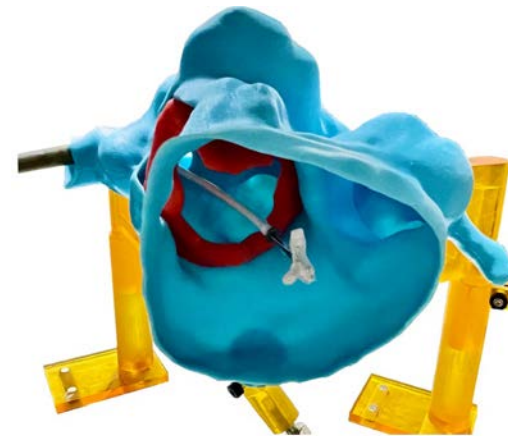
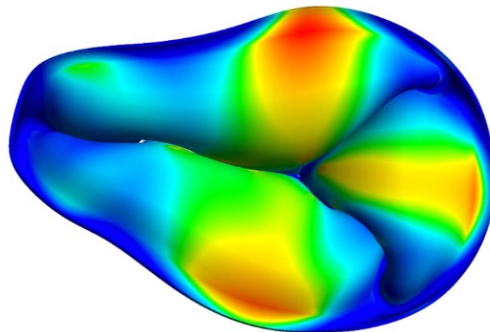
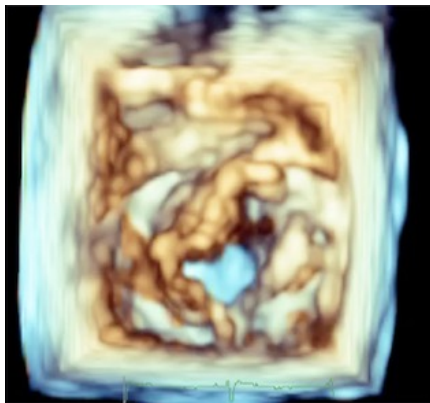


# How Valves Work and How We Might Fix Them in the Future



**Matthew Jolley, MD**

Assistant Professor

Pediatric Cardiac Anesthesia and Pediatric Cardiology (Imaging)

