3D Printing & Echocardiography

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Rapid Prototyping 101

Complex Geometry + Multi-Material Fusion = Functional Anatomy (?)
Finish this sentence....At my institution we use 3D printing to:
1. Plan all complex structural heart procedures.
2. Plan for selected complex structural heart procedures.
3. As a research tool with very little clinical usage.
4. What the heck is 3D printing? We never use it.
CV 3D Print Applications

- Anatomic Teaching Tools
- Functional Flow Modeling
- Procedural Planning
- Device Innovation

The 3D printing steps

1. CT Images
2. Segmentation
3. 3D Reconstruction
4. Digital Patient-specific 3D Model
5. Multi-material 3D-Printed Patient-Specific Model
AVA Replication

Patient CT → Tissue Segmentation → Aortic Valve Replication → Model CT ← 3D-Printed Model

Aortic Root Replication

Maragiannis et al. Circ Cardiovasc Imaging. 2015
HeartBeat Simulator™ Setup

Plan to TAVR

Pressure Tx

Patient-Specific LVOT Model

Flow Probe

Pulsatile Pump

Pressure Tx

Arterial Compliance Chamber

Arterial Resistance Clamp

Venous Reservoir

Flow Probe

Mechanical Mitral Valve

Patient-Specific LVOT Model

Calcific Aortic Valve Stenosis Model

Pulsatile flow across a 3D printed model
Mechanical Testing of Print Materials

Compression testing for rigid calcific nodules and tensile testing for soft tissue structures.

Replicating AS pressure gradients
Replicated AVA flow dependency

Maragiannis et al. Circ Cardiovasc Imaging. 2015

Aortic Regurgitation: Doppler Replication

Hemodynamic Parameters:  Patient | Model
Regurgitation Time: 460 ms | 458 ms
Peak Velocity: 4.6 m/s | 4.7 m/s
Pressure half time: 312 ms | 331 ms
Time-velocity index: 167 cm | 162 cm
CoreValve Prosthesis

Sheathed Transcatheter CoreValve Prosthesis

Crossing Stenotic Aortic Valve

CoreValve Deployment

CoreValve Expanded Within LVOT Model

Bench-top TAVR

Replicating PVL

Patient Echo

LVOT

LV

Ao

Patient Short-Axis

Patient Long-Axis

Model Echo

LVOT

LV

Ao

Model Short-Axis

Model Long-Axis
Mitral Valve reconstruction from 3D TEE

3D TEE Data → Segmentation software → Digital patient-specific multi-layer 3D MV model → STL file → 3D printed multi-material mitral valve model

Mechanical Testing of Mitral Valve Materials

Bending test → Tension testing

Mitral Leaflet Response to Stress

Tension Testing


P2 perforation & central MR
Pre-procedural Planning of perforated mitral valve repair

A. CT imaging data set
B. Color Doppler of the Mitral Regurgitation detected through the perforation
C. Digital Patient-Specific 3D model
D. Reconstructed Patient-Specific Mitral Valve with perforation on posterior leaflet
E. 3D printed Patient-Specific model
F. 3D printed Patient-Specific model with perforation at posterior leaflet
G. Vascular Plug 4
H. Repaired 3D printed Mitral Valve model with vascular plug 4

Patient-Specific 3D Print
P2 perforation
### What device will fit?

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**Amplatzer Duct Occluder II**

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### Patient-Specific 3D Print Modeling for Leaflet Repair

**Atrial View**
Replicating the calcium too

Ventricular View

Guiding the practiced procedure

MitraClip @ A2/P2
ASD occluder within P2

*Little et al. JACC Interventions (2016)*
A familiar result?

The Never Ending story dog

Modeling LVOT obstruction

M. Vukicevic, S. Little et al. JACC Img. (2017)
CT-based patient-specific MV

Mitral valve 3D printing

M. Vukicevic, S. Little et al. JACC Img. (2017)
MitraClip implantation in a patient-specific 3D printed MV apparatus

Why do we need models?

3D-Printed Valve models:

- Can replicate patient-specific geometry
- Can be coupled to physiologic flow
- Provide a reproducible testing environment
- Are a cheap arena for mistakes and innovation
- Have already changed how we practice and perfect structural heart interventions