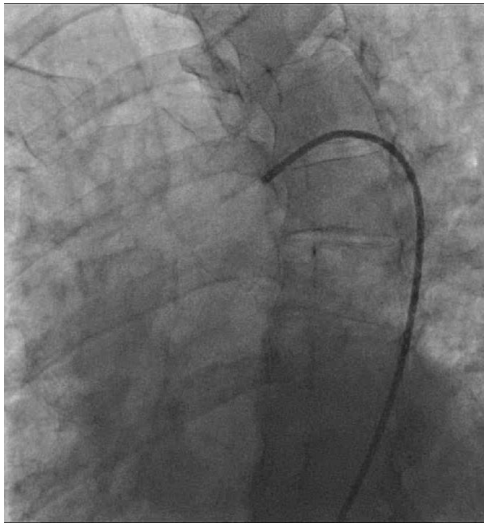
Is there something we can do to improve her clinical status, can she be repaired?

Pulmonary atresia, VSD, ductal origin of RPA, APC to LPA

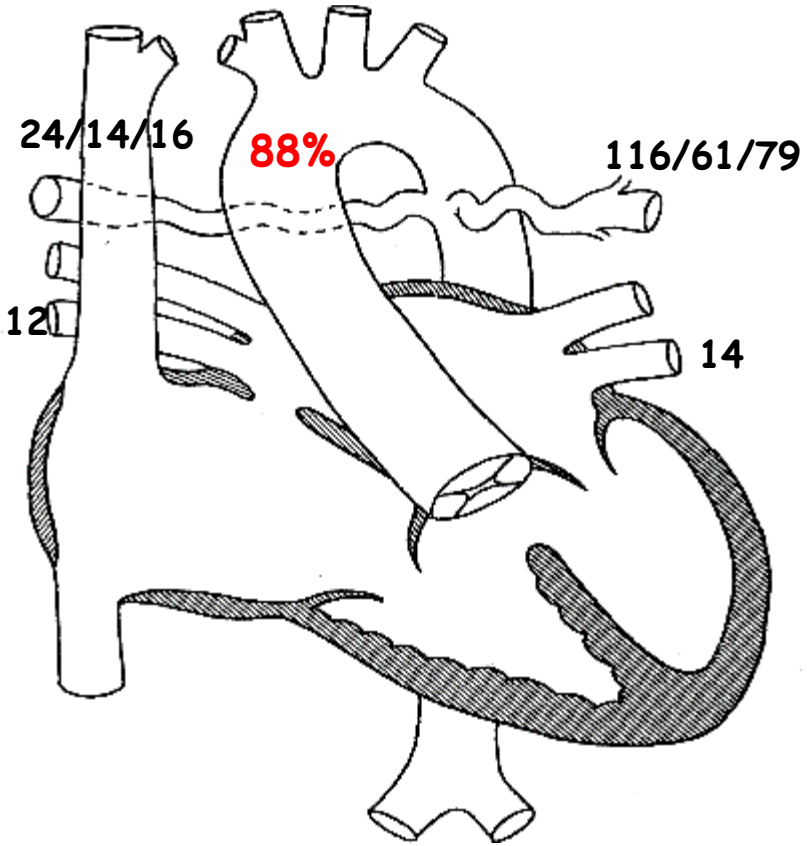
Cardiac catheterization in patients with known PAH

