The Role of 3D Printing for RVOT Intervention

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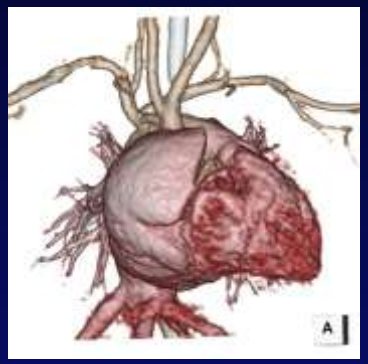
Dr. Evan Zahn - Cedars Sinai Guerin Family Congenital Heart Program
Dr. Isao Shiraishi - Osaka National Cerebral and Cardiovascular Center
Materialise - The manufacturing company

What is 3D Printing

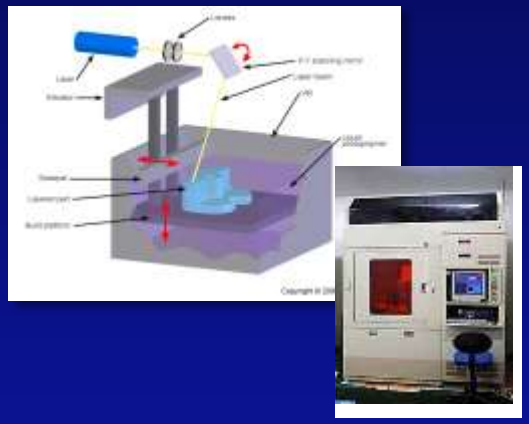
- 3D Printing = Rapid Prototyping
- 3D computerized models are converted into physical models



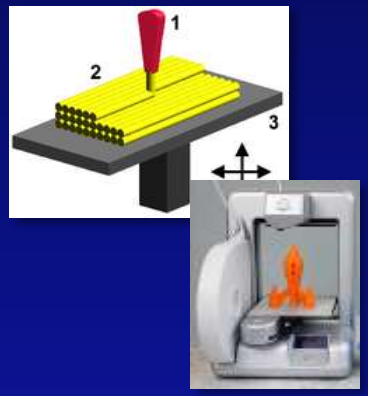
What Types of 3D Printing

3D Printing	Methods	Advantages	Disadvantages
Stereolithography	A laser beam selectively solidifies photosensitive liquid plastic.	Suitable for creating complicated 3D objects.	Epoxy or ABS resins are expensive
Fused Deposition M odeling (FDM)	Thermoplastic filament is heated and extruded to create a 3D object.	ABS plastics are solid and durable.	Surface is not smooth and exhibits step-like structures.
Selective Laser Sintering (SLS)	Tiny particles of plastic, ceramic or glass are fused together by heat.	Precise and durable.	Surface is coarse
Inkjet 3D printing	Use inkjet nozzle and solidify with UV light.	Easy to use different material and colors	Degradation may occur under the sunlight.
Plaster 3D printing	Plaster powder is applied in layers and a binder is printed on it.	Fastest in 3D printers. Good for making small figures.	Plaster is coarse and fragile.

Stereolithography (SL)

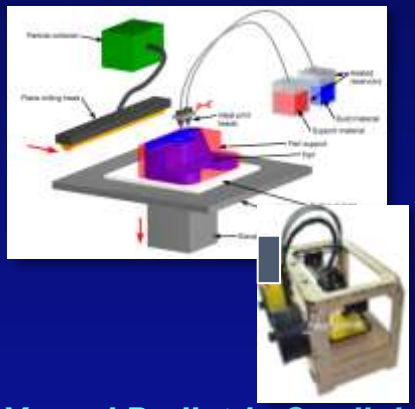


Fused Deposition Modeling (FDM)



Selective Laser Sintering (SLS)

Inkjet 3D printing



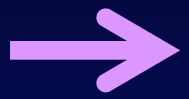
Why 3D Printing

- Multi-slice computed tomography has allowed the visualization of congenital heart disease from any angle of view and perspective.
- However, significant discrepancies still remain between the 3D images and the real structures of the anatomy.