Children's Hospital of Philadelphia

University of Pennsylvania Medical School

# NO CONFLICT OF INTEREST OR FINANCIAL DISCLOSURES

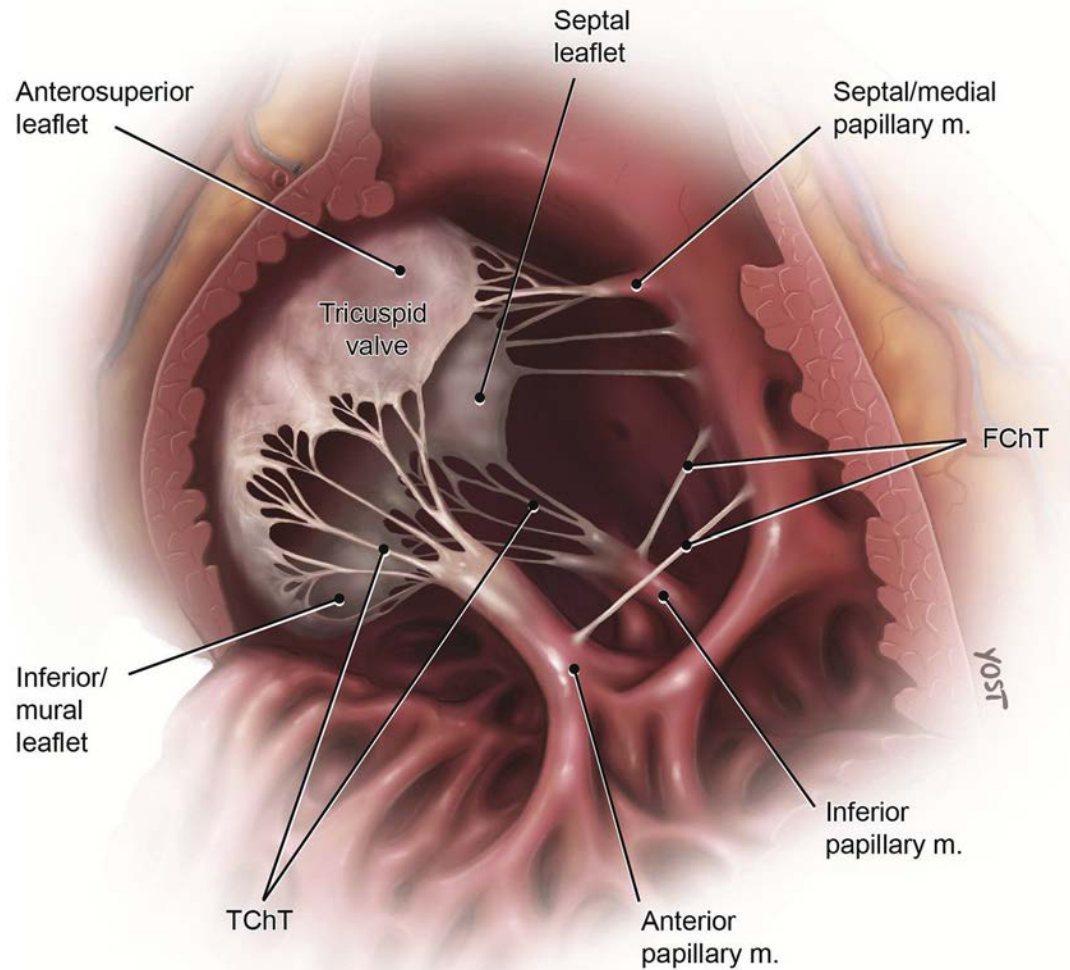




I

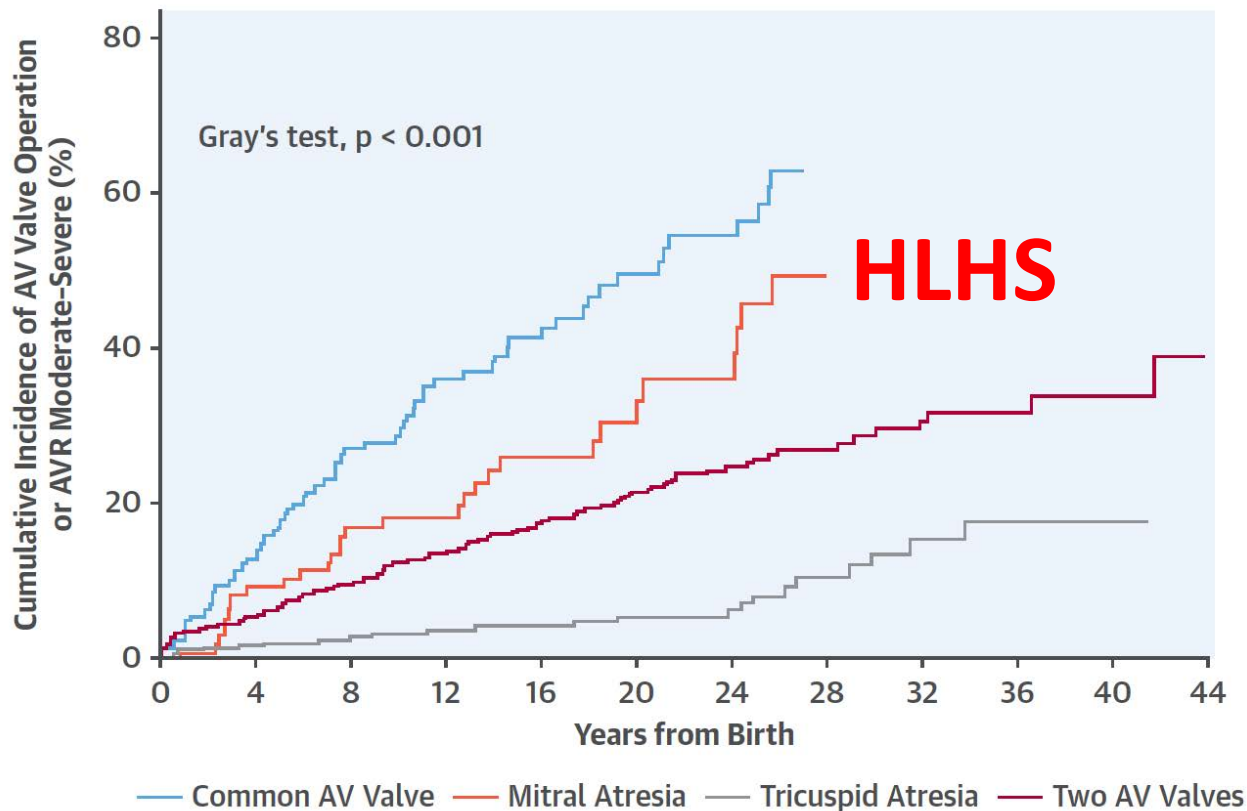


MYOCARDIUM

