

The Future of 3D Imaging for Intervention

The Heart Center



John P. Cheatham, MD, MSCAI

George H. Dunlap Endowed Chair in Interventional Cardiology

Co-Director, The Heart Center, Nationwide Children's Hospital

Professor, Pediatrics & Internal Medicine, Cardiology

The Ohio State University

Columbus, Ohio, USA



NATIONWIDE CHILDREN'S
When your child needs a hospital, everything matters.™

Disclosures

- As a faculty member of the 3DI3 Conference, I have the following disclosures:
 - None

Acknowledgements

- Mansour AlJufan, MD
 - KFSH & RC, Riyadh, KSA
- Kanishka Ratnayaka, MD
 - Rady Children's Hospital, San Diego
- Robert Lederman, MD
 - NIH/NHLBI
- Elchanan Bruckheimer, MD
 - Schneider Children's Hospital, Petach Tikva, Israel
- Michal Yamin
 - Office Manager, RealView Imaging Ltd.

The Future of 3D Imaging

- Look at what was presented at this conference:
 - 3DRA
 - 4DRA
 - MR 4D Flow
 - MR T2 Relaxometry & O2 sats
 - Computational Fluid Dynamics from 3DRA
 - 3D Fusion
 - Vessel Navigator & CT Overlay
 - 3D ICE

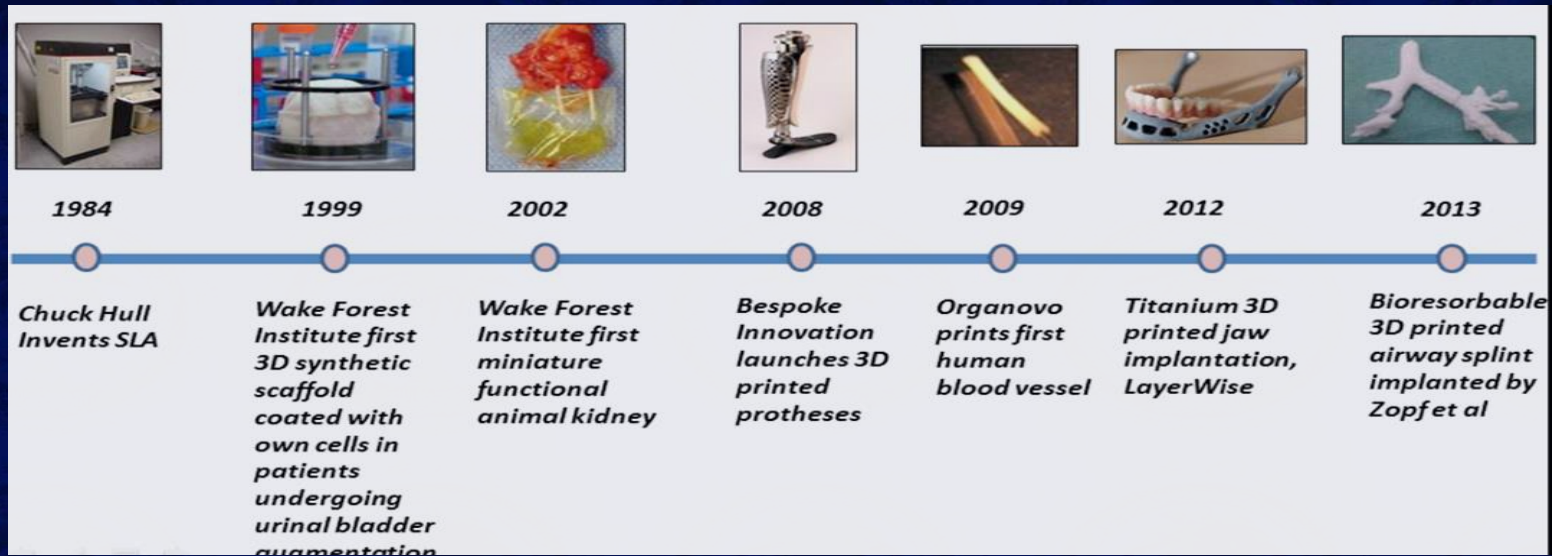
The Future of 3D Imaging

- 3D Printing & Modeling
- ICMR
- Holography

CARDIOVASCULAR 3 D PRINTING , when will it be useful?

cardiovascular application is behind

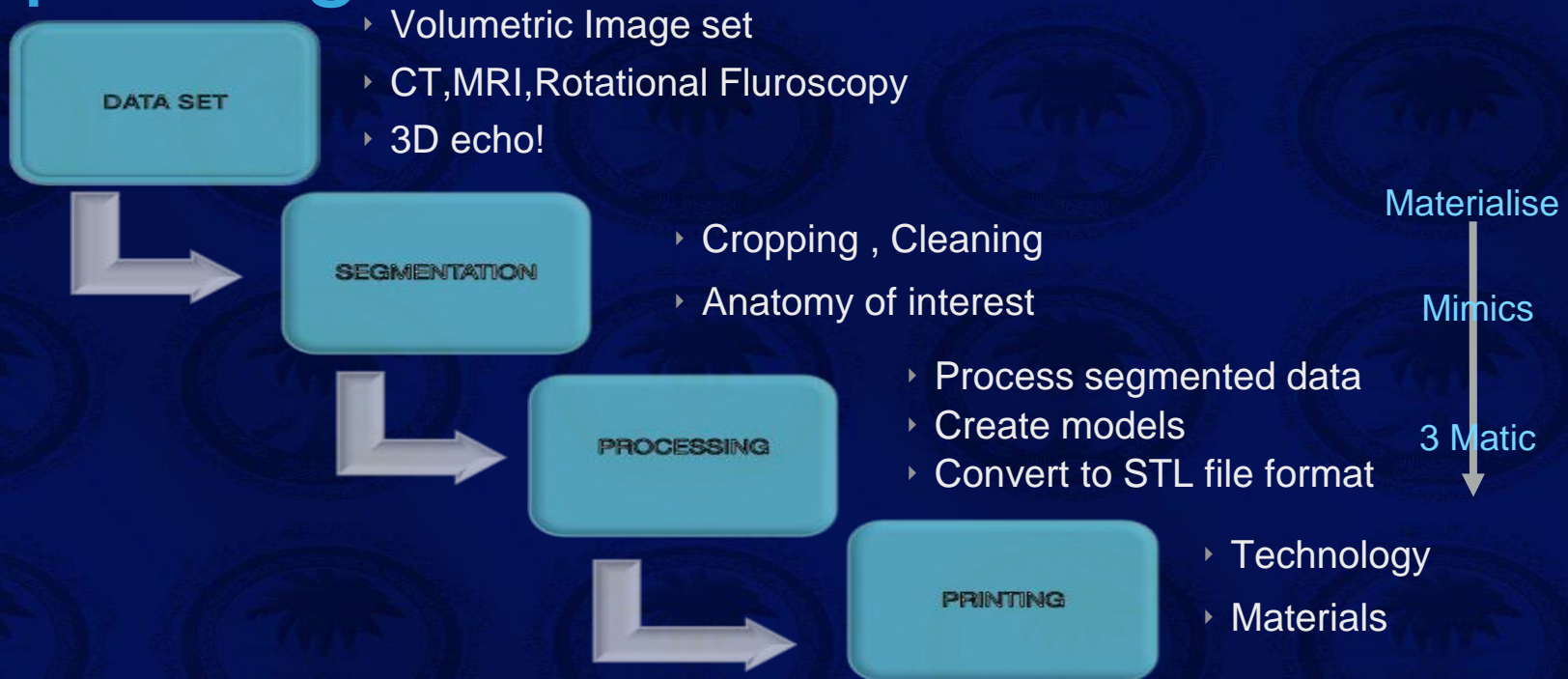
- ▶ Rapidly growing, disruptive technology in medicine



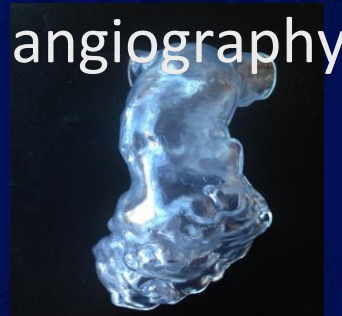
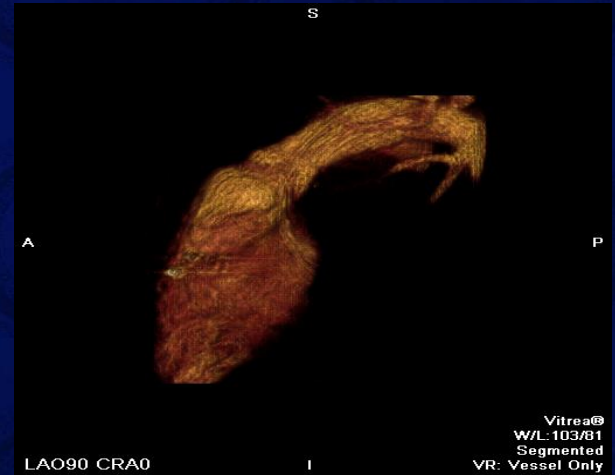
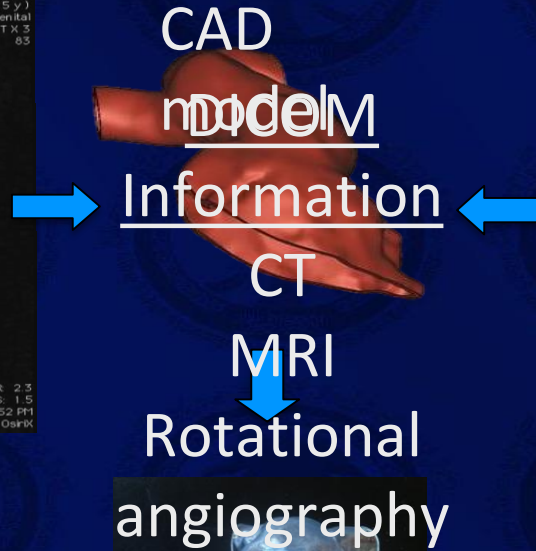
Fabrication of graspable objects from digital models



3 D printing - Work flow



CARDIOVASCULAR 3 D PRINTING , where will it be useful?



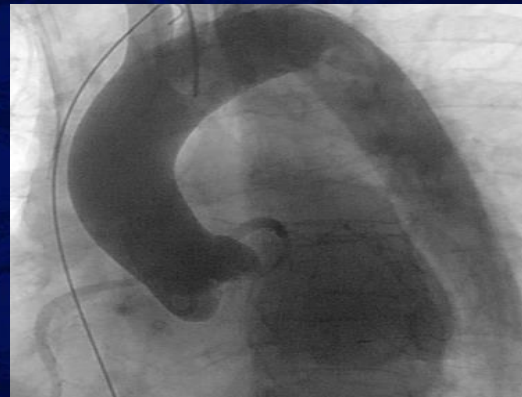
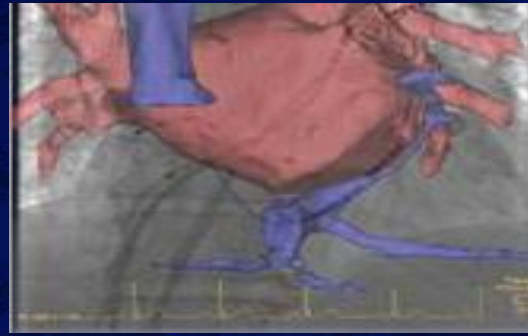
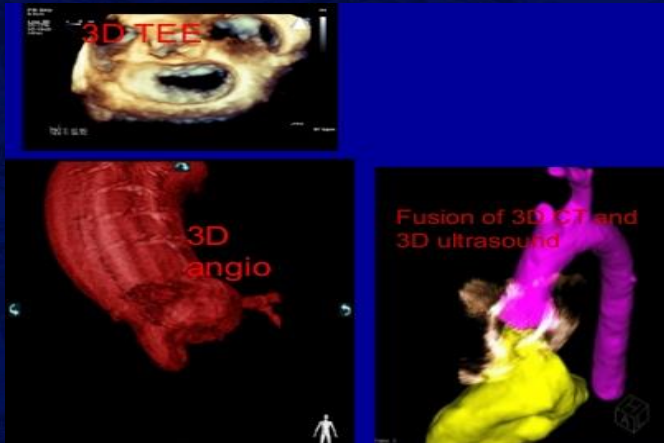
SLA printed model



CARDIOVASCULAR 3 D PRINTING , when will it be useful?

ADDED VALUE OF THE PRINTED MODELS

- 3 D Rotational Angiography
- 3 D Echo, MRI ,
CT angiography
- 3 D Multi-Modality fusion



CARDIOVASCULAR 3 D PRINTING , when will it be useful?

ADDED VALUE OF THE PRINTED MODELS

Tactile objects We still look at 2 D screen



CARDIOVASCULAR 3 D PRINTING , where will it be useful

Wet desktop testing ..