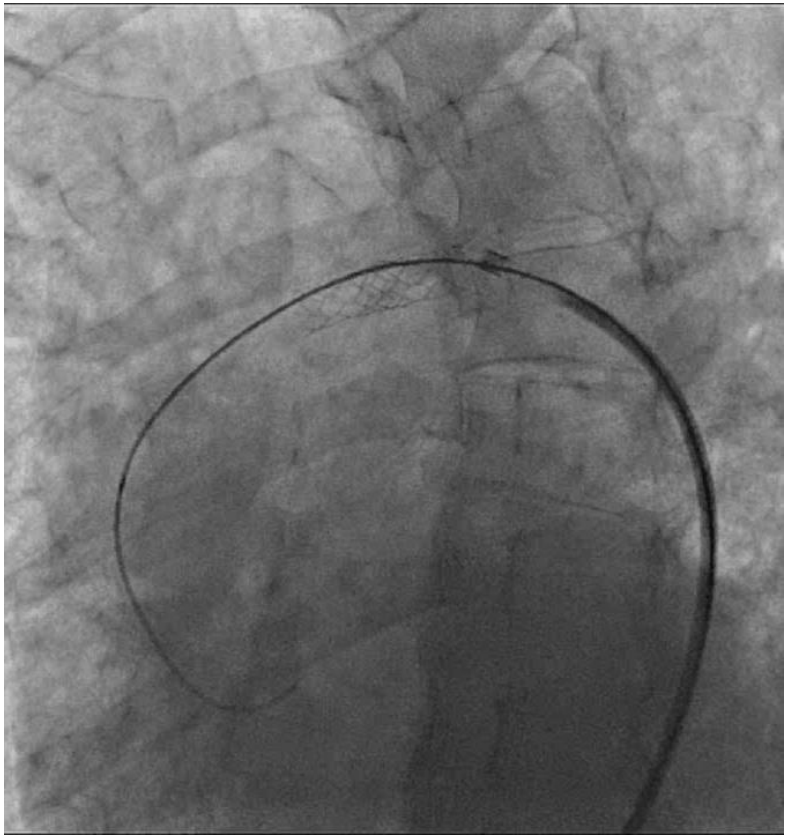






Cardiac catheterization in patients with known PAH





Cardiac catheterization in patients with known PAH

Data from cMR (includes arterial collateral flow)