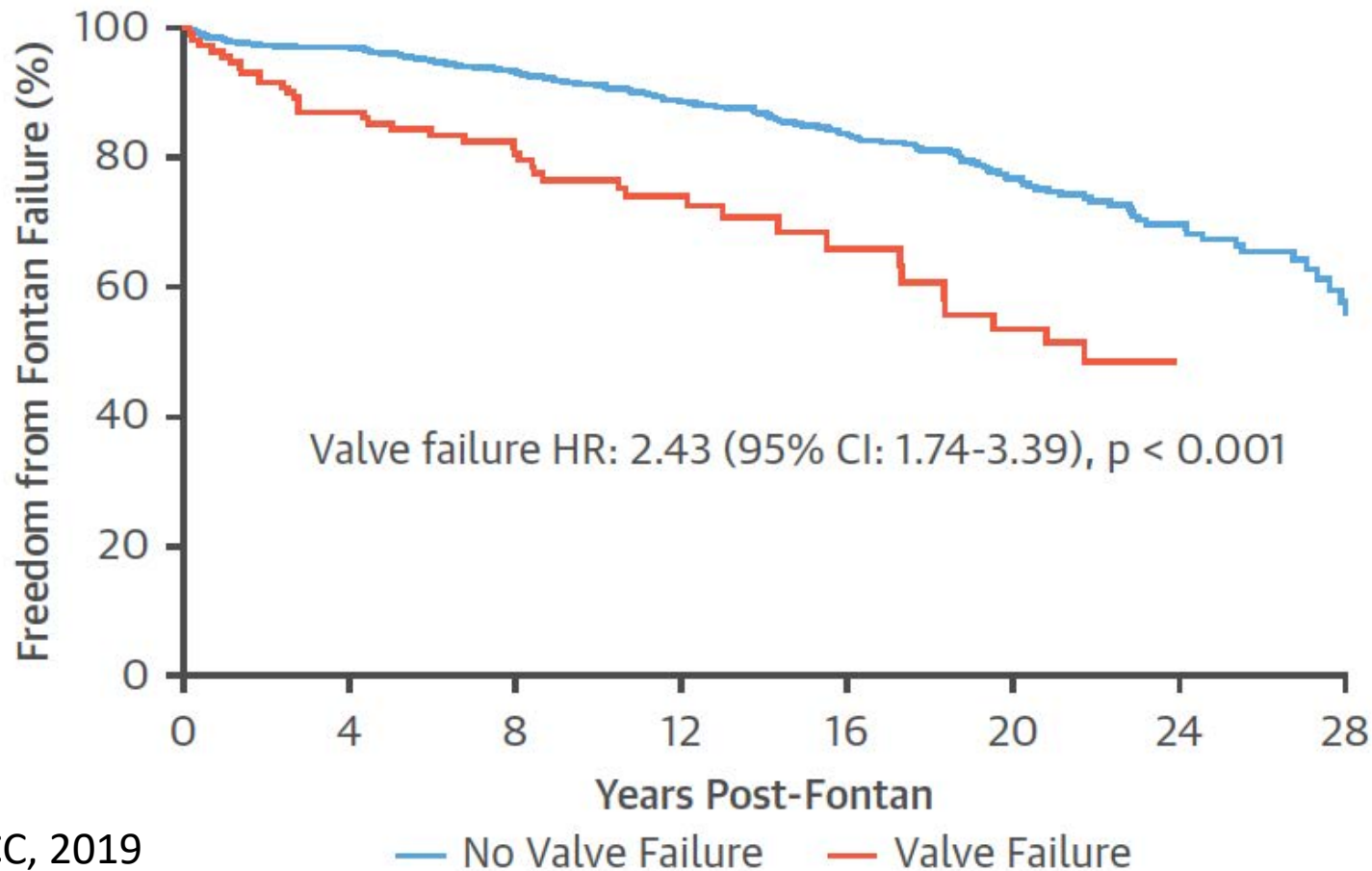


**B**

## Cumulative Incidence of Atrioventricular Valve Failure Stratified by Valvular Morphology



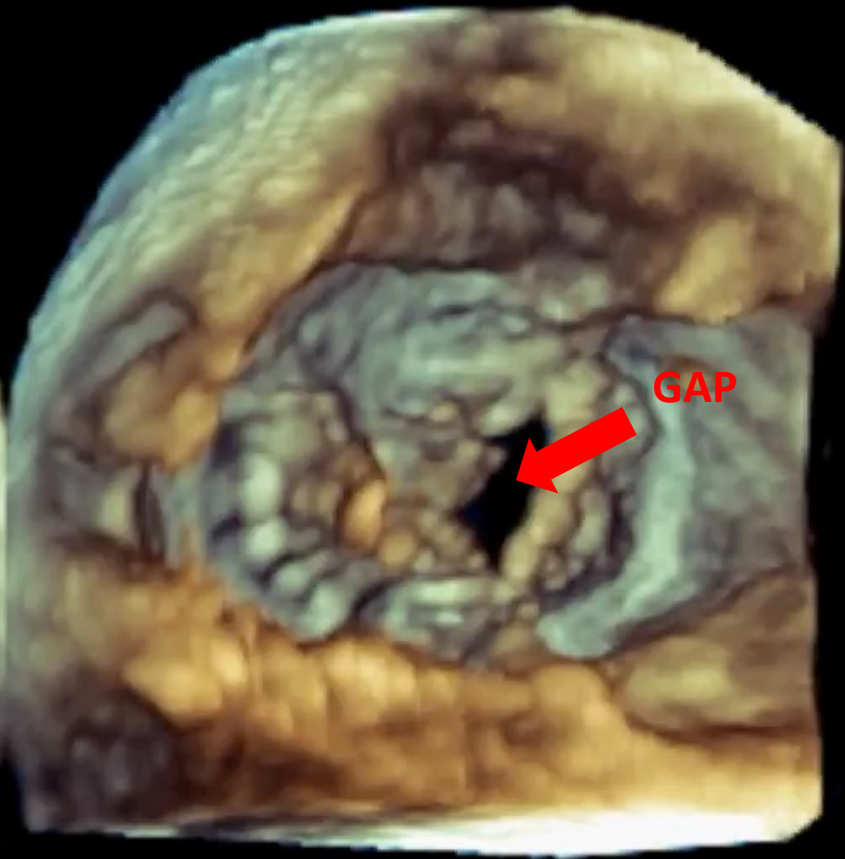
**FIGURE 5** AV Valve Function and Fontan Failure