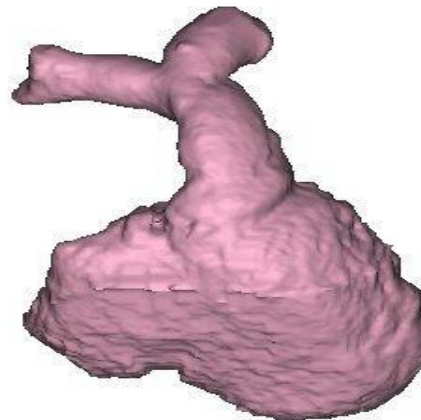
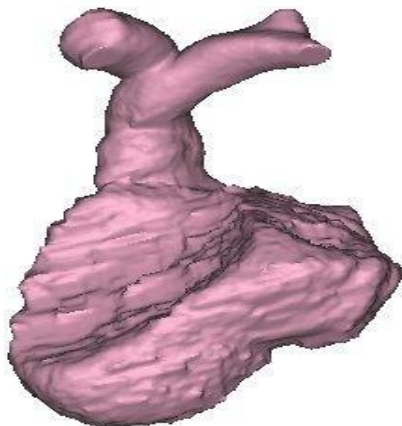
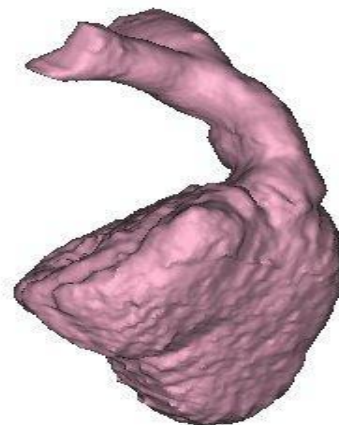
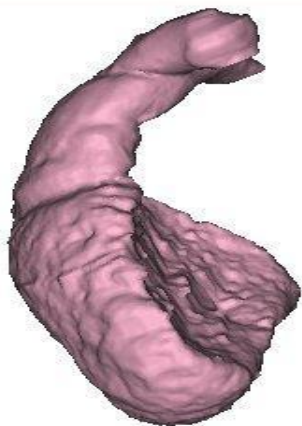
First 29 mm Edward implanted in Native RVOT in Human , 2014 PICS



The Medtronic Harmony TPV EFS

Dual Source Flash CT

The Heart Center

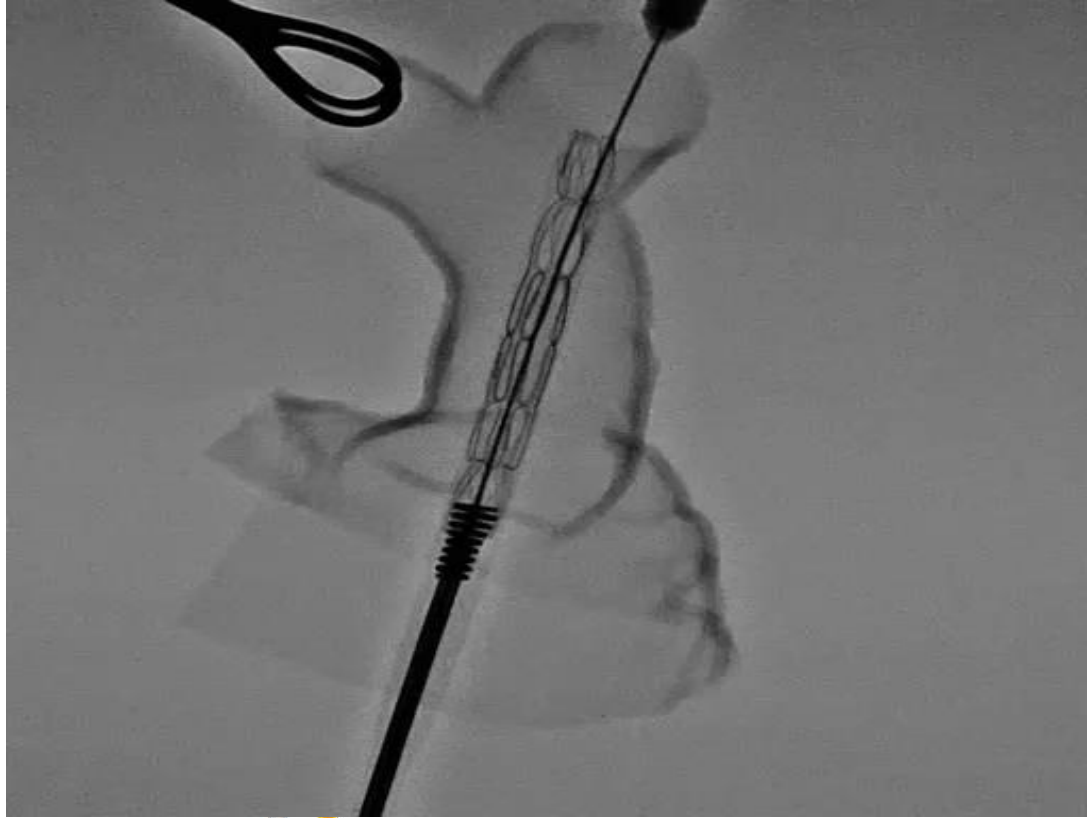


We take pictures & movies of the virtual SLA implant in systole & diastole

The Heart Center

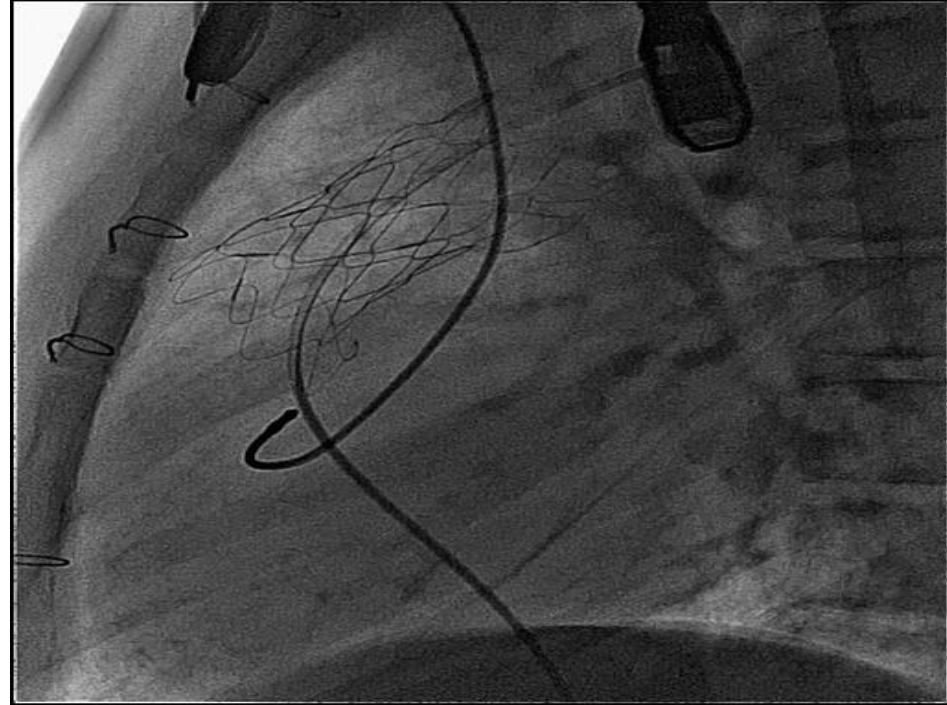
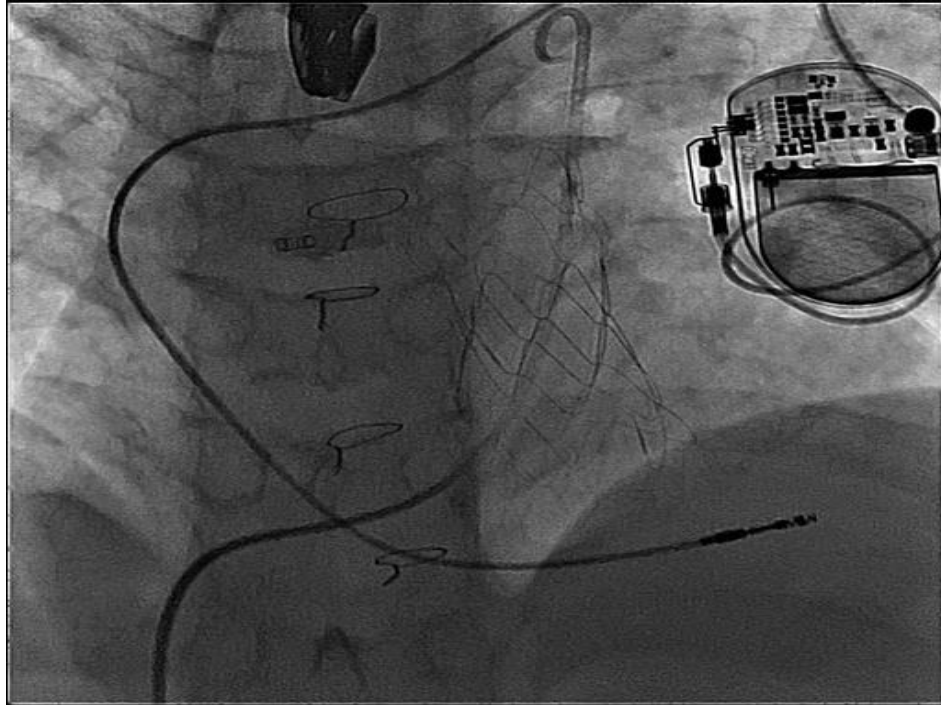


Simulating Implant in the SLA Model The Heart Center



NATIONWIDE CHILDREN'S
When your child needs a hospital, everything matters.™

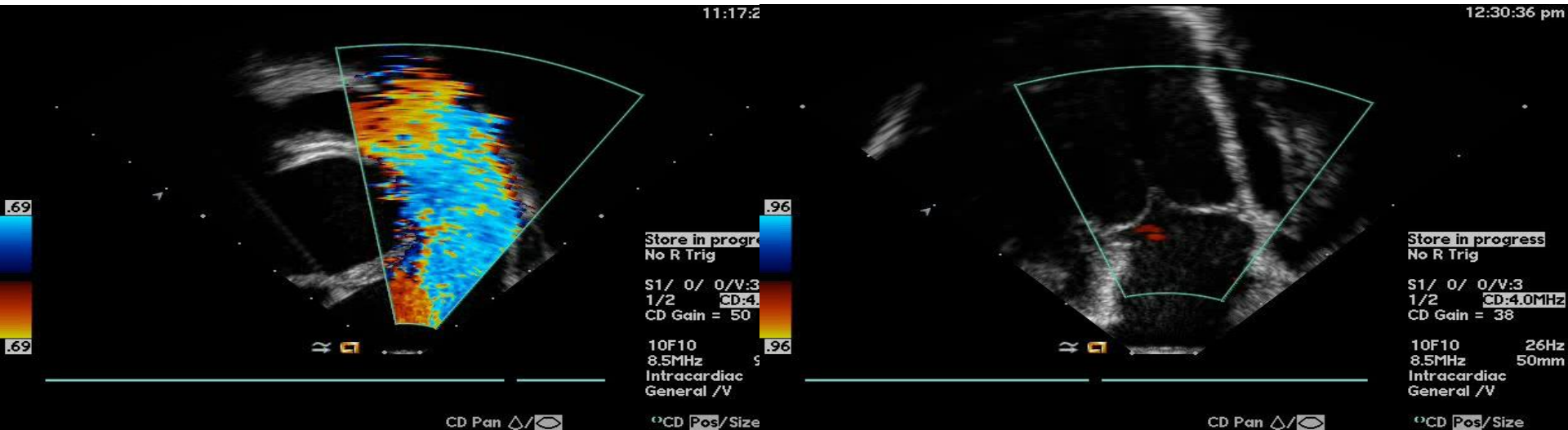
PA Angiogram Post Implant



May 30th, 2013 FIM Implant: ICE

PRE

POST



Hybrid Per-Atrial MVSD Closure

- 4 mo/old with a large apical MVSD, abnormal TV and MV, and CHF
- Close MVSD vs PA band ?
- How to close MVSD
 - Surgical? No way
 - Per-Ventricular? Large moderator band “guarding” MVSD and no room in RV apex
 - Per-Atrial? **Use 3D printing to “practice”**