Began in the 1990's – craniofacial surgery

Why 3D Printing

- Angioplasty
- Valvuloplasty
- PDA closure
- ASD closure
- Stent implantation

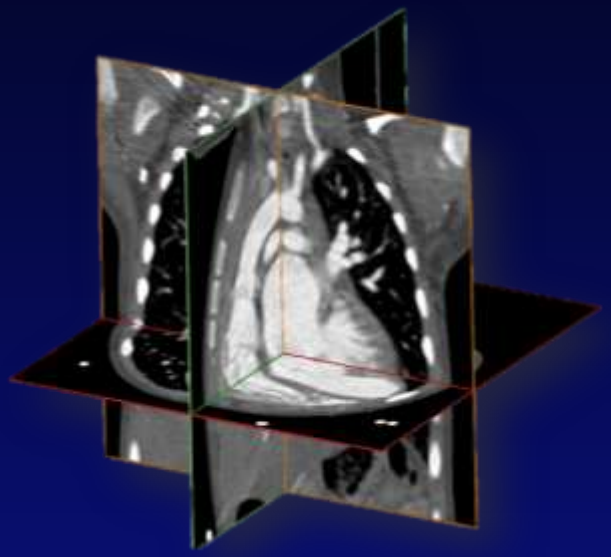


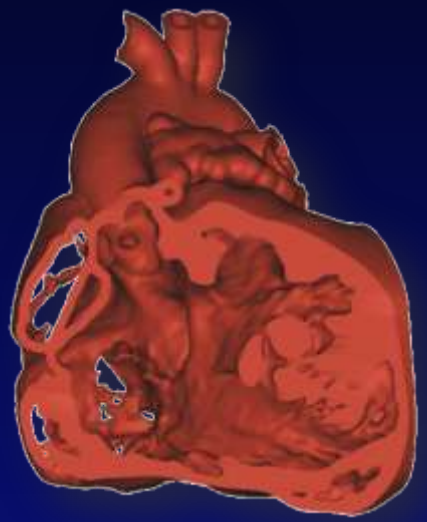
- Valve implant
- Valve repair
- VSD closure
- Hybrid approach
- Fontan revisions
- Fontan creations
- Extra-vascular shunt creations

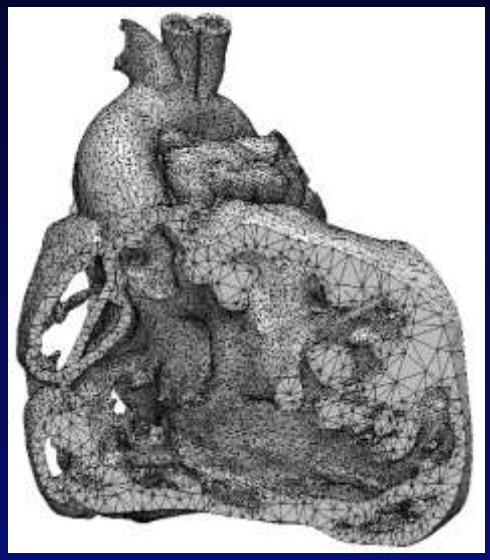
- Our interventions continue to become more complex !
- Our medical teams continue to become multi-disciplinary !

How to Do 3D Printing

Imaging → **3D Reconstruction** → **3D Print**







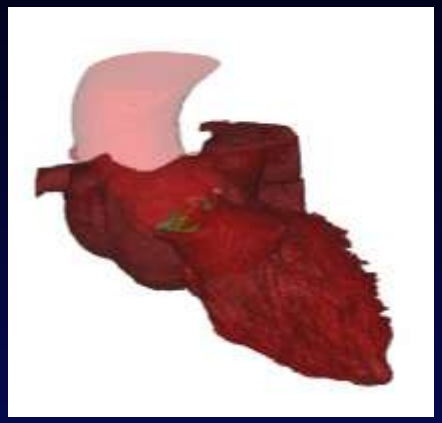
Thanks to Materialise

- Segmentation – isolate anatomy
  from CT, MRI, 3D RA, 3D echo
- Create 3D surface models 3D computer model prepared
- 3D printing choose desired material based on model requirements