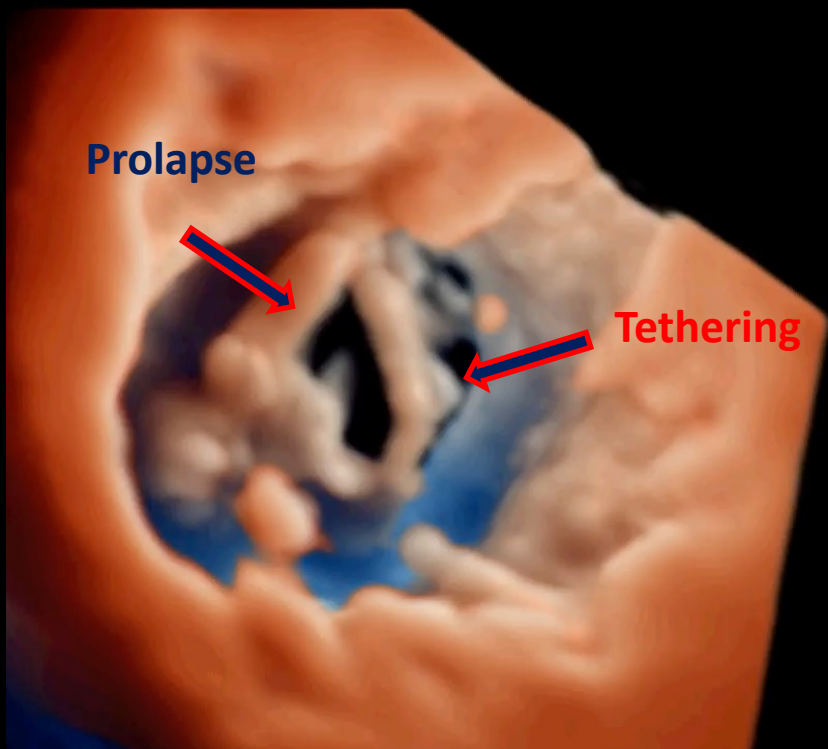




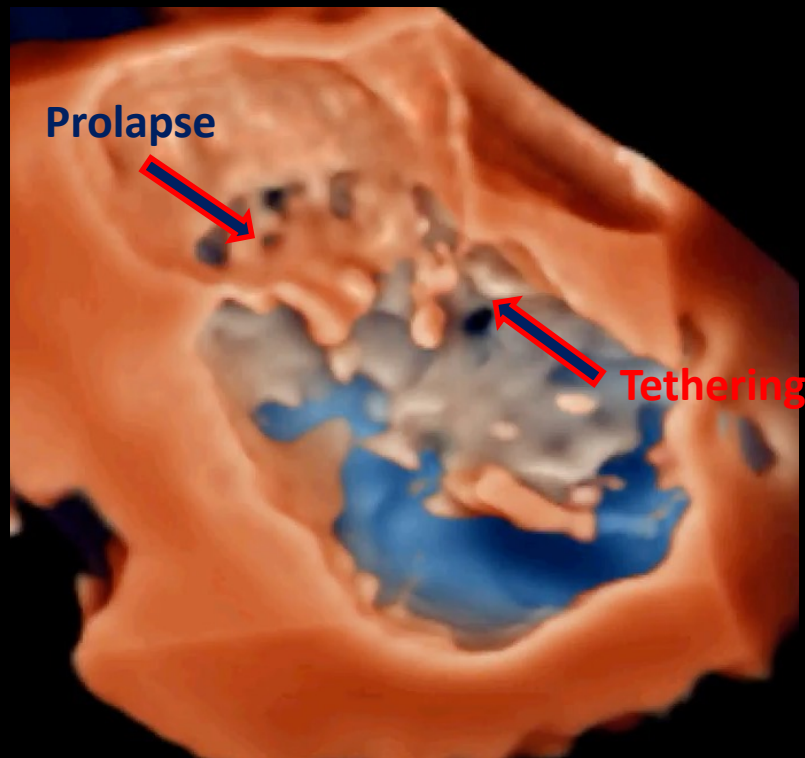
Atrial View



Ventricular View

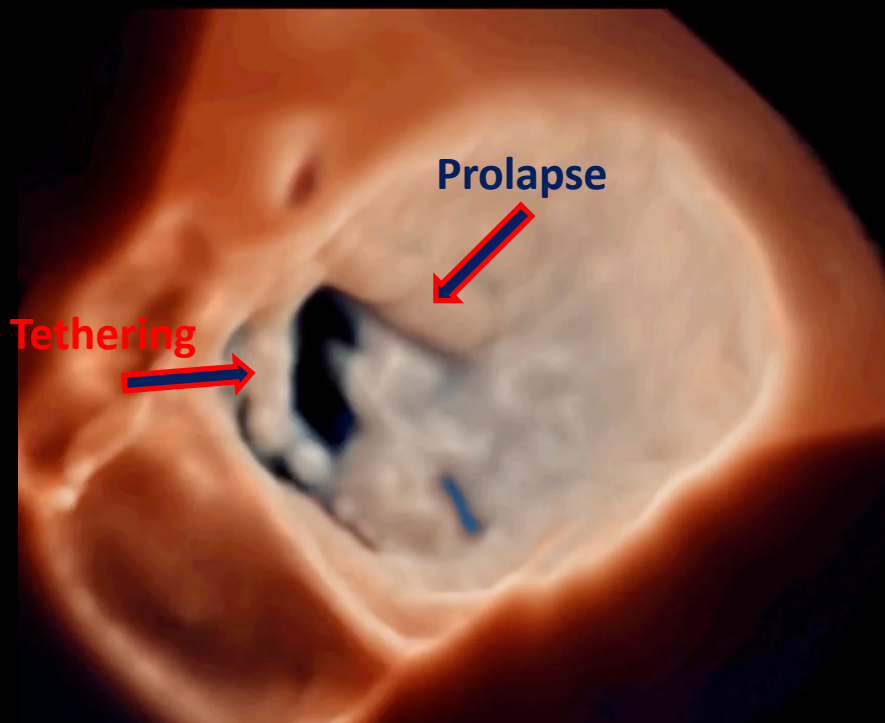


Ventricular View



"4-Chamber" Cross Section





Atrial View



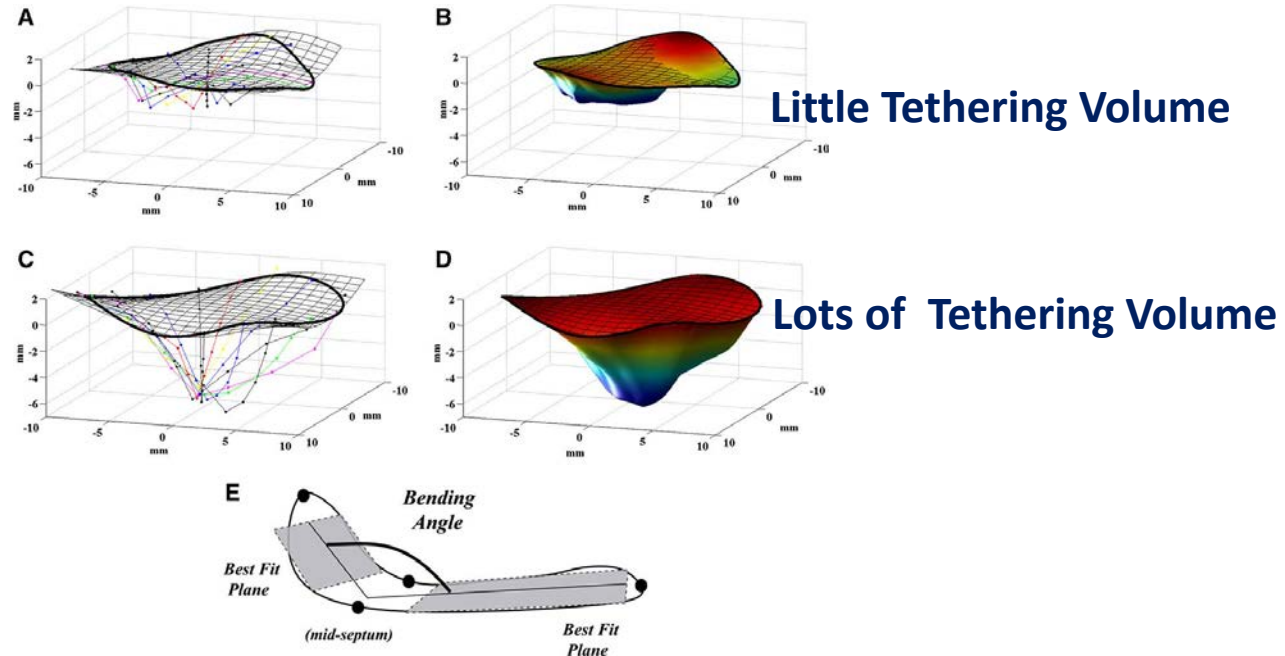
Atrial View

**Can We Get More  
Quantitative?**

# Tricuspid Regurgitation in Hypoplastic Left Heart Syndrome

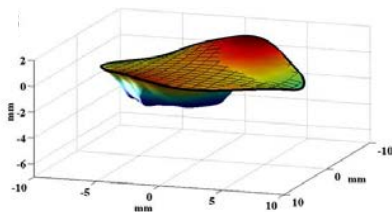
## Mechanistic Insights From 3-Dimensional Echocardiography and Relationship With Outcomes

Shelby Kutty, MD\*; Timothy Colen, MBBS\*; Richard B. Thompson, PhD; Edythe Tham, MBBS;  
Ling Li, MD, PhD; Chodchanok Vijarnsorn, MD; Amanda Polak, RDCS;  
Dongngan T. Truong, MD; David A. Danford, MD; Jeffrey F. Smallhorn, MBBS;  
Nee Sze Khoo, MBChB

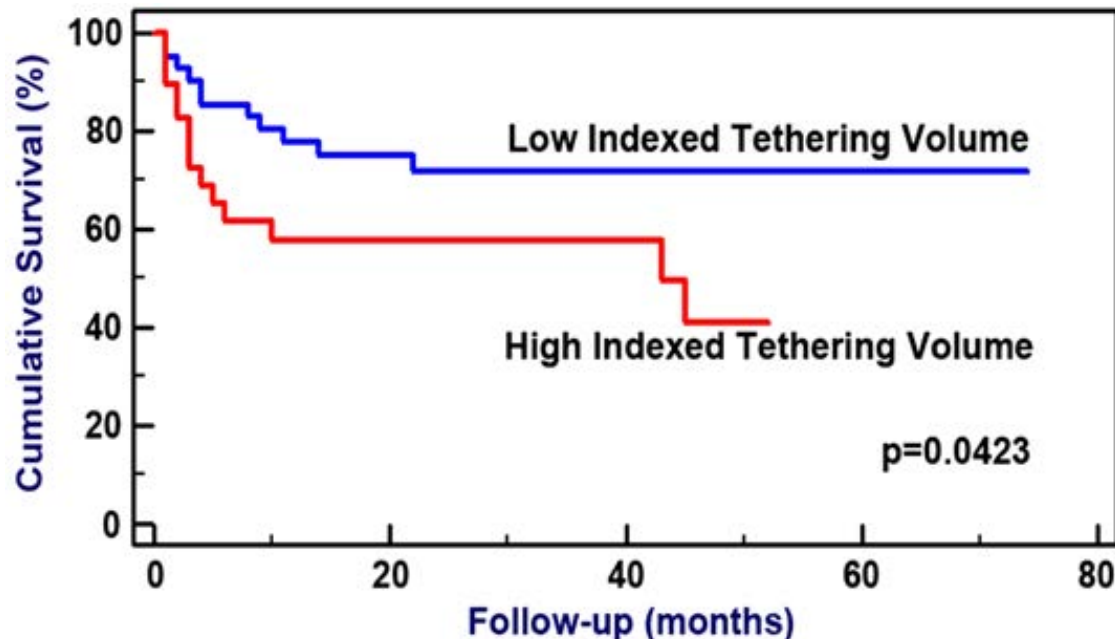
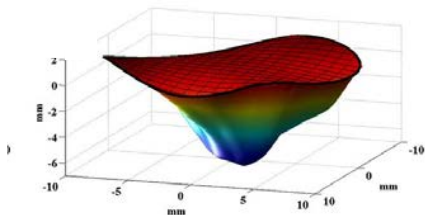