3D Printing Shows The Answer

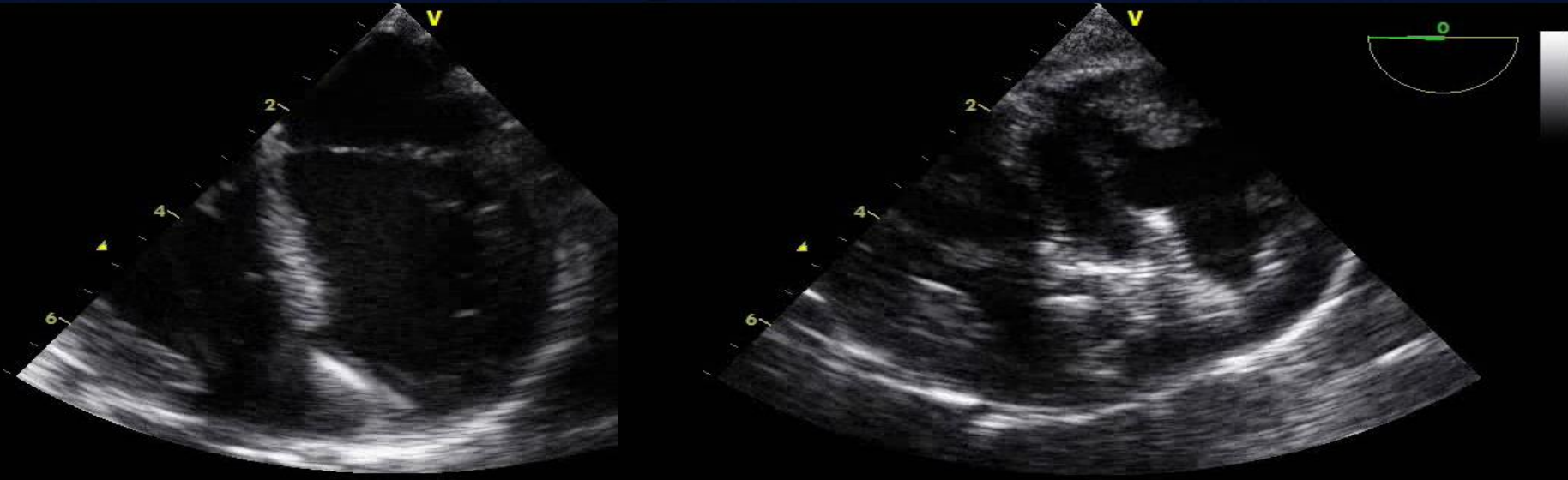
The Heart Center



Hybrid Per-Atrial Apical MVSD Closure Large Apical MVSD

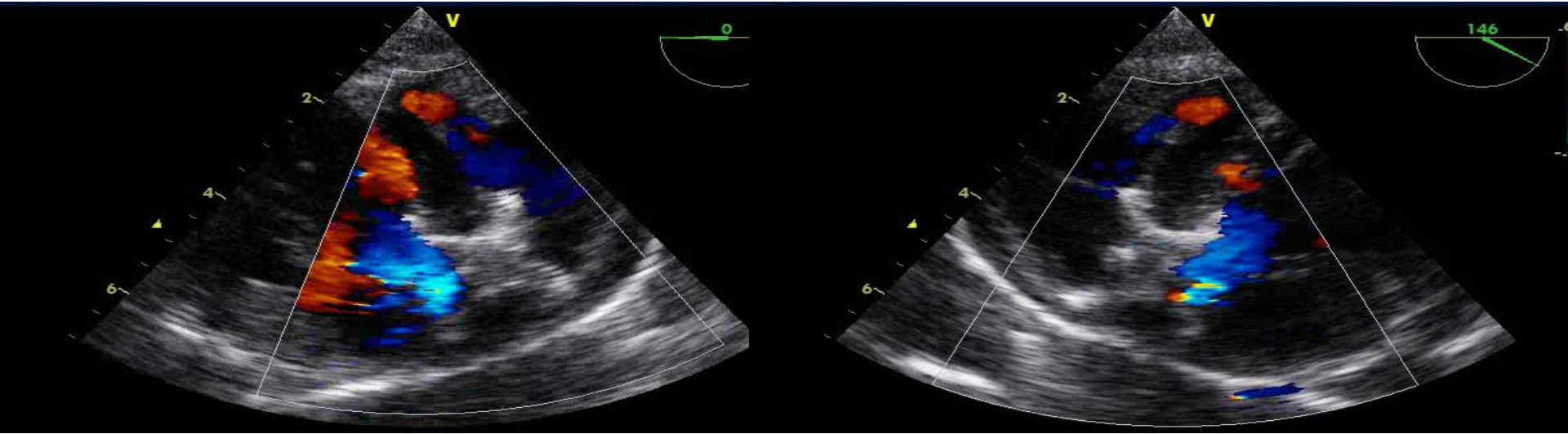


Hybrid Per-Atrial Apical MVSD Closure Sheath from RA and 16mm MVSDO



Hybrid Per-Atrial Apical MVSD Closure

No significant residual flow



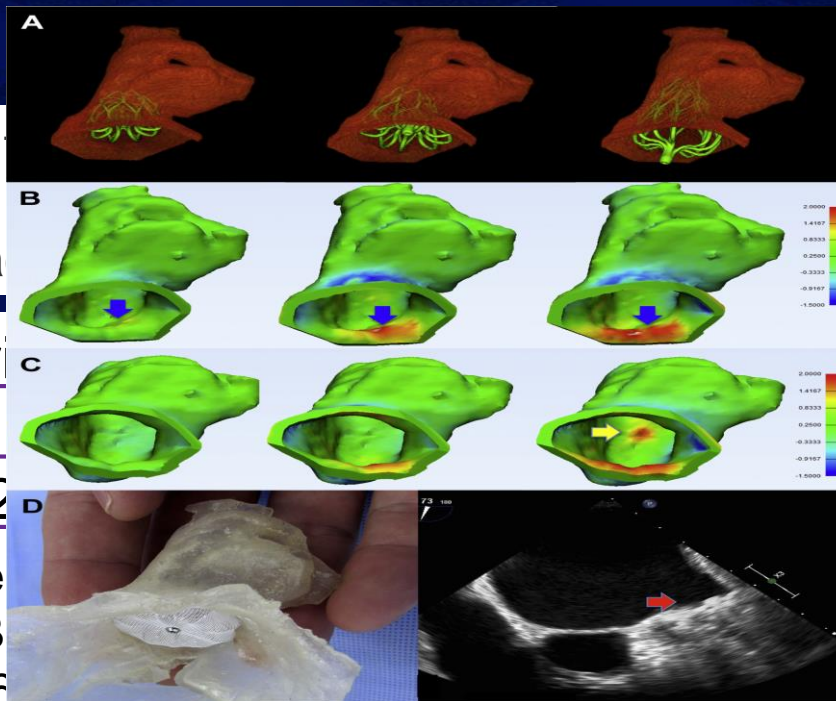
CARDIOVASCULAR 3 D PRINTING , where will it be useful?

Custom design Device for intervention ..

3-Dimensional Printed
Embolization of an
The Annals of Thoracic

3-dimensional printed
coil embolization
Sodian R , et al 2015

Left Atrial Appendage
James M. Otton, MB
2015;8(7):1004-1006



Devices for Coil
Replacement
19

3D-printed devices for
aortic arch replacement

Cardiac Reconstruction
, J Am Coll Cardiol Intv.



CARDIOVASCULAR 3 D PRINTING , where will it be useful?

Surgical Planning for complex repair

Three-dimensional printing for perioperative planning of complex aortic arch surgery.

Schmauss D, Juchem G, Weber S, Gerber N, Hagl C, Sodian R. Ann Thorac Surg. 2014 Jun;97

Cardiovascular Images

Use of 3-Dimensional Printing to Demonstrate Complex Intracardiac Relationships in Double-Outlet Right Ventricle for Surgical Planning

Kanwal M. Farooqi, MD; James C. Nielsen, MD; Santosh C. Uppu, MD;
Shubhika Srivastava, MBBS; Ira A. Parness, MD; Javier Sanz, MD;
Khanh Nguyen, MD

Circ Cardiovasc Imaging.
2015 May

Three-dimensional printing in cardiac surgery and interventional cardiology: a single-centre experience. Schmauss D, et al , Eur J Cardiothorac Surg. 2014 Jun;47(6):1044-52.

May decrease Mortality ..



Patients Communications

BMJ Open 3D-manufactured patient-specific models of congenital heart defects for communication in clinical practice: feasibility and acceptability

Giovanni Biglino,¹ Claudio Capelli,¹ Jo Wray,² Silvia Schievano,¹
Lindsay-Kay Leaver,² Sachin Khambadkone,² Alessandro Giardini,²
Graham Derrick,² Alexander Jones,¹ Andrew M Taylor¹

BMJ 2015 Apr 30;5(4):e007165. doi: 10.1136/bmj -2014-007165.

Conclusions: Patient-specific models can enhance engagement with parents and improve communication between cardiologists and parents, potentially impacting on parent and patient psychological



Final Thoughts

- ▶ It is useful adjunct to performing complex and Novel hybrid interventions
- ▶ Improves the ability to understand complex relationships
- ▶ Ability test various treatment strategies
- ▶ Improve communications among teams
- ▶ Potential to shorten procedure time , and precision , thus improving outcome
- ▶ Teaching
- ▶ Many New 3 D technology triggers , will enhance it's utility, and presence in Cardiovascular therapeutics



Interventional Cardiovascular MRI is perfect for Structural Heart Disease

Radiation exposure significant

- AHA Science Advisory (Circ 2009)
- Children are radiosensitive; carry lifetime risk
- Fluoroscopy times are 5-10x longer than adult procedures
- Cancer & leukemia risk (Kleinerman, Ped Rad 2006)
- Chromosomal damage evident in the peripheral blood of children exposed to catheterization-related radiation (Andreassi, EHJ 2006; Beels, Circ 2009)

Children's National Medical Center – NHLBI



ICMR = cardiac imaging core

Diagnostic

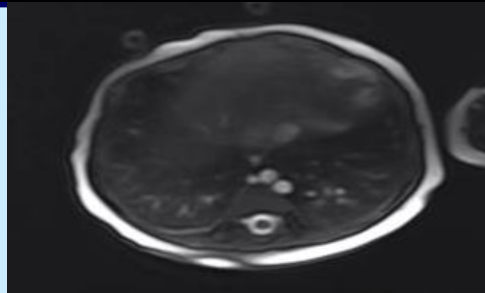
Intervention

MRI
inspired

3D
printing

Cardiac
Mechanics

- Sedation Free MRI
- Function:
 - Heart Failure
 - Cardiomyopathy
- Perfusion
 - Kawasaki's, Coronary
- Adult Congenital Heart Disease
- Fetal
- Clinical trials
 - Duchenne Muscular Dystrophy
 - Obesity



ICMR = cardiac imaging core

Diagnostic

Intervention

MRI
inspired

3D
printing

Cardiac
Mechanics

- Radiation Free diagnostic catheterization
 - Pulmonary Hypertension Center
- Radiation Free interventional radiology
- Structural heart procedures
 - Conventional
 - Novel
- Electrophysiology
- XFM (Xray Fused with MRI)
 - Other Fusion (CT, U/S)

ICMR = cardiac imaging core

Diagnostic

Intervention

MRI
inspired

3D
printing

Cardiac
Mechanics

- Novel procedures
 - Backstabbing
 - Caval-aortic
 - Valve repair
- Innovation pathway
 - Devices
 - Patents
 - Grants, Contracts

ICMR = cardiac imaging core

Diagnostic

Intervention

MRI
inspired

3D
printing

Cardiac
Mechanics

- Great data set
- Surgical/interventional planning
- Future: biologic “inks” / bioprinting



ICMR = cardiac imaging core

Diagnostic

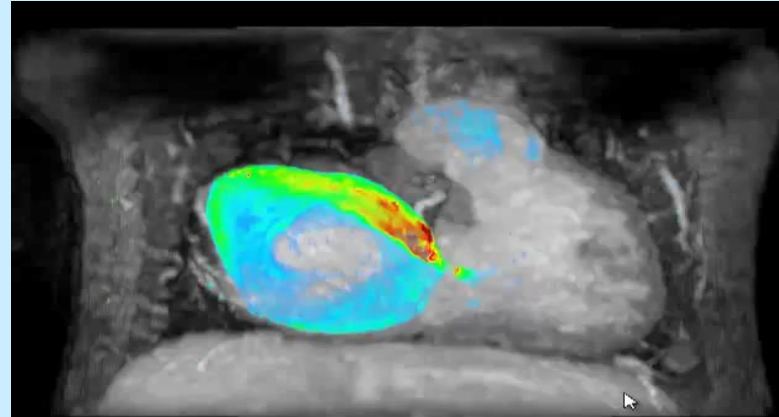
Intervention

MRI
inspired

3D
printing

Cardiac
Mechanics

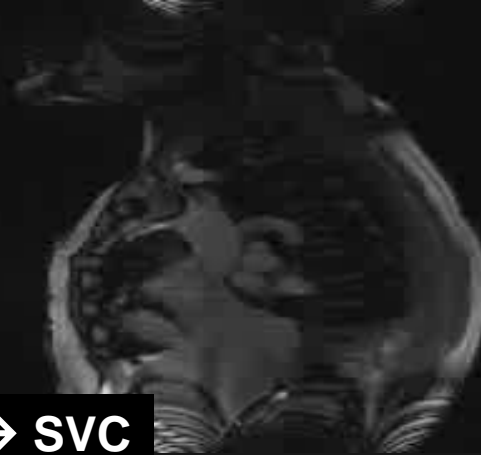
- Great data set for computational fluid dynamics
- 4D Flow