Cardiac 3D Printing

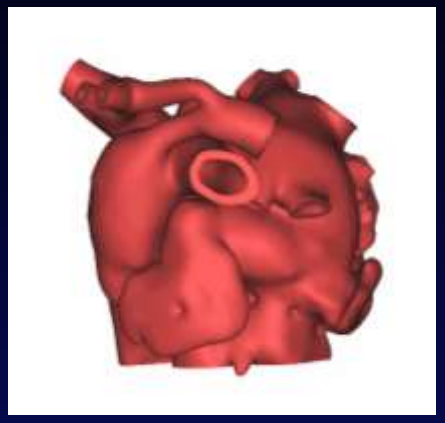
CT

Dr. Chan
Queen Elisabeth Hospital,
Hong Kong, China



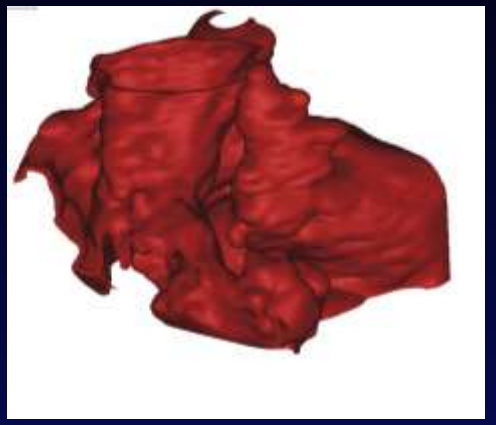
3D RA

Prof. Johan Bosmans,
University Hospital Antwerp,
Belgium



MR

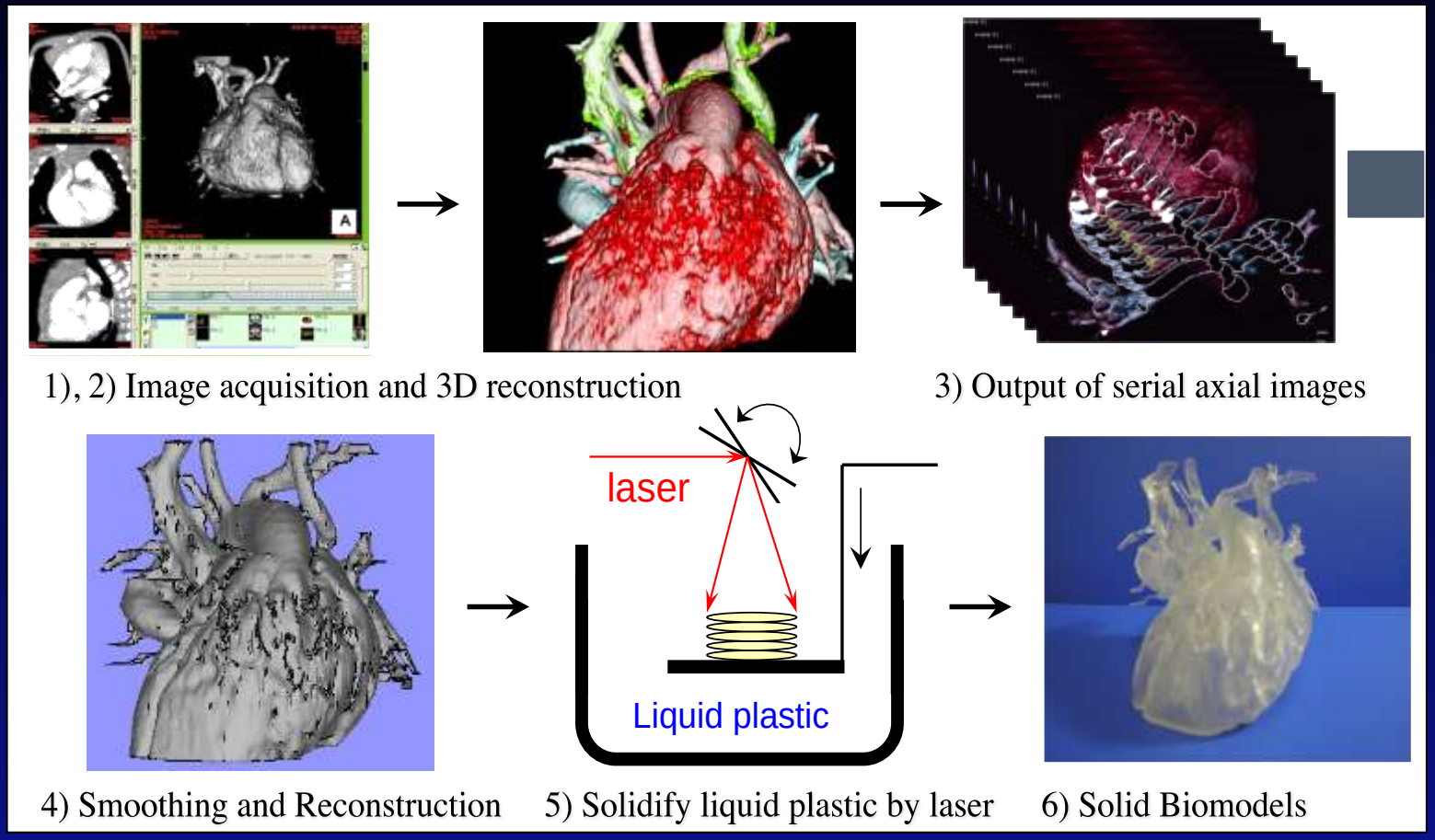
Dr. Shi-Joon Yoo,
Hospital for Sick Children,
Toronto, Canada