## HLHS Pre-Stage 1

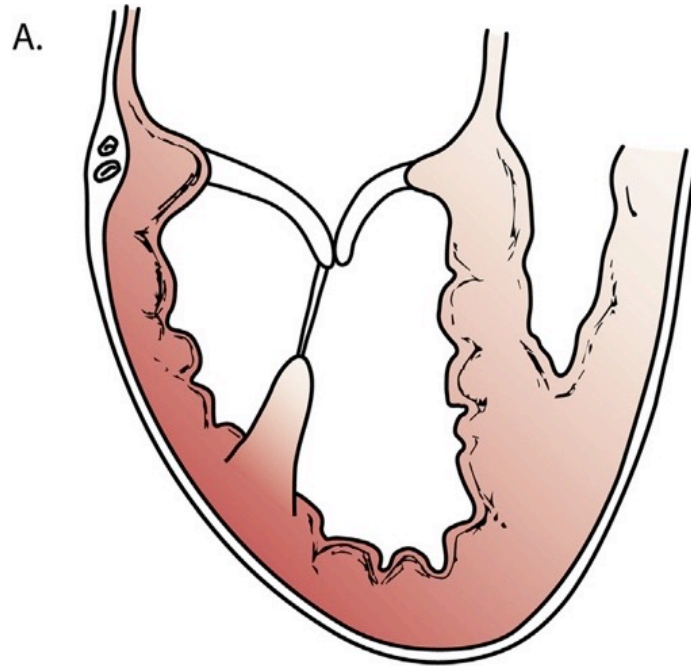
Low Tether



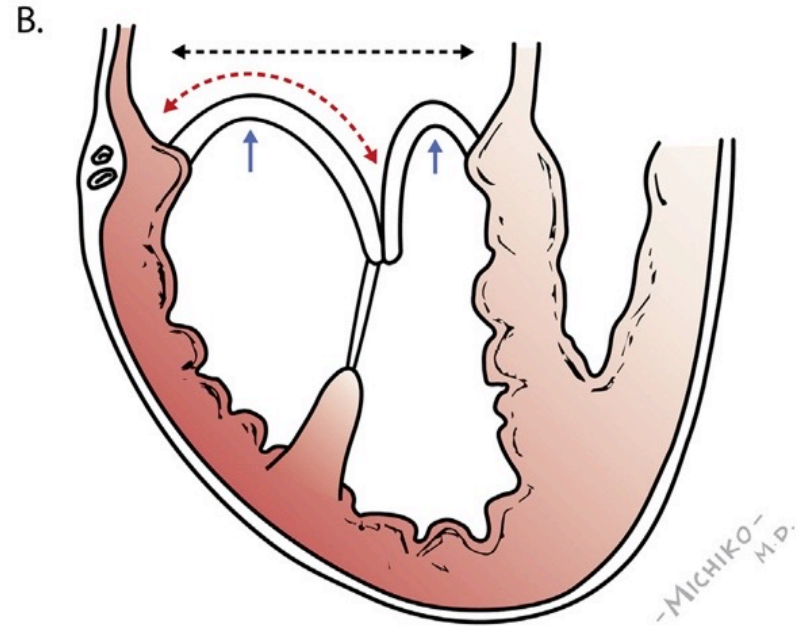
High Tether



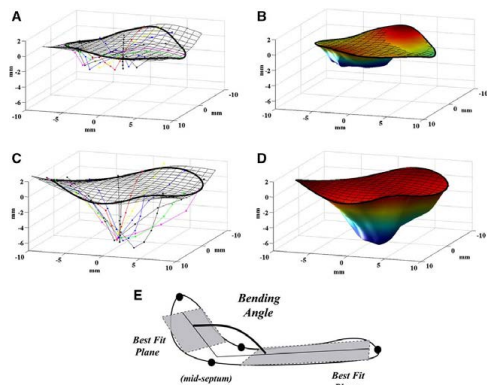
# HLHS with Glenn



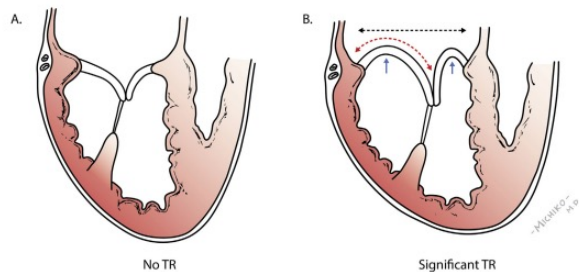
No TR



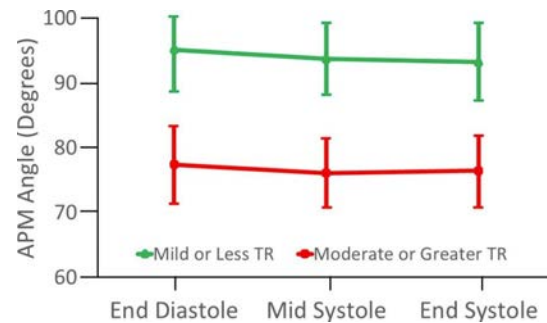
Significant TR



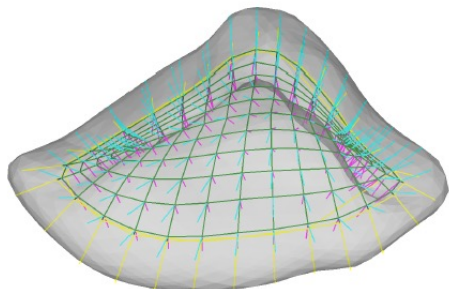
Kutty et al Circ Imaging, 2014



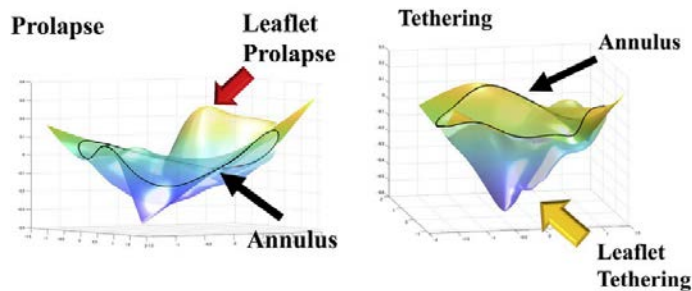
Colen et al, JASE, 2018



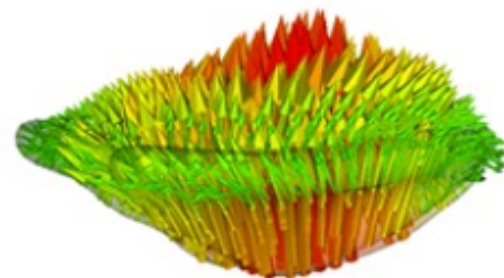
Nguyen et al, JASE, 2019



Vicory et al, LNCS, 2022.