Diagnostic MRI Cardiac Catheterization



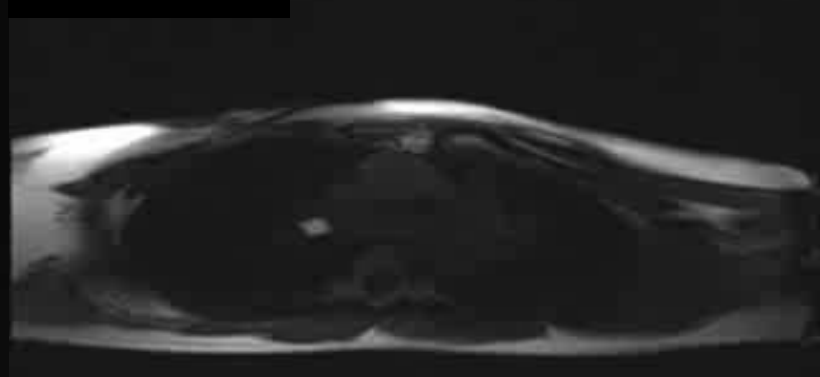
IVC → RA



RA → SVC



RV → MPA



MPA → RPA → LPA

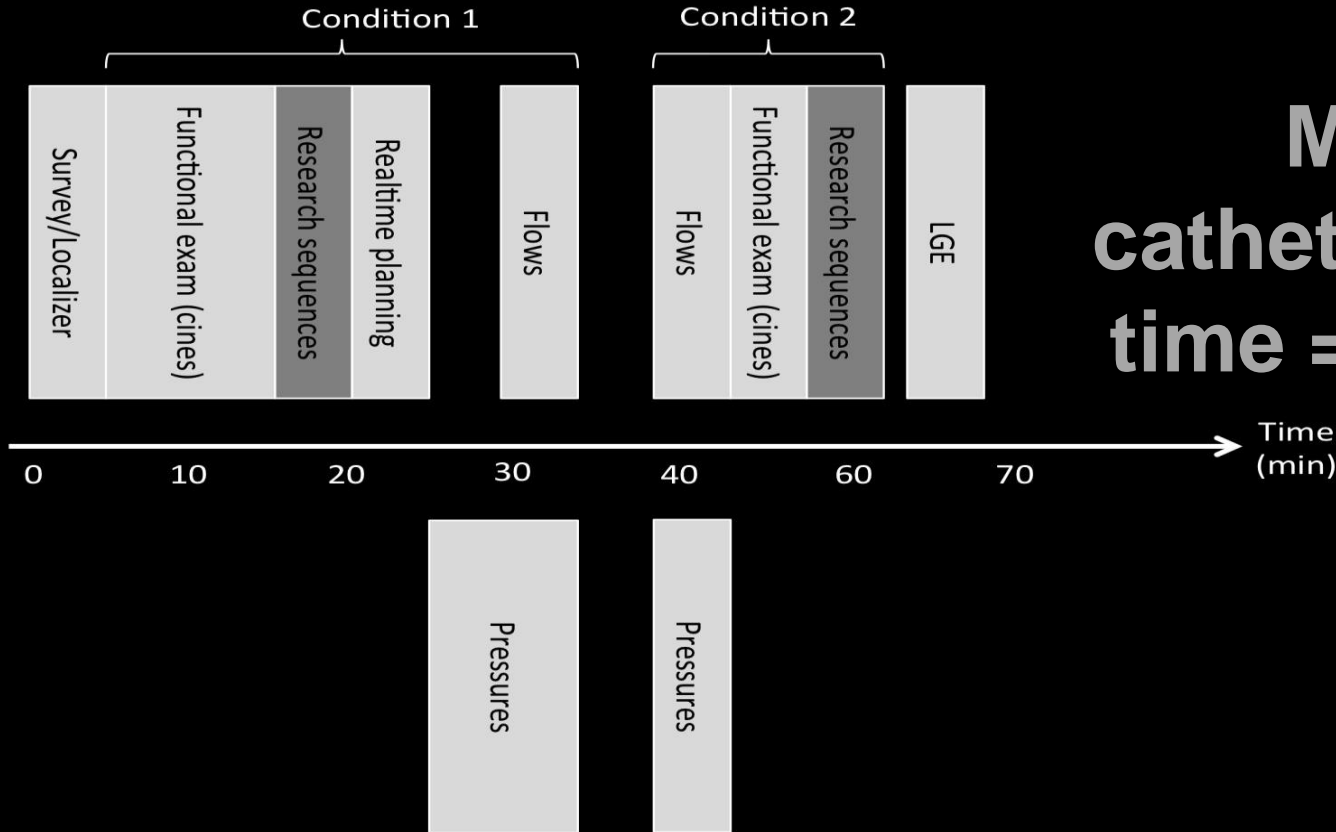
Diagnostic | Intervention | XFM | EP | Novel | MRI Inspired

MRI Catheterization World Experience

Location	Cases
NIH <i>***Now Clinical Standard for Right Heart Catheterization</i>	> 100
Kings College London	> 300
Great Ormond Street Hospital London <i>***All Pediatric Pulmonary Hypertension Patients</i>	> 350
Berlin Charite	32
Other Literature reports	>200
Total World Experience	> 950 cases



Procedure Time



**Mean
catheterization
time = 31 mins**

Diagnostic

Intervention

XFM

EP

Novel

MRI Inspired

Structural Heart Intervention

BBC Mobile News | Sport | Weather | Travel | TV | Radio | More

NEWS ▶ Watch ONE-MINUTE WORLD NEWS

News Front Page Page last updated at 05:31 GMT, Saturday, 9 January 2010

 [E-mail this to a friend](#) [Printable version](#)

Heart operation using MRI is world first

A British six-year-old boy has become the first person in the world to have a heart valve widened using an MRI scan for guidance rather than X-ray imaging.

Jack Walborn was born with the heart condition pulmonary valve stenosis, which reduces blood flow to the lungs.



Jack had a blocked heart valve

Using MRI means patients are not exposed to radiation - particularly important for children.

The scan also provides a clearer image, and information about the body's tissues, in real time during surgery.

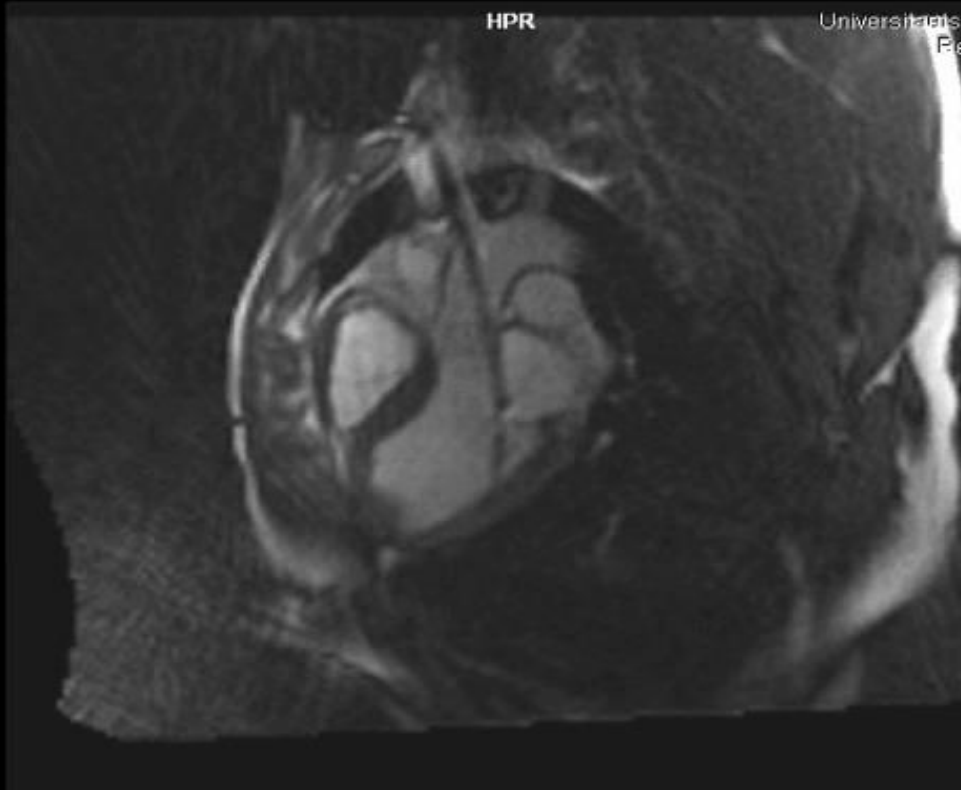
Health | Medical notes | Science & Environment | Technology | Entertainment | Also in the news | Video and Audio

Real-time MRI TAVR Direct Aortic CoreValve

Anihhqi,Lila No.2
ID: M1232897
* 18.12.1900
Study 1543713
18.12.2009
23:51:40
89 IMA

HPR

Universitätsklinikum
Ref.: WISS
Avanto
FFS



ARH

SL 6

TE 1.20
TR 2.24

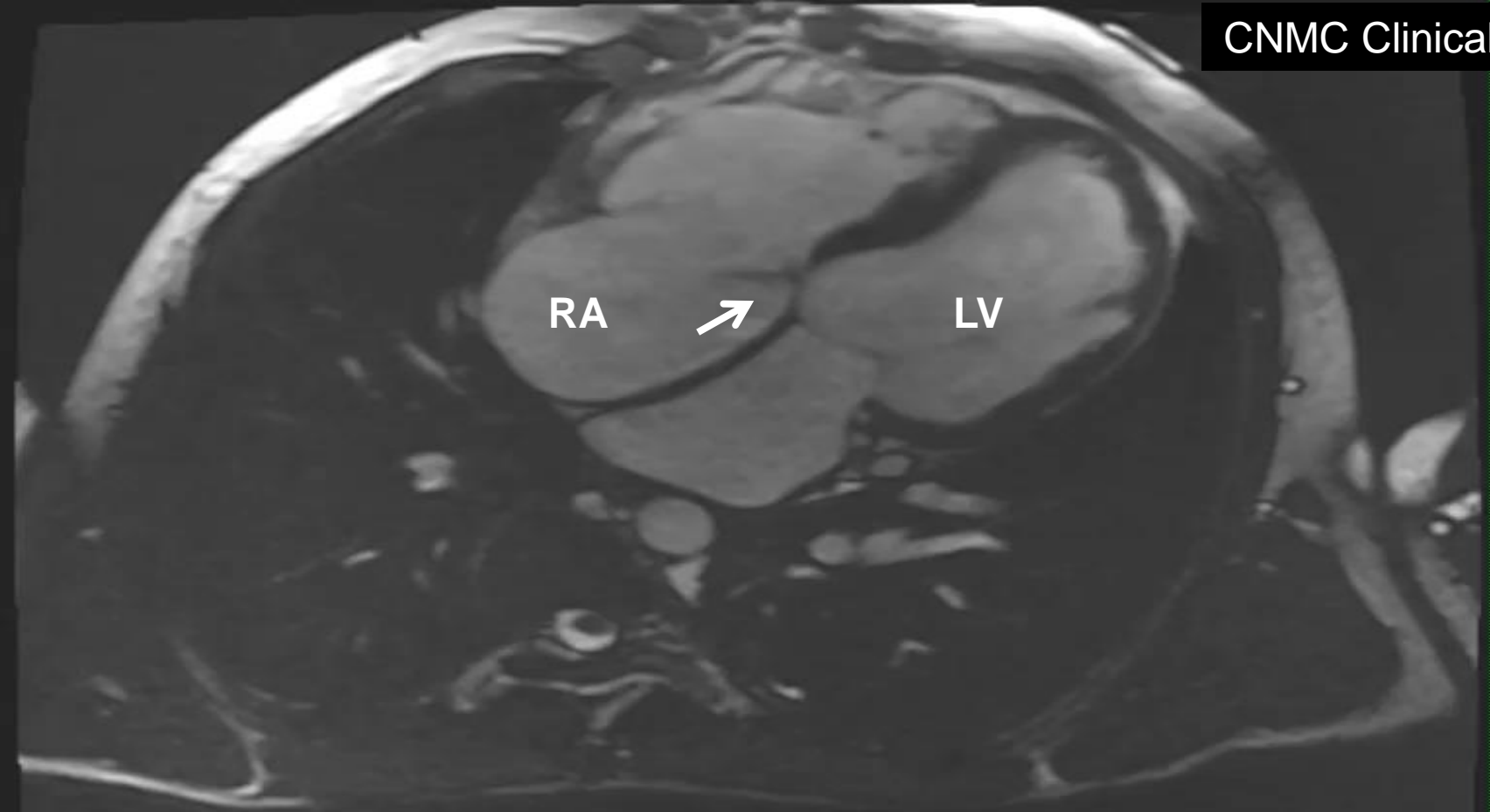
SP L68.2
FoV 360*360
160*160s
Sag>Cor(25.2)>Tra(-8.4)
W: 841
C: 332