3D US

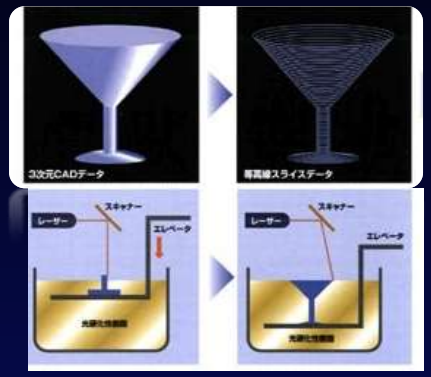
A. Pearce, S. Robinson, Dr B. Rana
"Papworth Hospital NHS Foundation Trust, UK

Cardiac 3D Printing

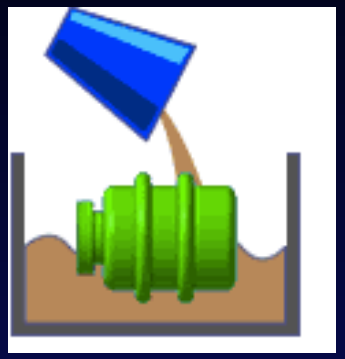


Thanks to Dr. Isao Shiraishi Osaka National Cerebral and Cardiovascular Center

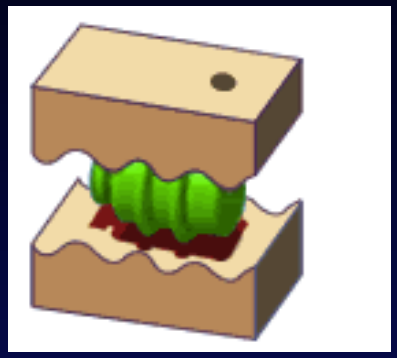
Cardiac Stereolithography



1) Manufacturing inner and outer master mold with stereolithography.



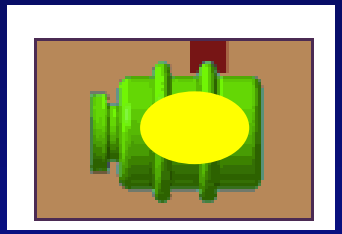
2) Making outer cast with polyurethane.



3) Removing outer master mold from the polyurethane cast.