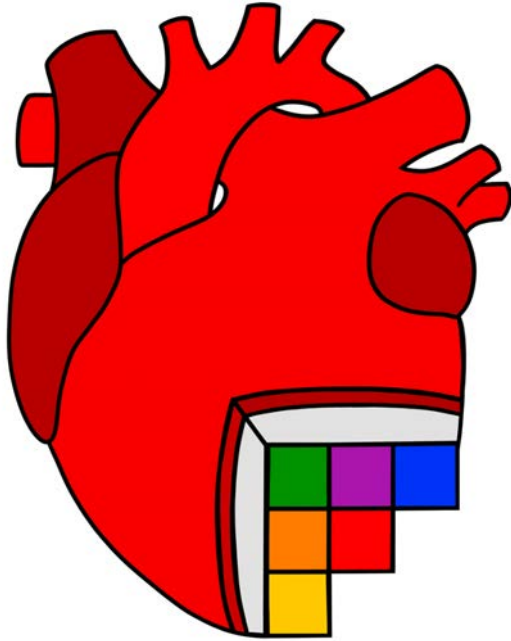
Shigemitsu et al, JASE, 2022



Nam et al, Circ Imaging, 2023.



# SlicerHeart



## REVIEW article

Front. Cardiovasc. Med., 06 September 2022

Sec. Pediatric Cardiology

Volume 9 - 2022 | <https://doi.org/10.3389/fcvm.2022.886549>

This article is part of the Research Topic

Advanced Non-Invasive Cardiac Imaging in Congenital Heart Disease

[View all 8 Articles >](#)

## SlicerHeart: An open-source computing platform for cardiac image analysis and modeling

Andras Lasso<sup>1</sup>, Christian Herz<sup>2</sup>, Hannah Nam<sup>2</sup>, Alana Cianciulli<sup>2</sup>, Steve Pieper<sup>3</sup>, Simon Drouin<sup>4</sup>, Csaba Pinter<sup>5</sup>, Samuelle St-Onge<sup>4</sup>, Chad Vigil<sup>2</sup>, Stephen Ching<sup>2</sup>, Kyle Sunderland<sup>1</sup>, Gabor Fichtinger<sup>1</sup>, Ron Kikinis<sup>6</sup> and Matthew A. Jolley<sup>2,7\*</sup>

<sup>1</sup> Laboratory for Percutaneous Surgery, School of Computing, Queen's University, Kingston, ON, Canada

<sup>2</sup> Department of Anesthesiology and Critical Care Medicine, Children's Hospital of Philadelphia, Philadelphia, PA, United States

<sup>3</sup> Isomics, Inc., Boston, MA, United States

<sup>4</sup> Software and Information Technology Engineering, École de Technologie Supérieure, Montreal, QC, Canada

<sup>5</sup> Pixel Medical, Kingston, ON, Canada

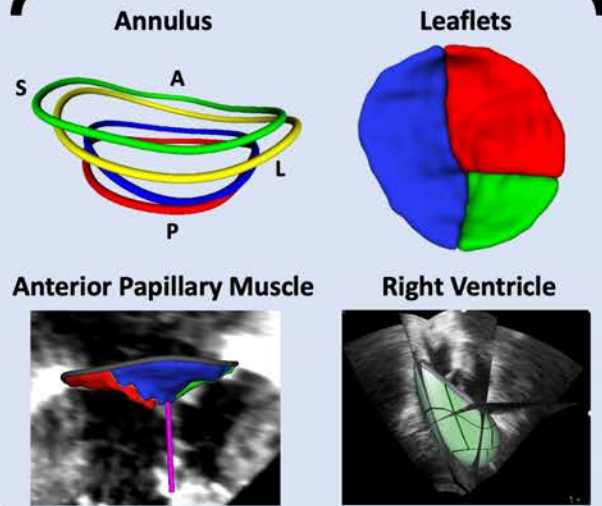
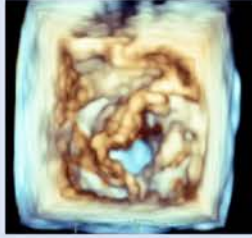
<sup>6</sup> Department of Radiology, Brigham and Women's Hospital, Harvard Medical School, Boston, MA, United States

<sup>7</sup> Division of Cardiology, Children's Hospital of Philadelphia, Philadelphia, PA, United States

Lasso et al, Frontiers in Cardiovascular Medicine, 2022.

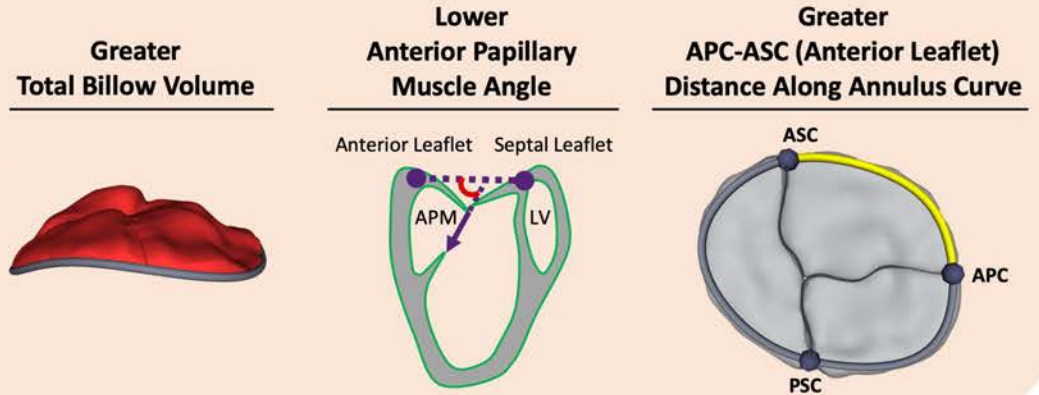
# 3D Modeling of Tricuspid Valve & Right Ventricle