Kahlert
JACC
2012

National Heart, Lung,
and Blood Institute



Diagnostic | Intervention | XFM | EP | Novel | MRI Inspired



Left Ventricle to Right Atrium Intracardiac Shunt

Diagnostic

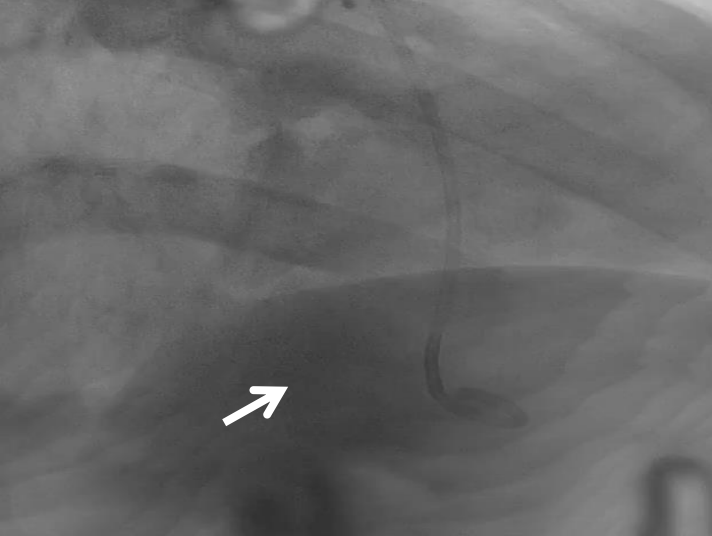
Intervention

XFM

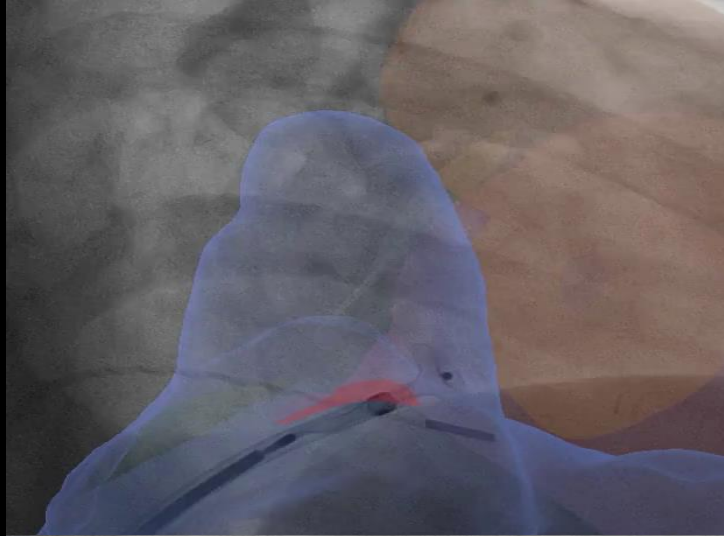
EP

Novel

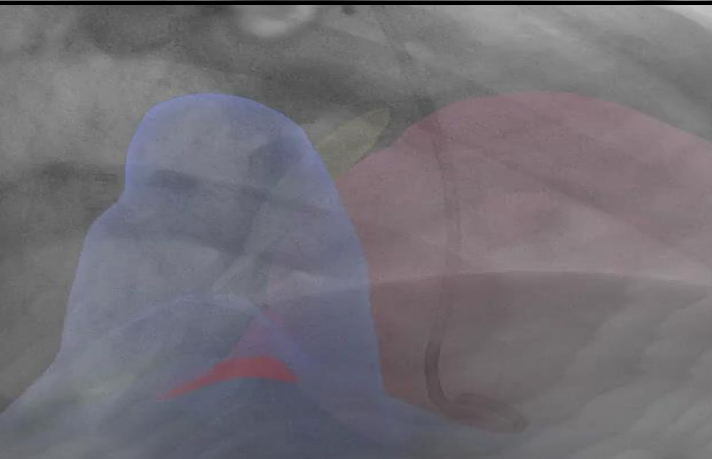
MRI Inspired



X-
Ray



XFM
device
closure



XFM



XFM
post
device
closure

Diagnostic

Intervention

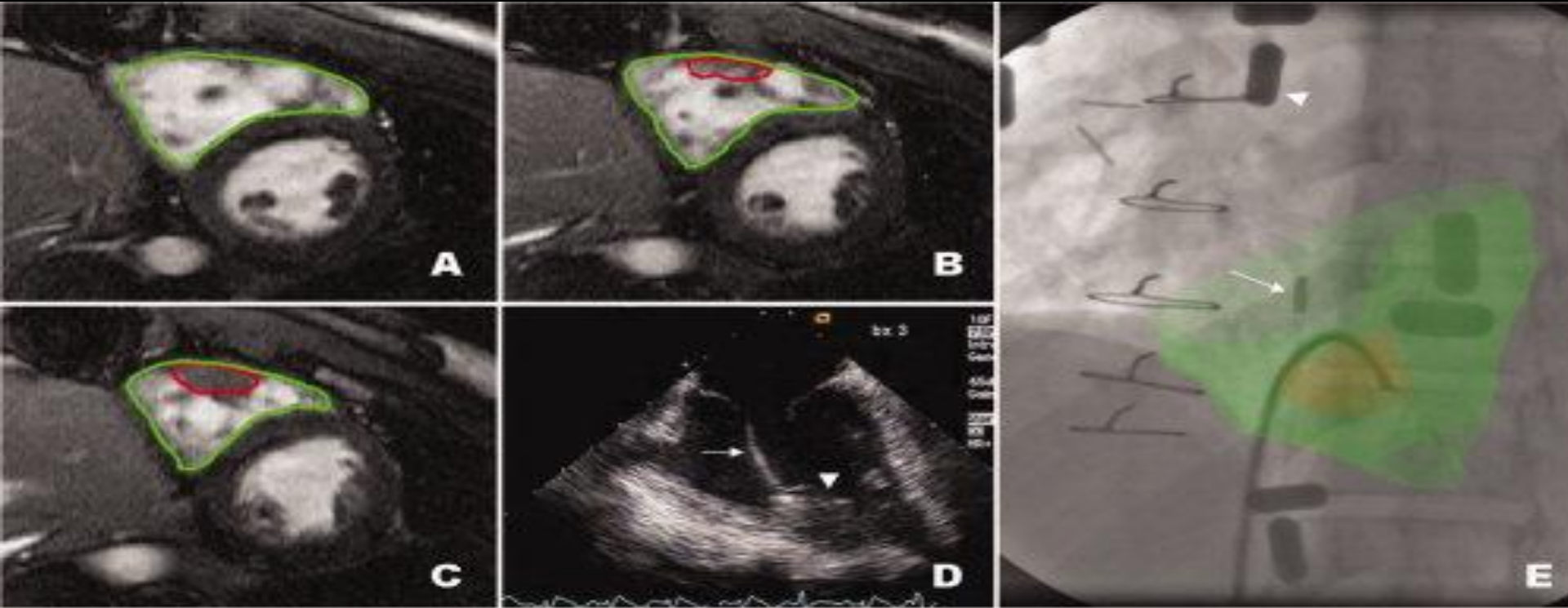
XFM

EP

Novel

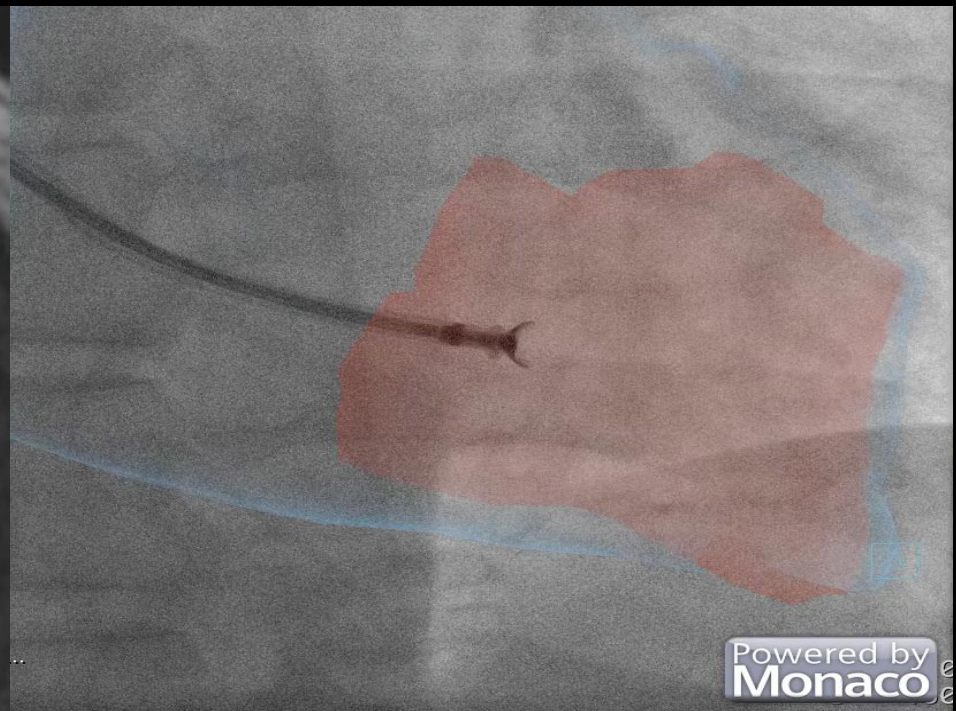
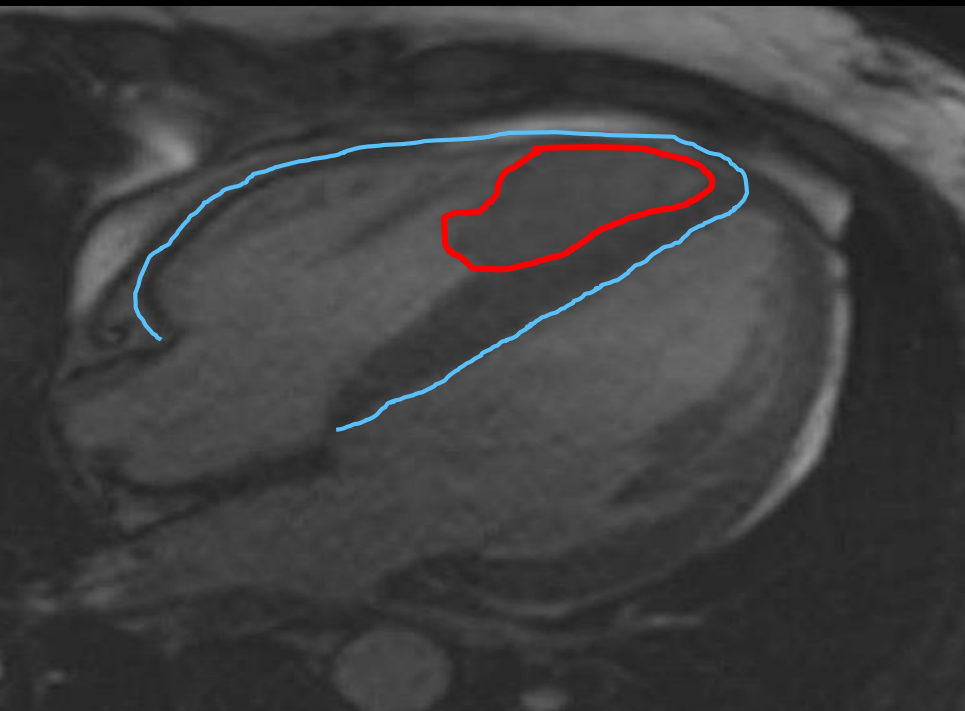
MRI Inspired