Inner master m

Outer cast



4) Injecting polyurethane material in between the outer and inner molds under the vacuum condition.

Thanks to Dr. Isao Shiraishi Osaka National Cerebral and Cardiovascular Center

RVOT 3D Printing

Figure 1

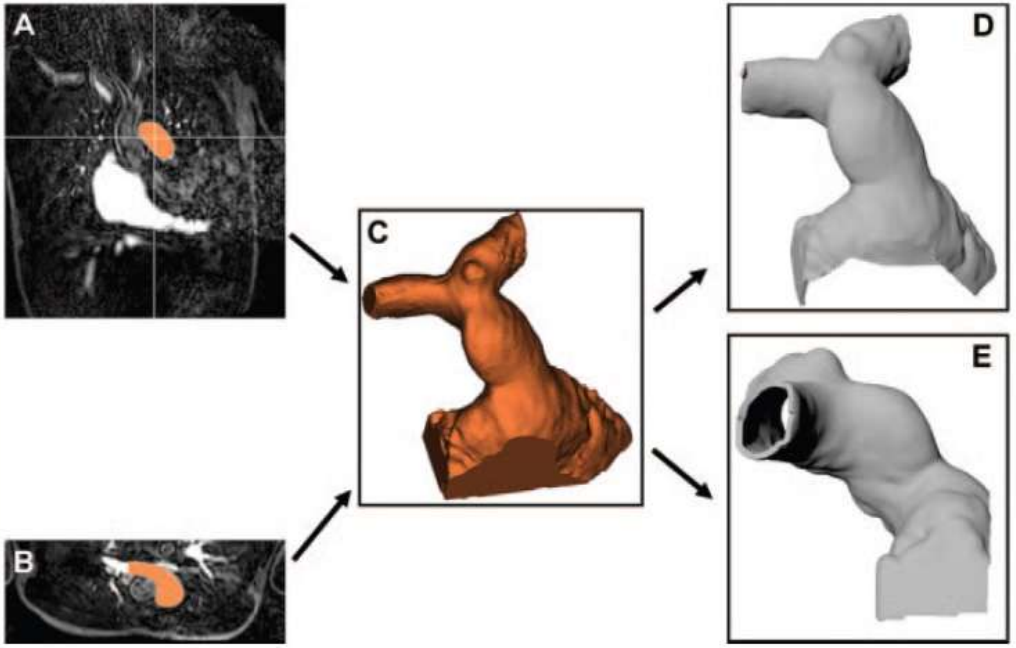
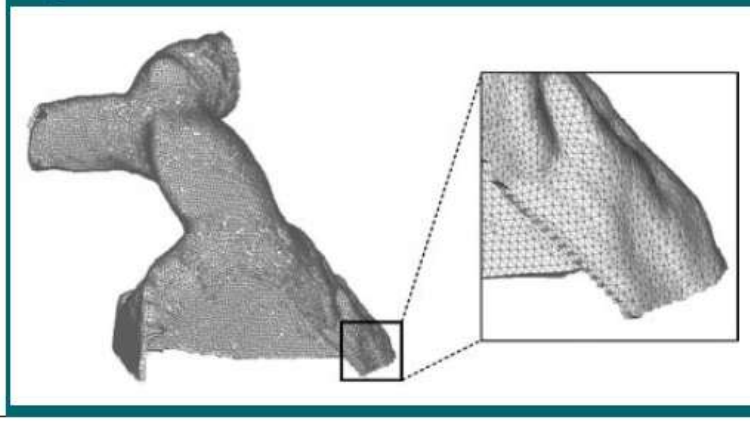


Figure 1: *A*, Original coronal, and, *B*, reformatted transverse MR images show segmentation mask (orange) of pulmonary trunk *(A)* and proximal right pulmonary artery after thresholding, region growing, and manual editing. *C*, Computer-generated 3D reconstruction of blood volume without arterial thickness (constant 2-mm thickness), anterior view of RVOT, and pulmonary bifurcation. *D*, *E*, Reconstructed *D*, anterior, and, *E*, lateral views of arterial wall.