3D Echo Image



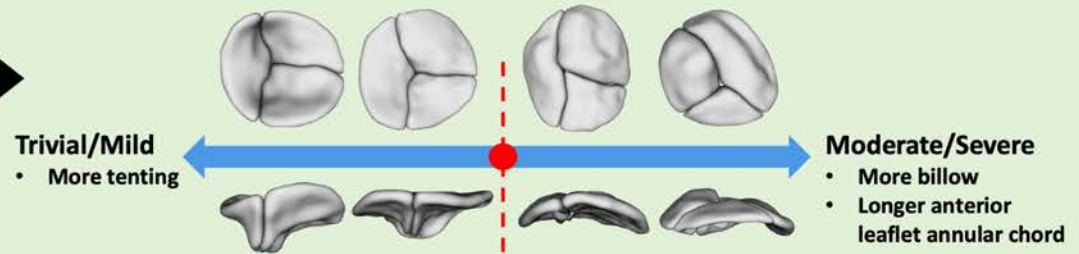
## Euclidian Metrics

### Associates of Increased Tricuspid Valve Regurgitation

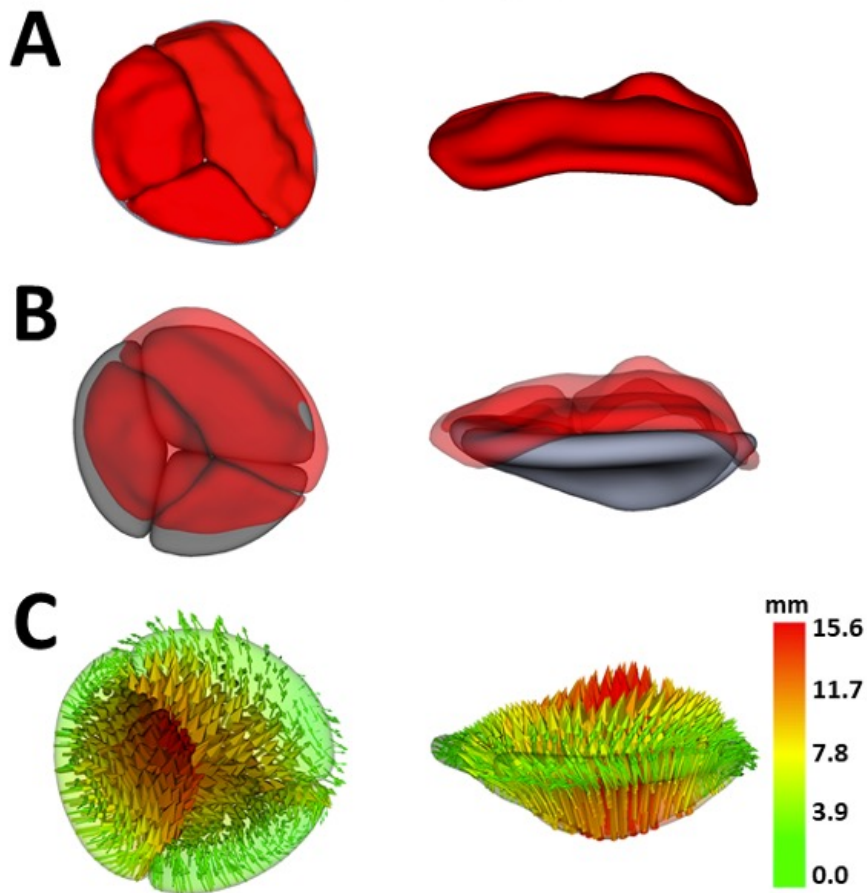


## Shape Analysis

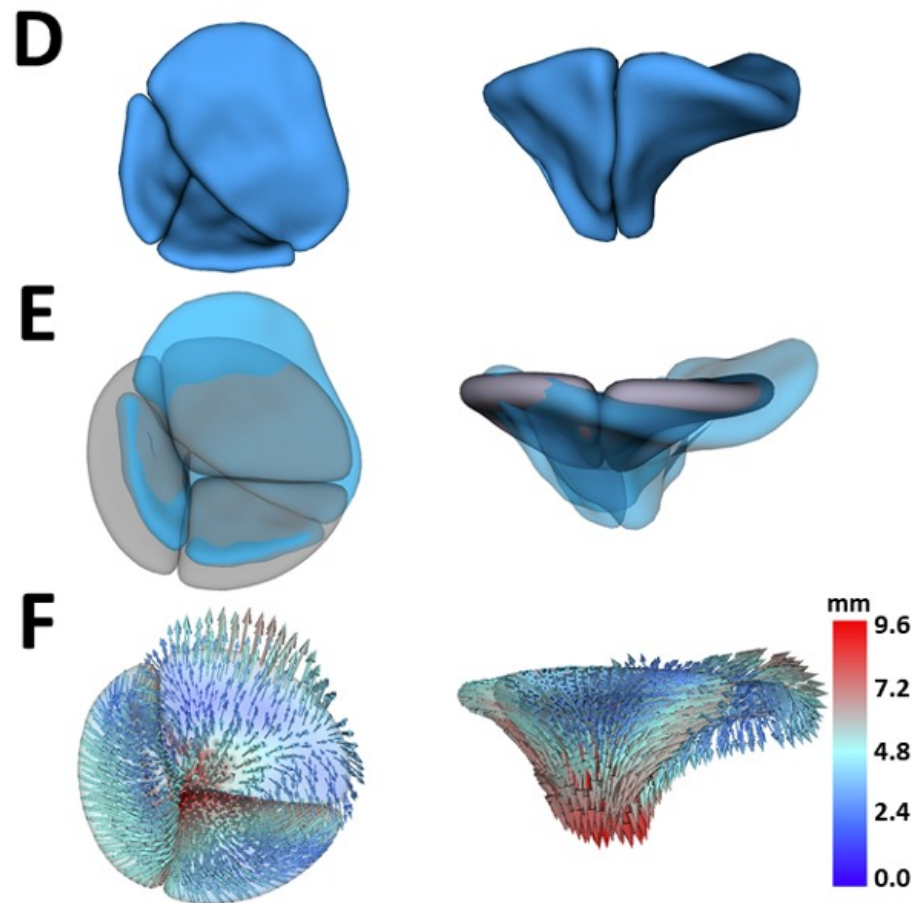
### Visual Representation of Distance Weighted Discrimination (DWD)