Cardiac Biopsy



Gutiérrez, CCI 2007

XFM: Intracardiac Mass Biopsy



NHLBI/NIH clinical

Diagnostic

Intervention

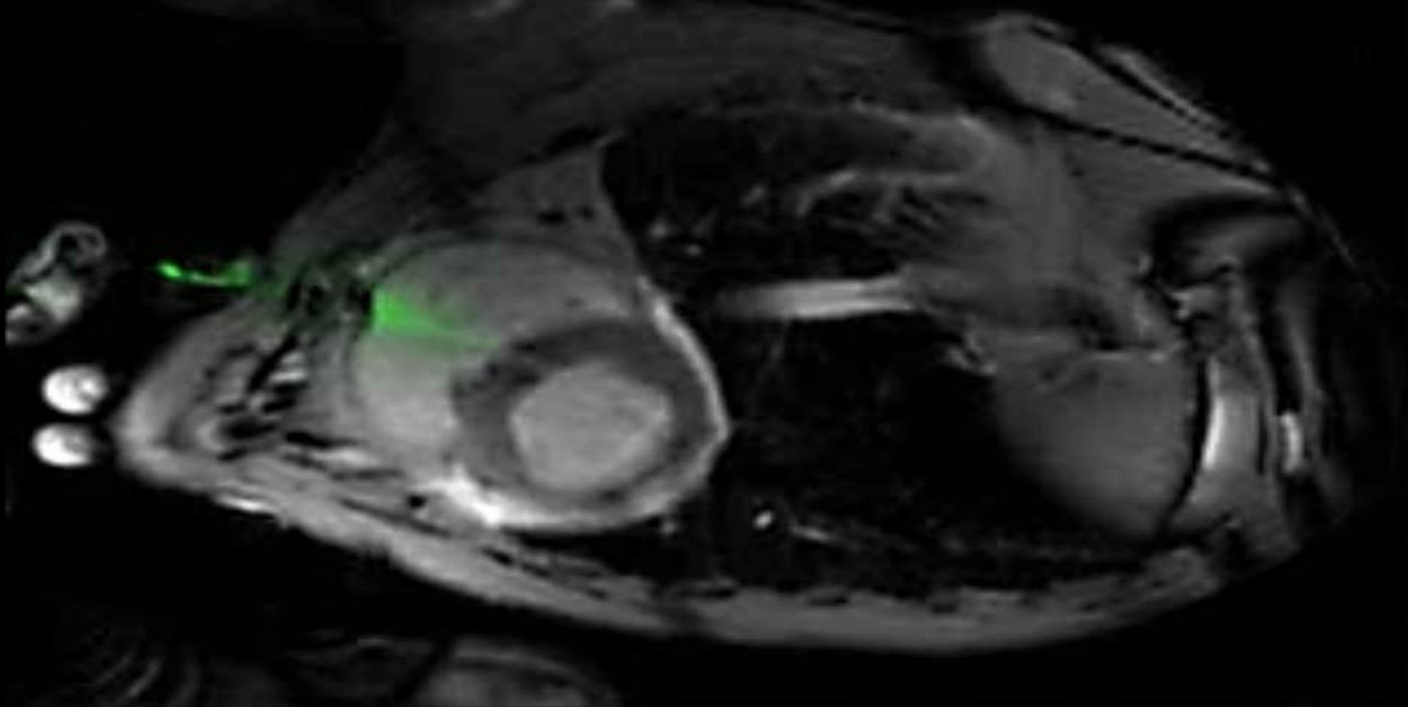
XFM

EP

Novel

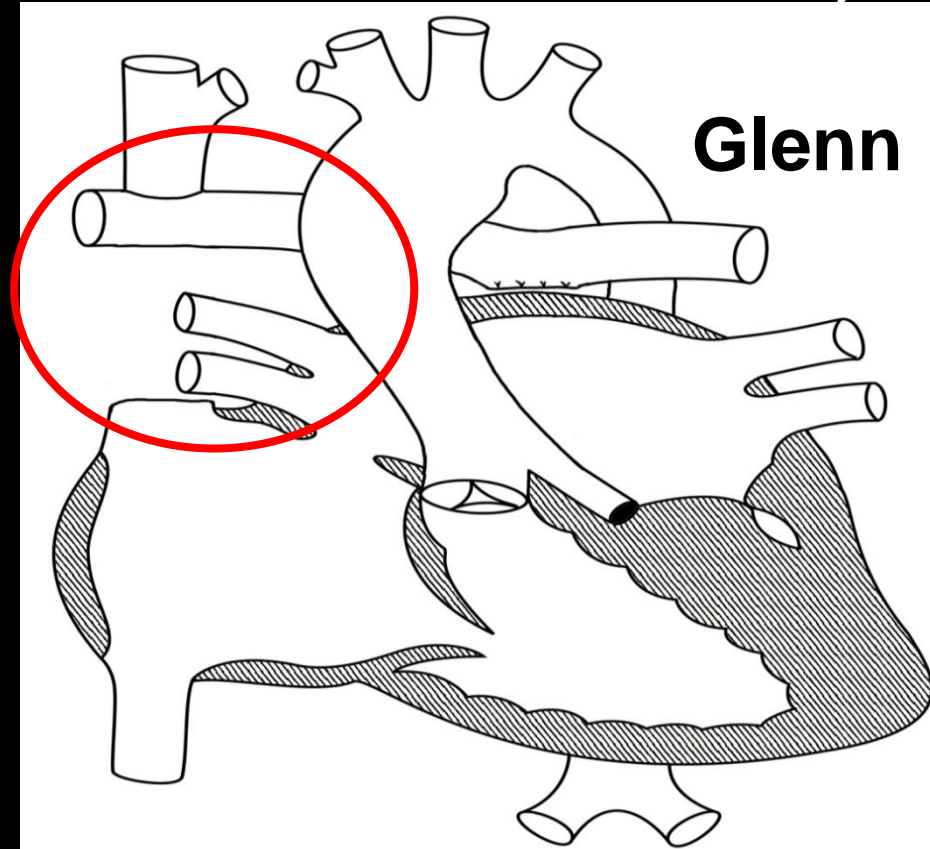
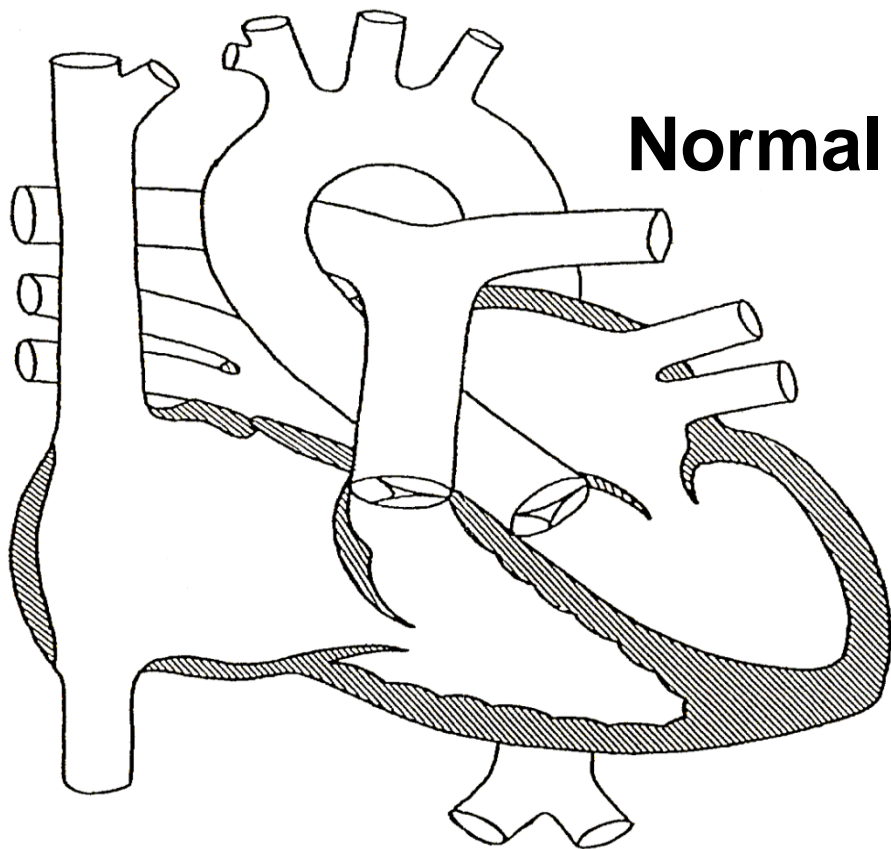
MRI Inspired

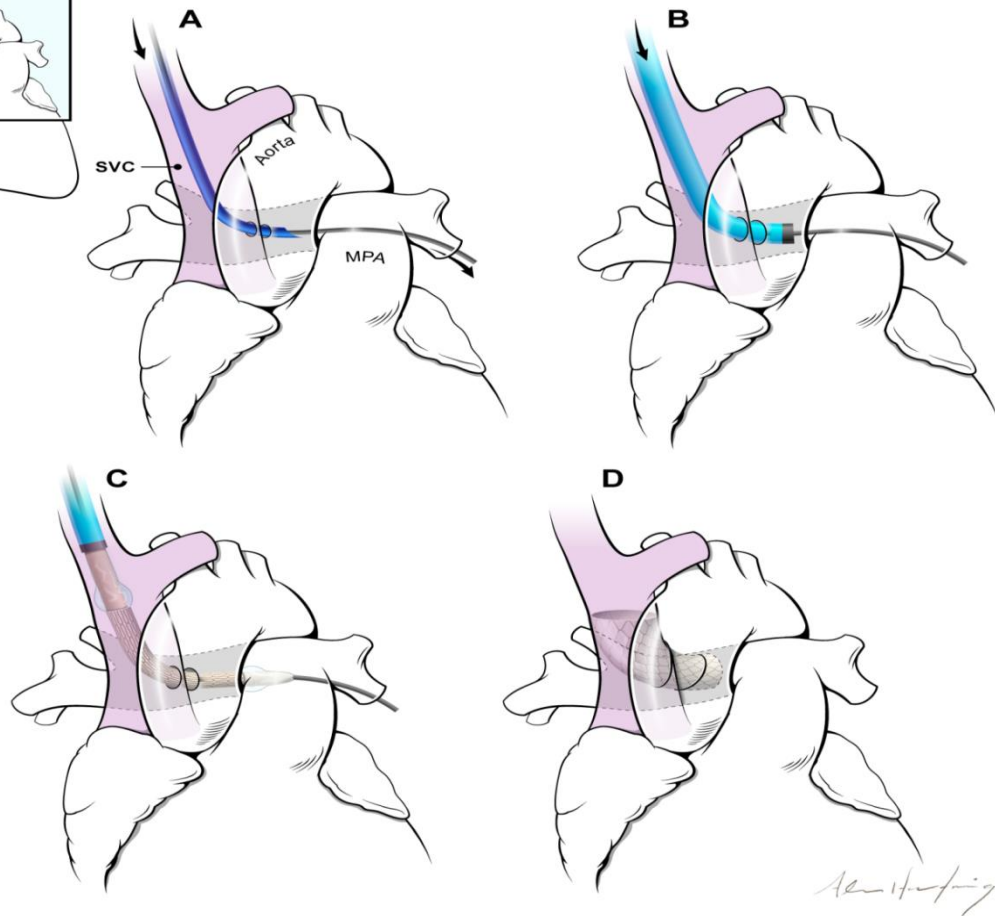
Real time MRI guided mVSD closure



Ratnayaka, JACCInter 2011

MRI Glenn (SVC – PA Anastomosis)

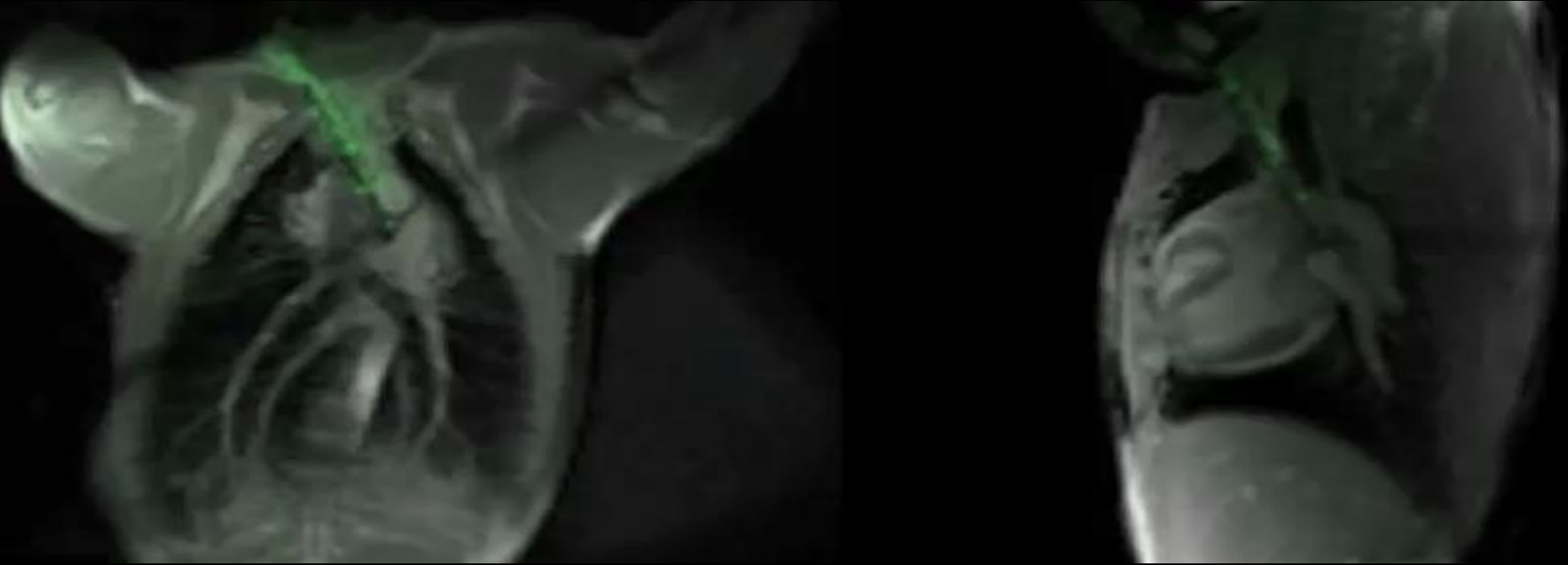




MRI Glenn: Concept

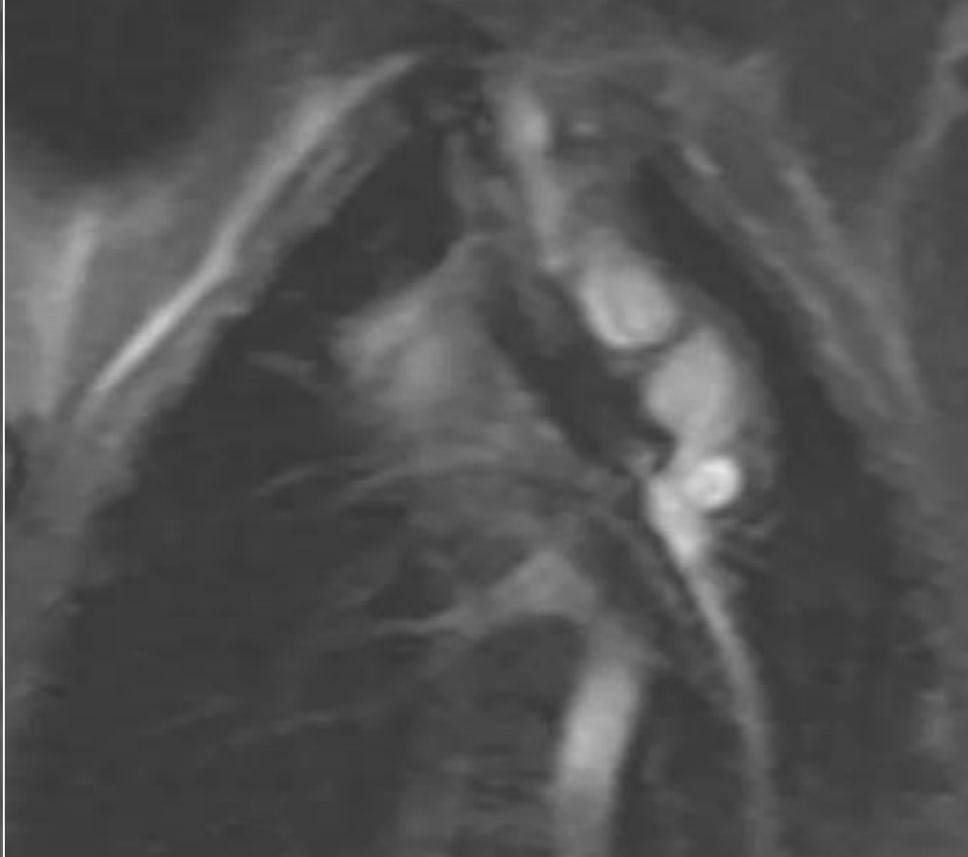
(Ratnayaka, under review)

“Active” Needle Puncture



(Ratnayaka, under review)

Covered Stent Deployment



Diagnostic

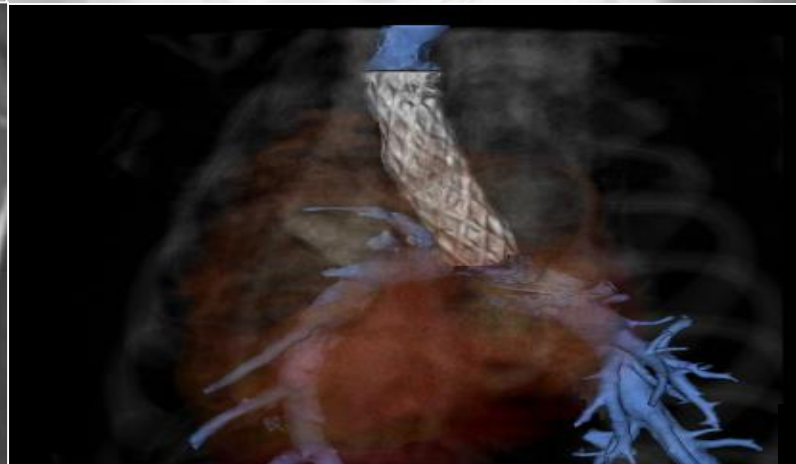
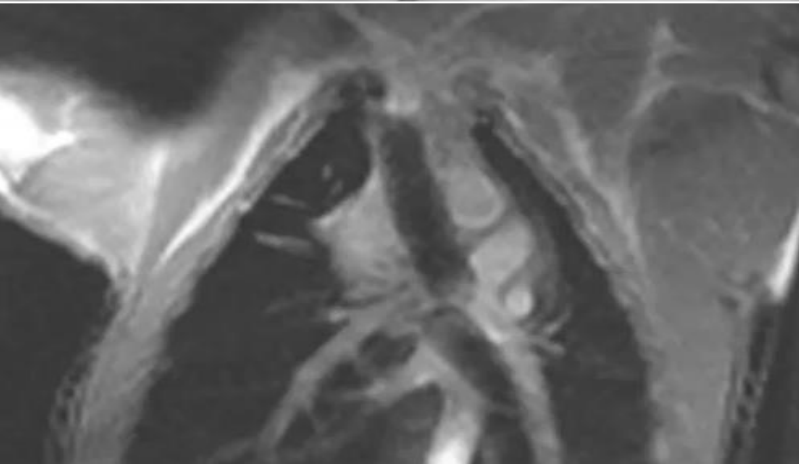
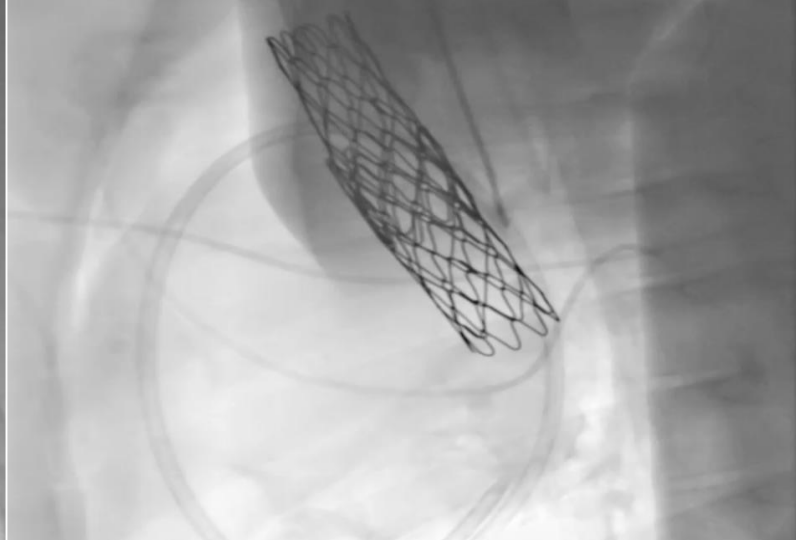
Intervention