Figure 2



and Pulmonary

R Data[1]

e if magnetic resonance (MR) imaging data
o create rigid models that are accurate repre-
the right ventricular outflow tract (RVOT)
ry trunk anatomy and if such models can be
e the selection of patients for percutaneous
alve implantation (PPVI).

Philipp Bonhoeffer, MD
Andrew M. Taylor, MD, MRCP, FRCR

Materials and Methods:

Institutional review board approval and informed patient consent were obtained. Twelve patients' MR data were

RVOT 3D Printing Cases

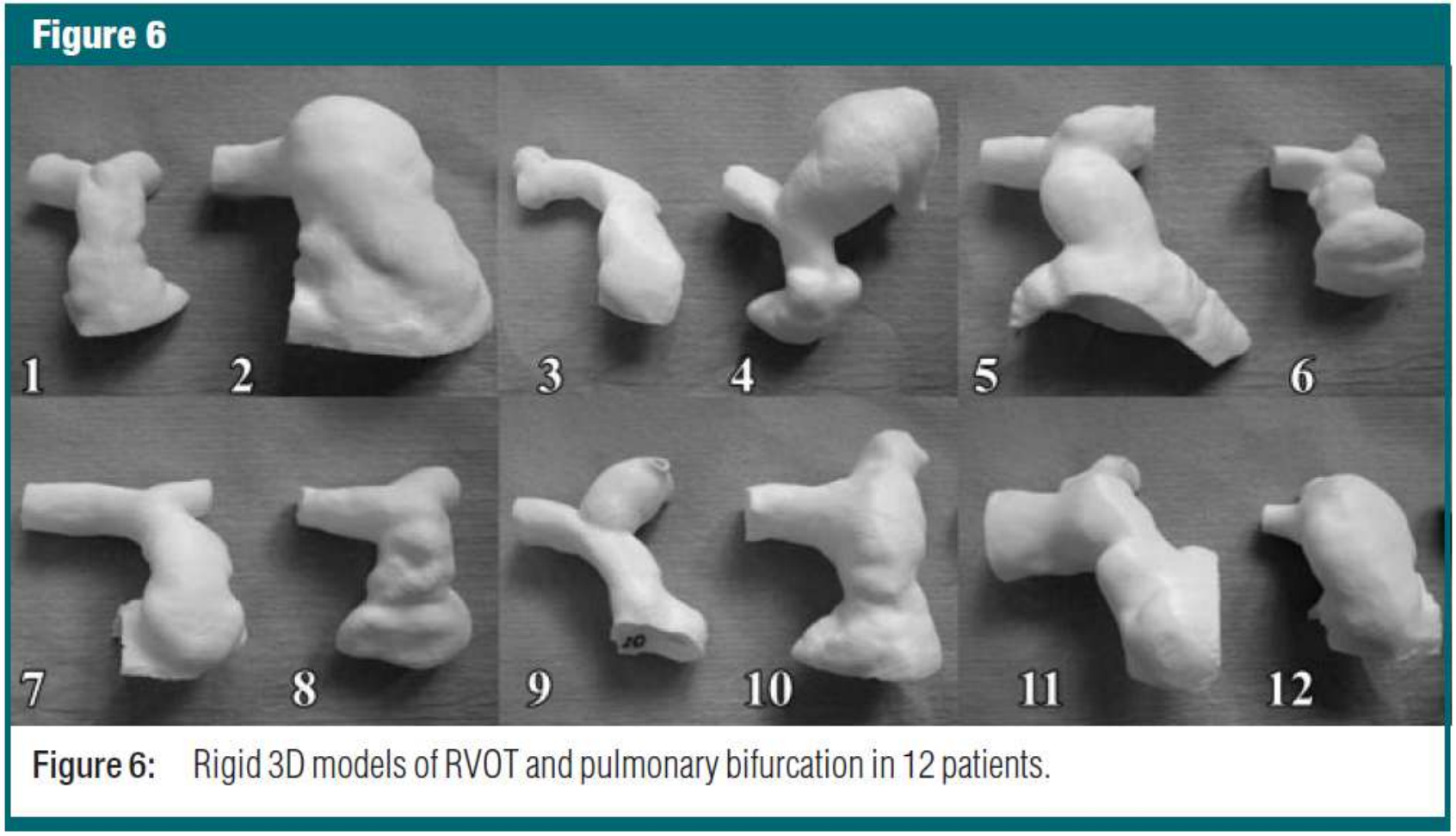


Figure 6: Rigid 3D models of RVOT and pulmonary bifurcation in 12 patients.