RPA/LPA flow ratio 92%/8%

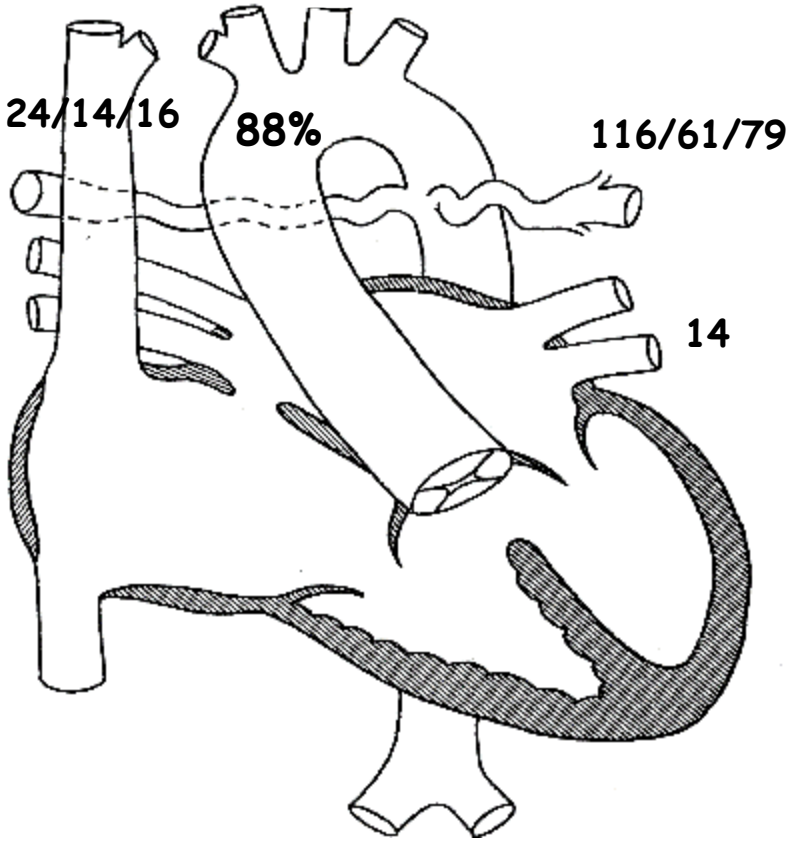
HR 57beats/min

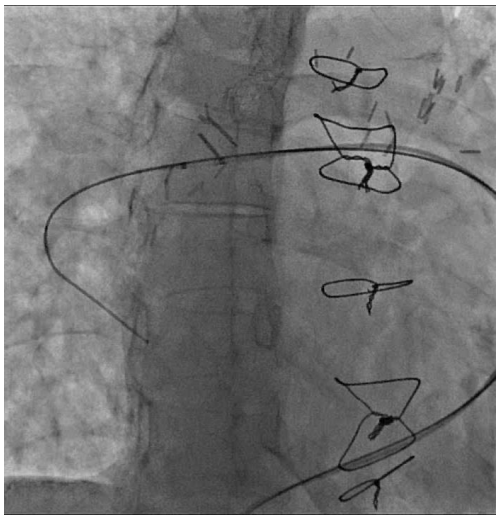
LPV flow 24ml/beat
TPG 65mmHg

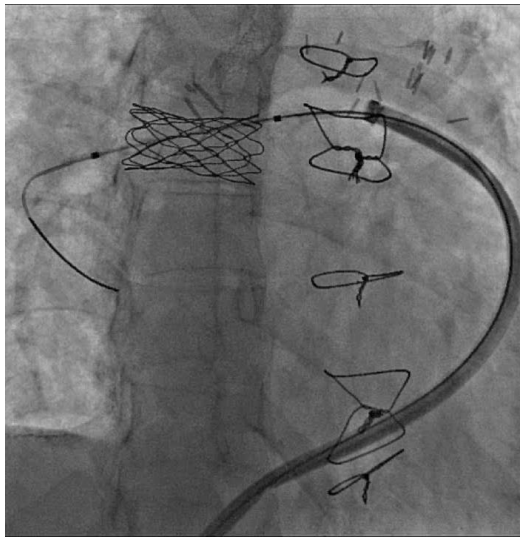
RPV flow 35ml/beat
TPG 4mmHg

R-PVR = 4/1.995 = 2 Wood Units

Cardiac catheterization in patients with known PAH







rPAP systolic ~40mm Hg

A Combined Unit

SickKids Lessons Learned

- Expensive investment
- Impacts on lab resources/scheduling
- Excellent for research purposes
- Benefits outweigh risks
- Allows for enhanced understanding of pathophysiology not possible with 2D invasive studies alone

Do I like the cMRI right next to the cath lab?

Yes

Jose Bautista Game 5 3-run home run AL Div series 2015

When it comes to improving our understanding of physiology & anatomy

Do I like the cMRI right next to the cath lab?