XFM

EP

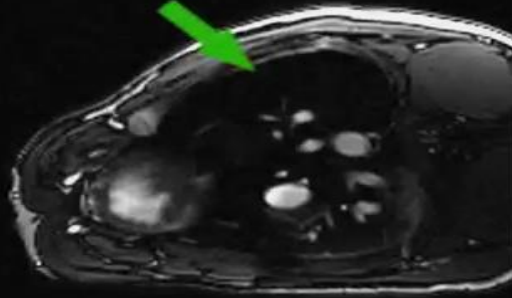
Novel

MRI Inspired

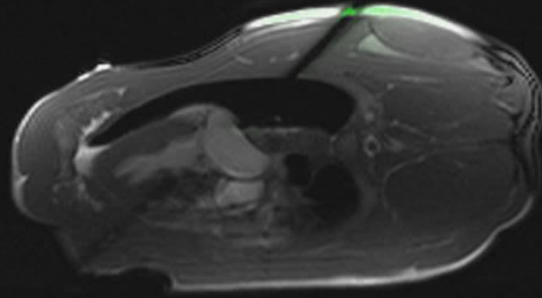


Diagnostic | Intervention | XFM | EP | Novel | MRI Inspired | (Ratnayaka, under review)

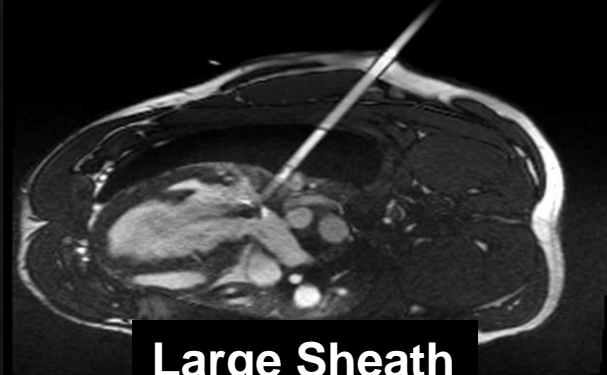
Backstabbing



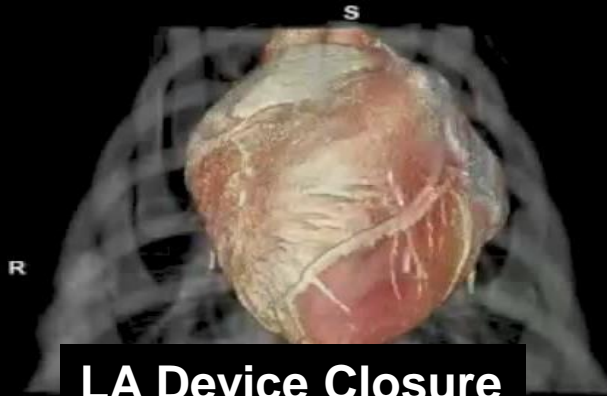
Lung Deflation



LA Access



Large Sheath

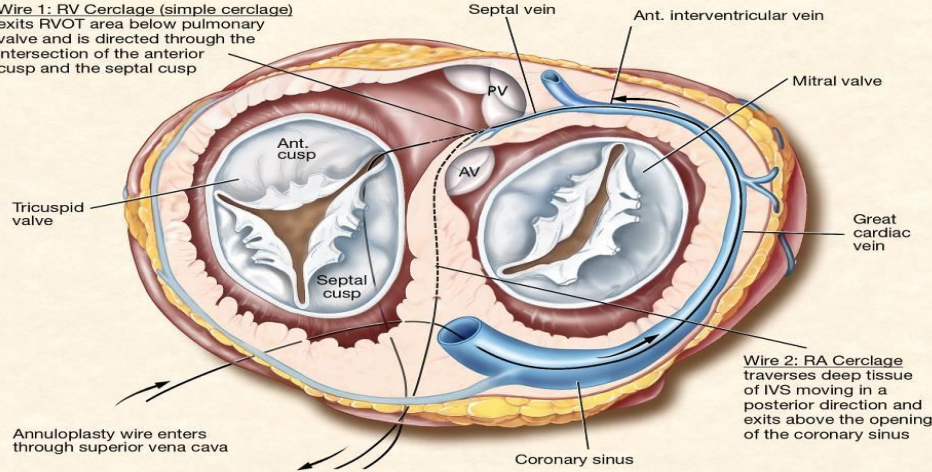


LA Device Closure

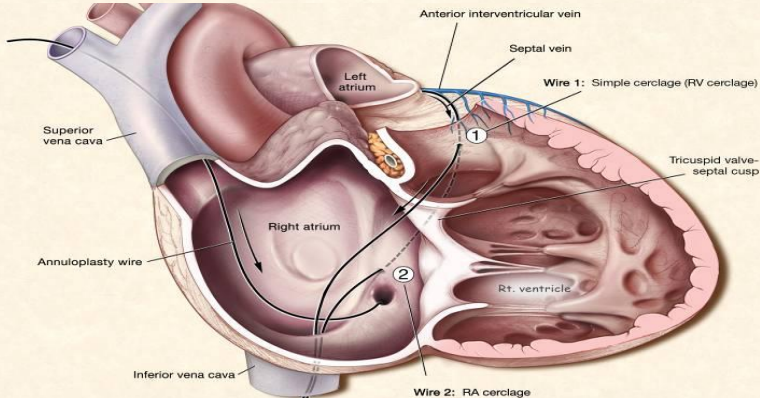
(Rogers,
Under
Review)

Transcatheter cerclage annuloplasty for mitral valve regurgitation

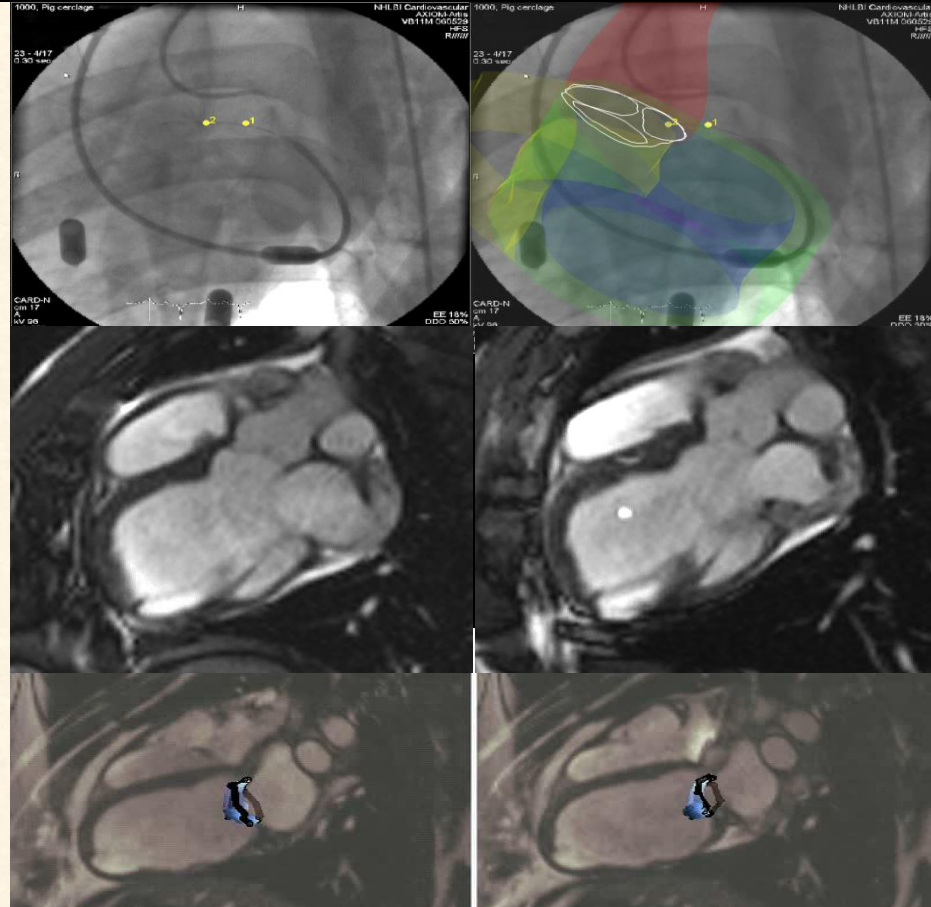
Wire 1: RV Cerclage (simple cerclage) exits RVOT area below pulmonary valve and is directed through the intersection of the anterior cusp and the septal cusp



Wire 2: RA Cerclage traverses deep tissue of IVS moving in a posterior direction and exits above the opening of the coronary sinus

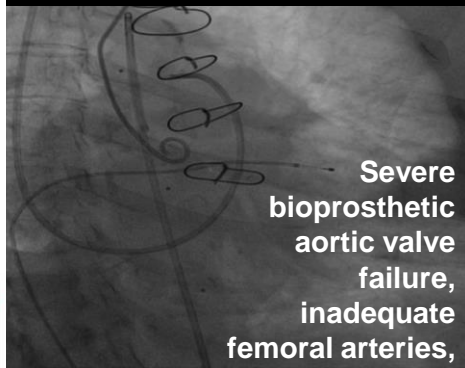
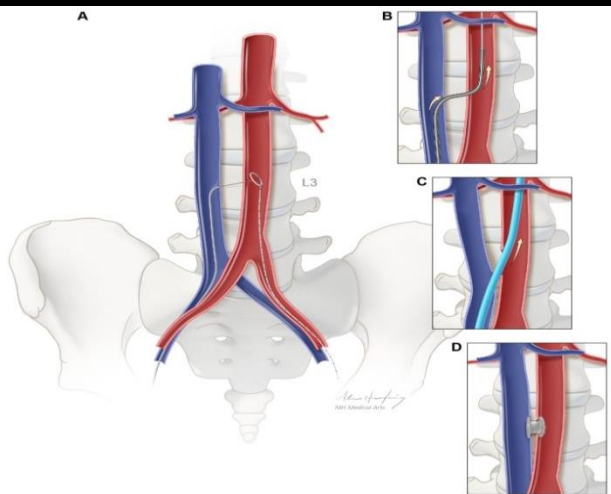


Kim,
JACC
2009

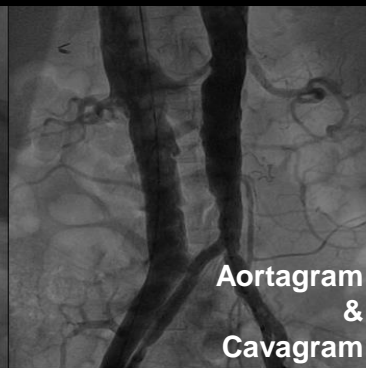


Caval-aortic access for TAVR

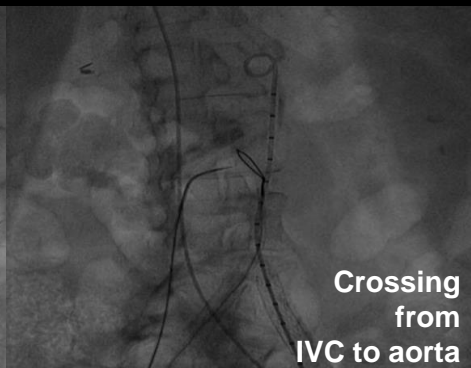
80 patients as of 2/10/2015 in 12 medical centers



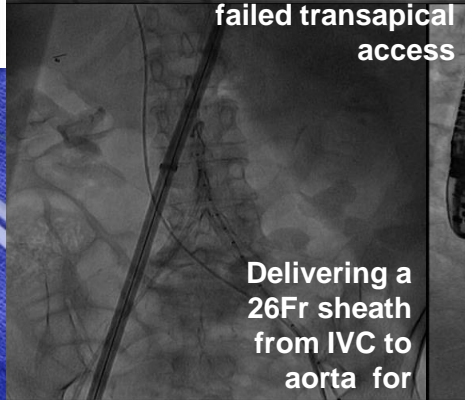
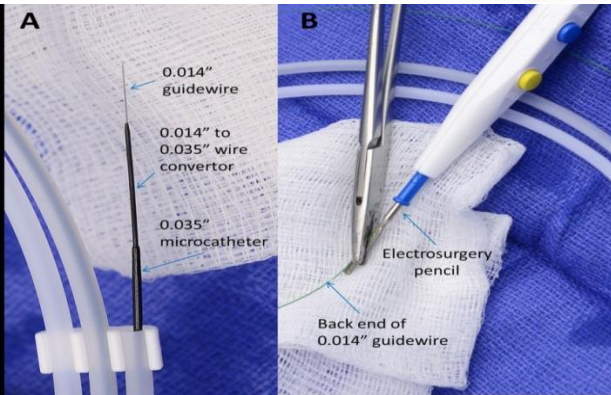
Severe bioprosthesis failure, inadequate femoral arteries, failed transapical access