Case – S/P TOF repair

- 16 yr old boy patient
- S/P TOF repair - infant
  trans-annular patch
- PR fraction : 40 %
- RVEDVi : 180 cc/m2
  (z score=6.7)
- Preserved RV systolic function
  (EF 55%)

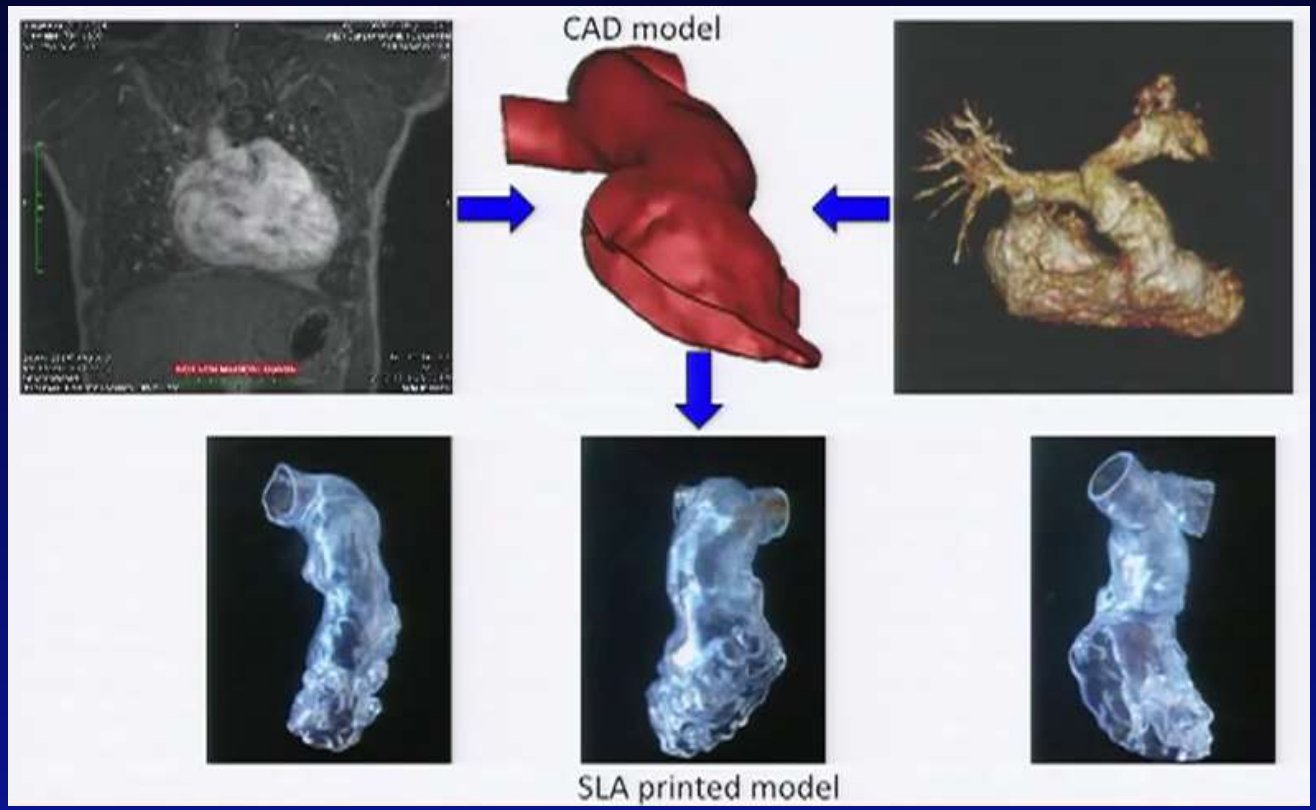
→ *too large, too irregular RVOT*

Dr. Evan Zahn at Cedars-Sinai

Creation of 3D Model

Balloon sizing -→ 28 mm

- Too large for conventional Melody implant



Concern…

- Create reliable landing zone
- Eliminate and minimize para-valve leak

Thanks to Dr. Evan Zahn at Cedars-Sinai

Conceptualizing and Virtualizing

Solutions…

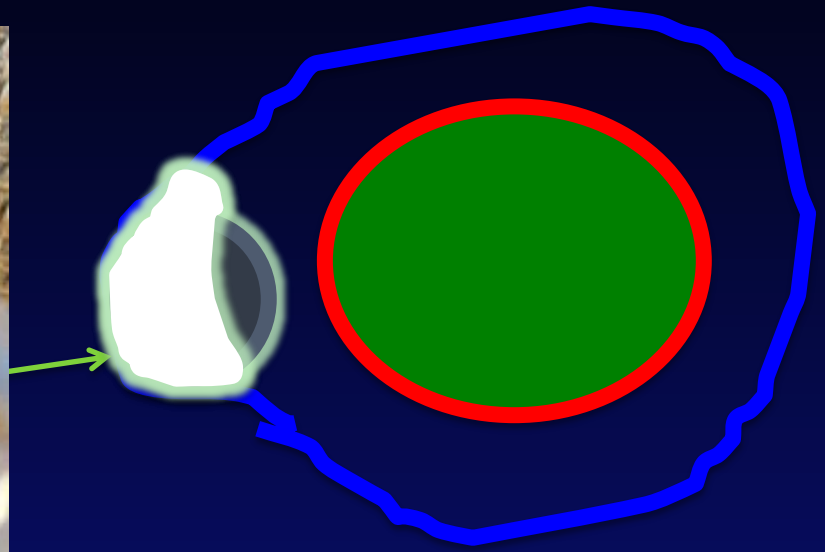
- Use a Per-ventricular approach
- Implant space occupier (covered stent, AVP II)
- Simultaneous implant large BMS landing zone
- Implant large TPV into landing zone

  Melody on 24 mm BiB

  26 or 29 mm Sapien

Thanks to Dr. Alistair Phillips and Dr. Evan Zahn at Cedars-Sinai