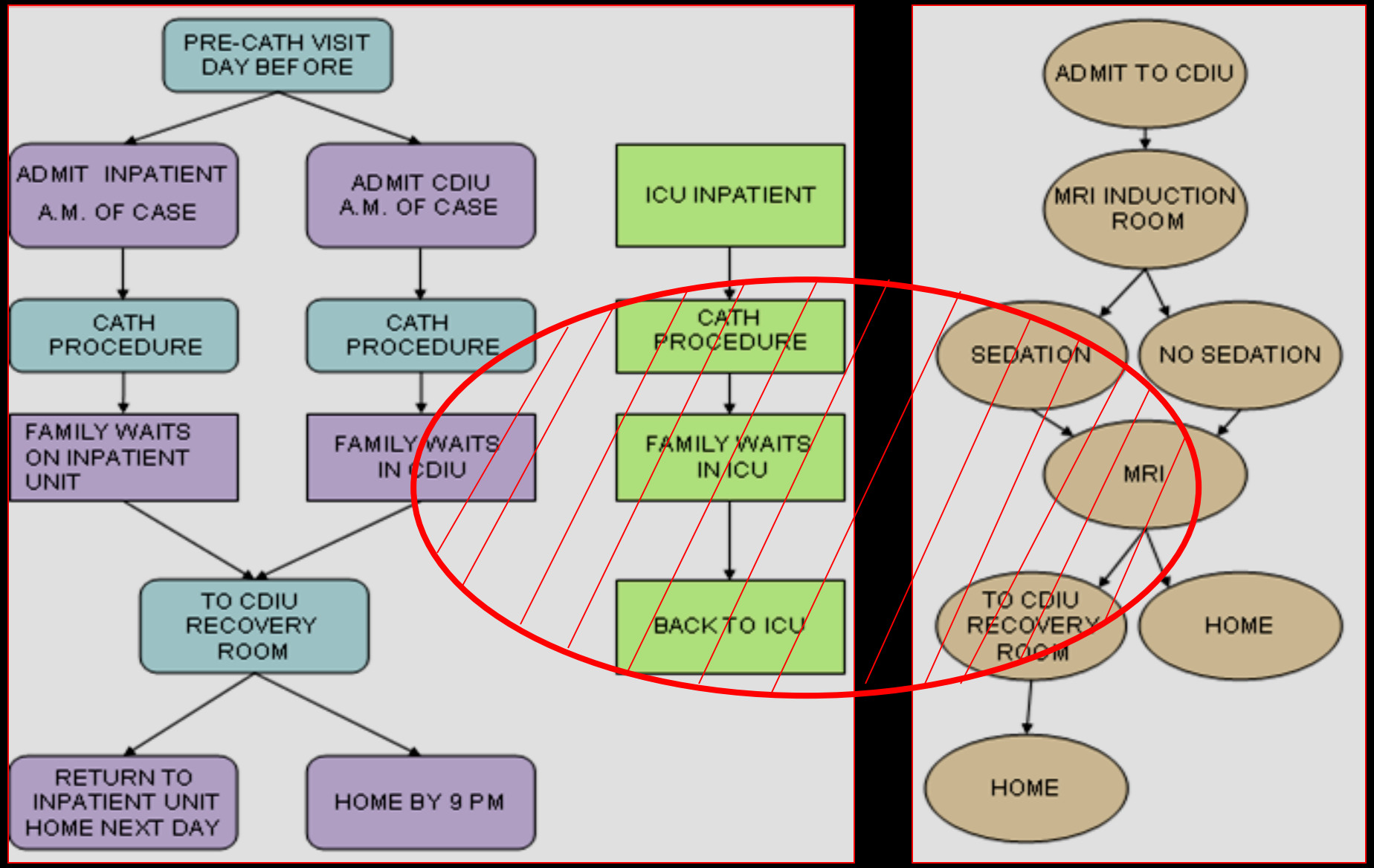
No

Jose Bautista taking a hard shot from Texas Ranger 2nd basemen Rougned Odor

When it comes room utilization and scheduleing

Cath Lab Patient Flow

cMRI Patient Flow



The Cardiac Diagnostic and Interventional Unit (CDIU)

Dr. Lee Benson

Dr. Jin Lee

Dr. Rajiv Chatervurdi

Dr. Andrews Wan

- Interventional

Dr. Shi-Joon Yoo

Dr. Mike Seed

Dr. Lars Grosse-Wortmann

- cMRI/Diagnostic

Dr. Robert Hamilton

Dr. Joel Kirsch

Dr. Gil Gross

Dr. Beth Stephenson

- Electrophysiology

Susan Johnston

Sandra Skrt-Martin

Janine Barclay

Jacqueline Viegas

Martine Dubreuil

- Nurse technicians

Darius Mroczek

- Biomedical techn.

Rachel Enkin

- Cath technician

Kelly Paredes

- Inform. Co-ordinator

Omar Thabit

Vinay Kainthla

Jothi Thind

Sundar Devadas

- cMR/MRT

"The future is not some place we are going to, but one we are creating. The paths are not to be found, but made, & the activity of making them changes both the maker & the destination"

John Schaar, Letgitimacy in the Modern State. 1989

THANK YOU