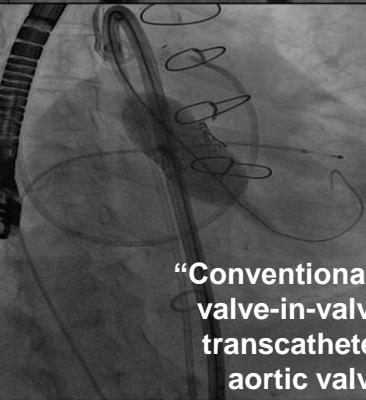
Aortogram & Cavagram



Crossing from IVC to aorta



Delivering a 26Fr sheath from IVC to aorta for TAVR



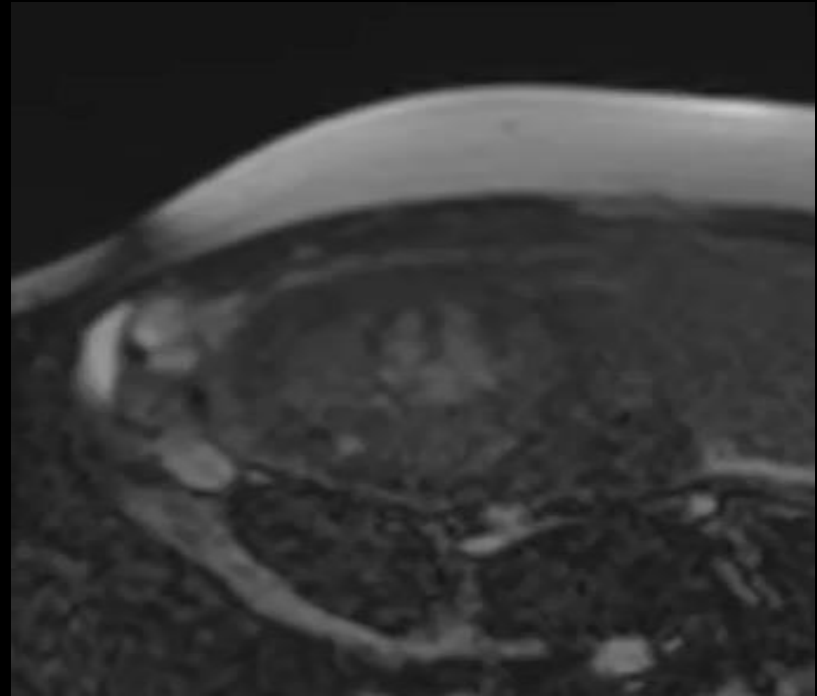
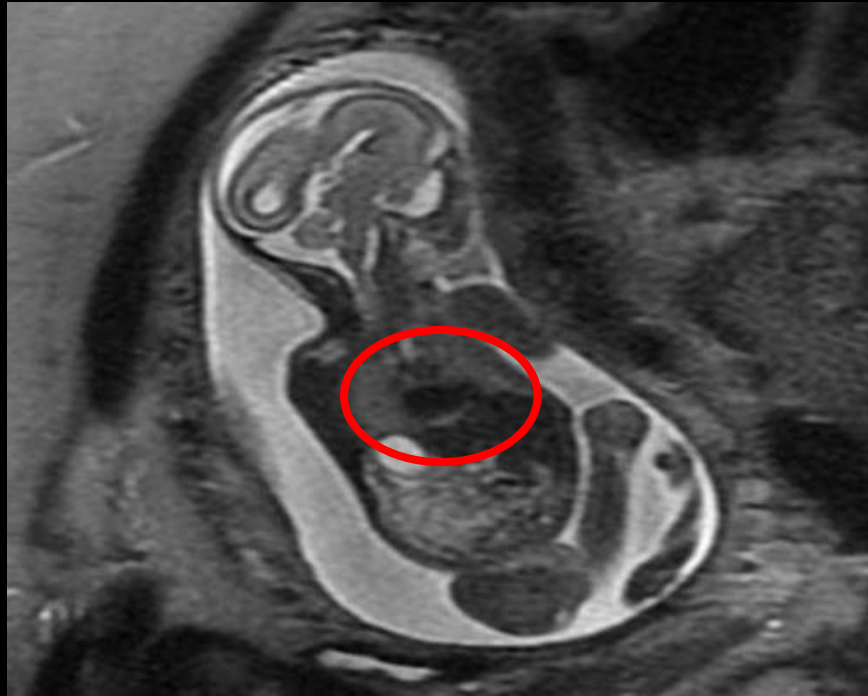
"Conventional" valve-in-valve transcatheter aortic valve replacement



Tract closure with Amplatzer Duct Occluder, minimal residual shunt

Halabi, JACC, 2013; Greenbaum, JACC, 2014

New Method for Fetal Intervention?



CNMC clinical

Conclusions

Real-time MRI is a promising interventional imaging modality

- Information Rich & Radiation Sparing

Interventional Cardiac MRI

- Enhances conventional interventional procedures
- Enables novel real-time MRI guided procedures
- Inspires novel X-Ray guided procedures

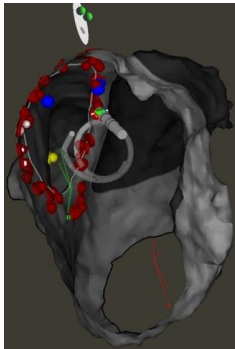
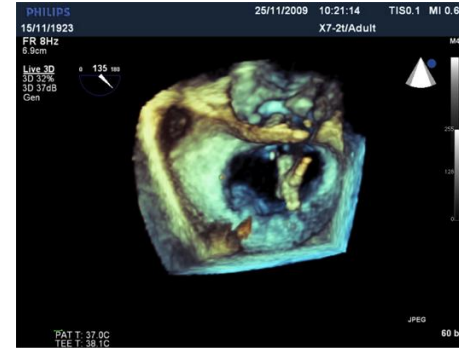
RealView Imaging

October 2016



Deep Perception™
Live Holography

3D Medical Imaging - The Path to Holography



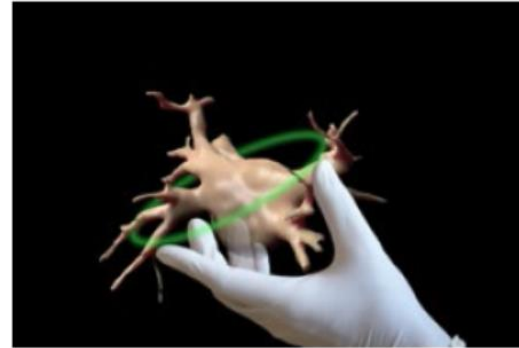
- Exponential advancement with 3D acquisition technologies and image processing capabilities
- ~~Current imaging provides high quality volumetric images, however still presented on flat 2D screens only~~

3D Volumetric Medical Data

3D Acquisition Modalities

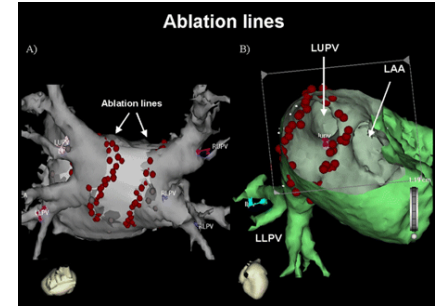
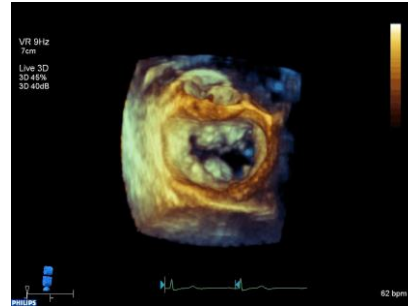


"In-Air" Holographic Display and Interface System



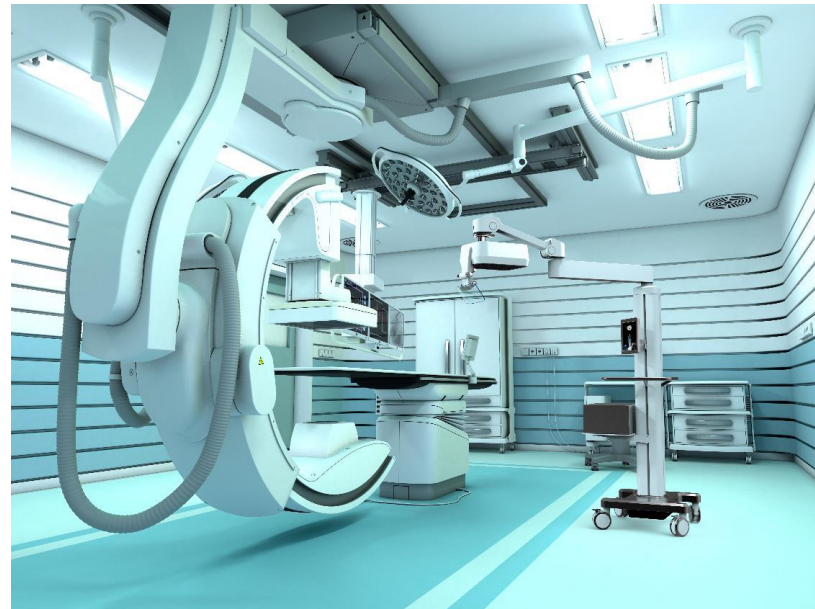
The Needs in the Modernized Interventional Suite

- 100% reliance on imaging
- Volumetric visualization of complex anatomy
- Navigation and device-tissue interaction
- Operator independence
- Communication within the medical team





HOLOSCOPE

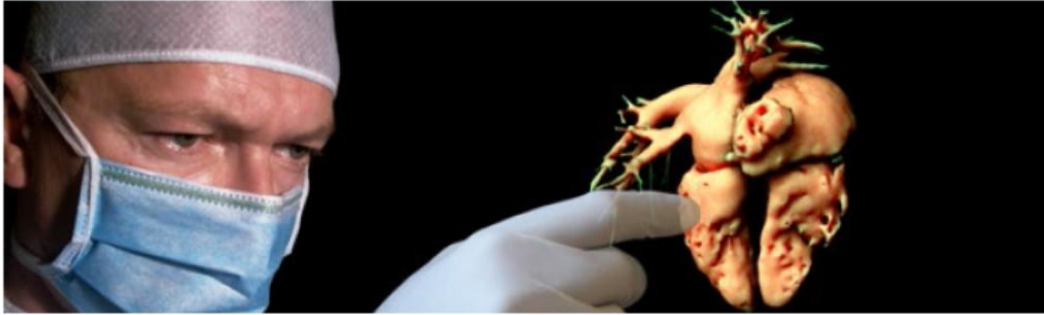


- Extremely realistic 3D holograms floating in “mid air”
- Easily accessible and interactive real time images
- 3D holograms accurately registered to free space
- Advanced optics allowing adjustable hologram location

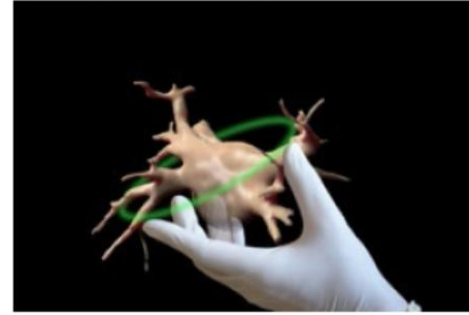
Configuration subject to change as part of the R&D process - not commercially available. Product launch planned for 2017.

3D Holography: image intimacy™ Capabilities

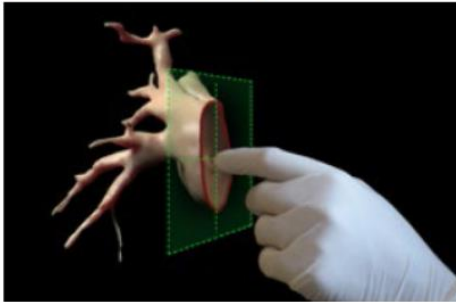
Visualize



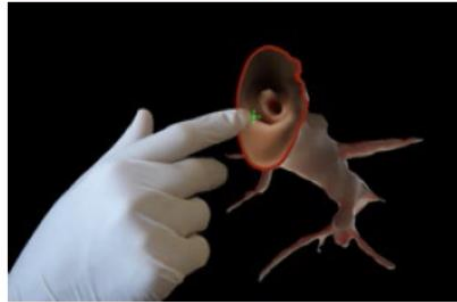
Rotate



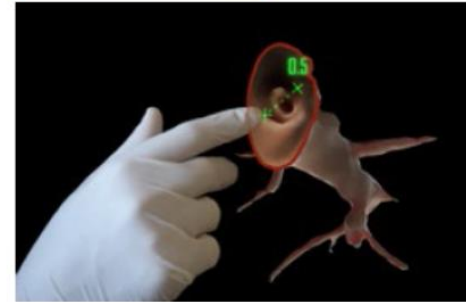
Slice



Mark



Measure



* Partial list of interaction capabilities

Interactive Live Holography - Interventional Cardiology (from RealView Lab)



Datasets Courtesy of St. Jude Medical

Interactive Live Holography - Interventional Cardiology

(from RealView Lab)



A virtually deployed Corevalve (Medtronic, USA) simulated with the TAVIguide™ technology (FEops, Gent, Belgium)

Interactive Live Holography - Example Holographic Images



Future for Holography

Current work with Philips

Plans for non-proprietary use

Use any 3D data set

Anticipated commercial release: 3rd quarter 2017

Cost ??????????????



Conclusions

- The future of 3D imaging will be limitless as advanced technology evolves
- To our sponsors, the costs of such technology needs to be affordable
- Our patients will directly benefit from this technology, so we need to “push on”

THANK YOU

Willa

Olivia



Stella



The Heart Center



A Grandson in 2017

Mya

Cooper