RVOT Geometric Remodeling

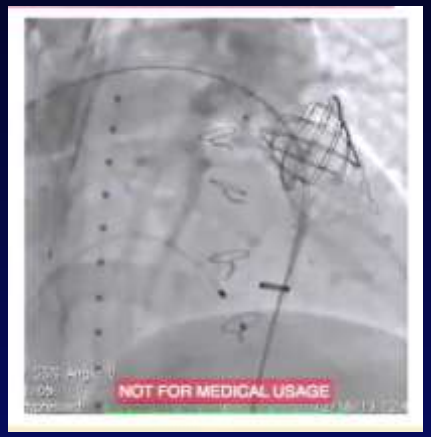


* RVOT remodeling
: Making a spherical landing zone

Thanks to Dr. Evan Zahn at Cedars-Sinai

Melody Valve Implant

- Melody on 24 BiB, modified Ensemble sheath



after 5 months

Thanks to Dr. Evan Zahn at Cedars-Sinai

Contributions of 3D Models

- Improved understanding complex anatomy and geometry of RVOT
- Procedural planning
- Proof of concept - virtual implants

- Teaching
- Communication

Conclusion

- 3D modeling appears to be a useful adjunct to performing complex and novel hybrid interventions, especially for RVOT cases.
- Advantages :
  - Improved ability to understand complex relationships
  - Ability to test various treatment strategies
  - Ability to assess virtual result
- 3D printing custom devices for RVOT cases could be a huge potential in the future.