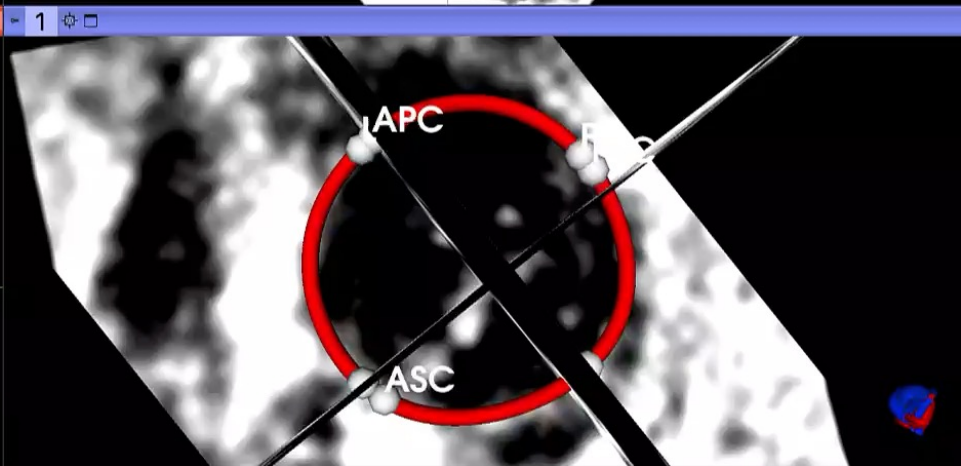
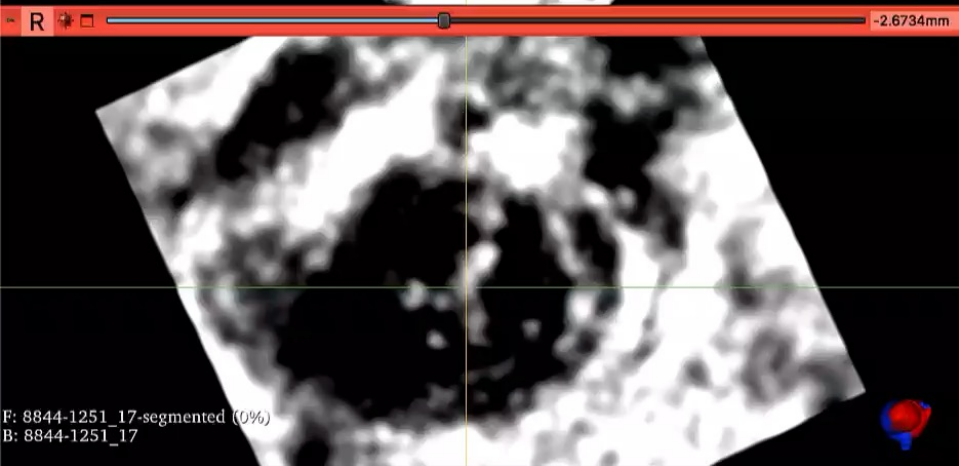
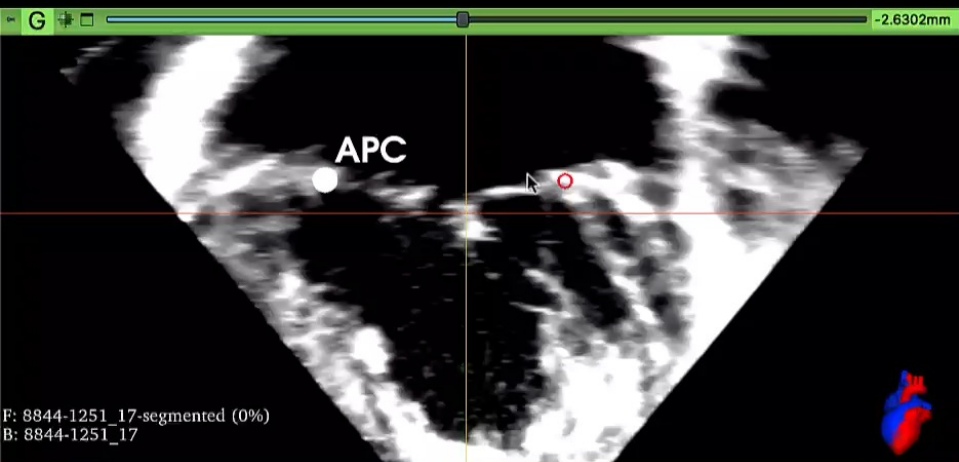
## Patient with Billow vs. Trivial TR Mean Shape



## Patient with Tenting vs. Trivial TR Mean Shape

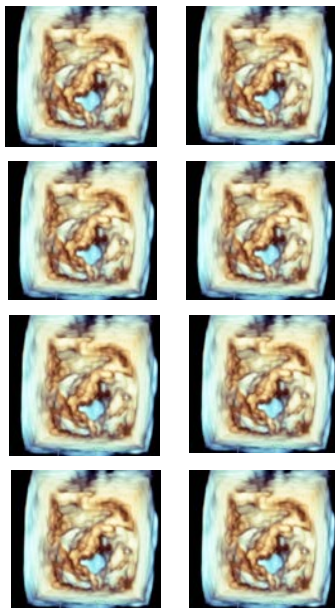


How can we make  
modeling faster?

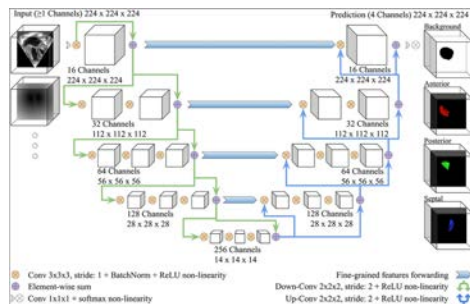




# Data

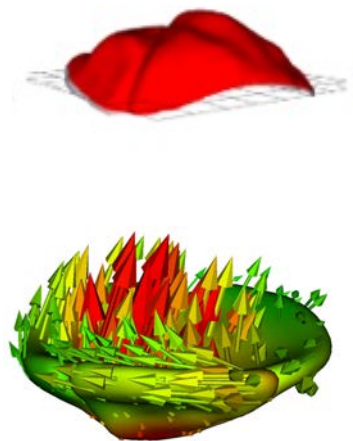


# Automation

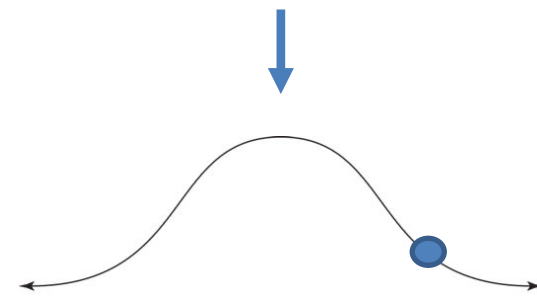
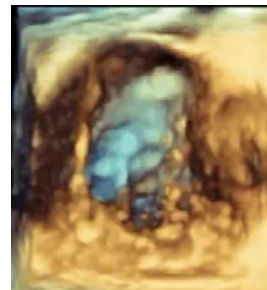


## Machine Learning

# Individual Assessment



## Quantification

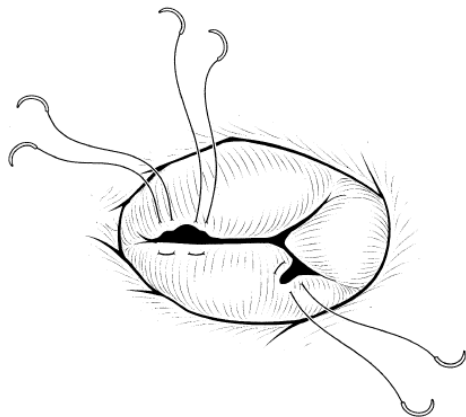


## Multiparameter Analysis



HOW ARE WE GOING TO FIX IT?

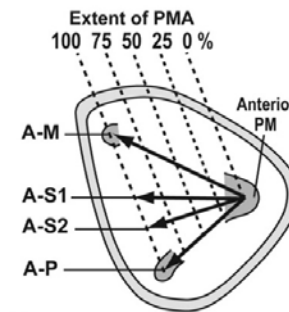
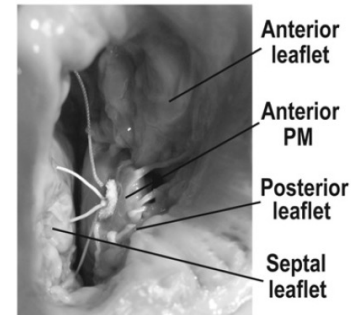
## Leaflets

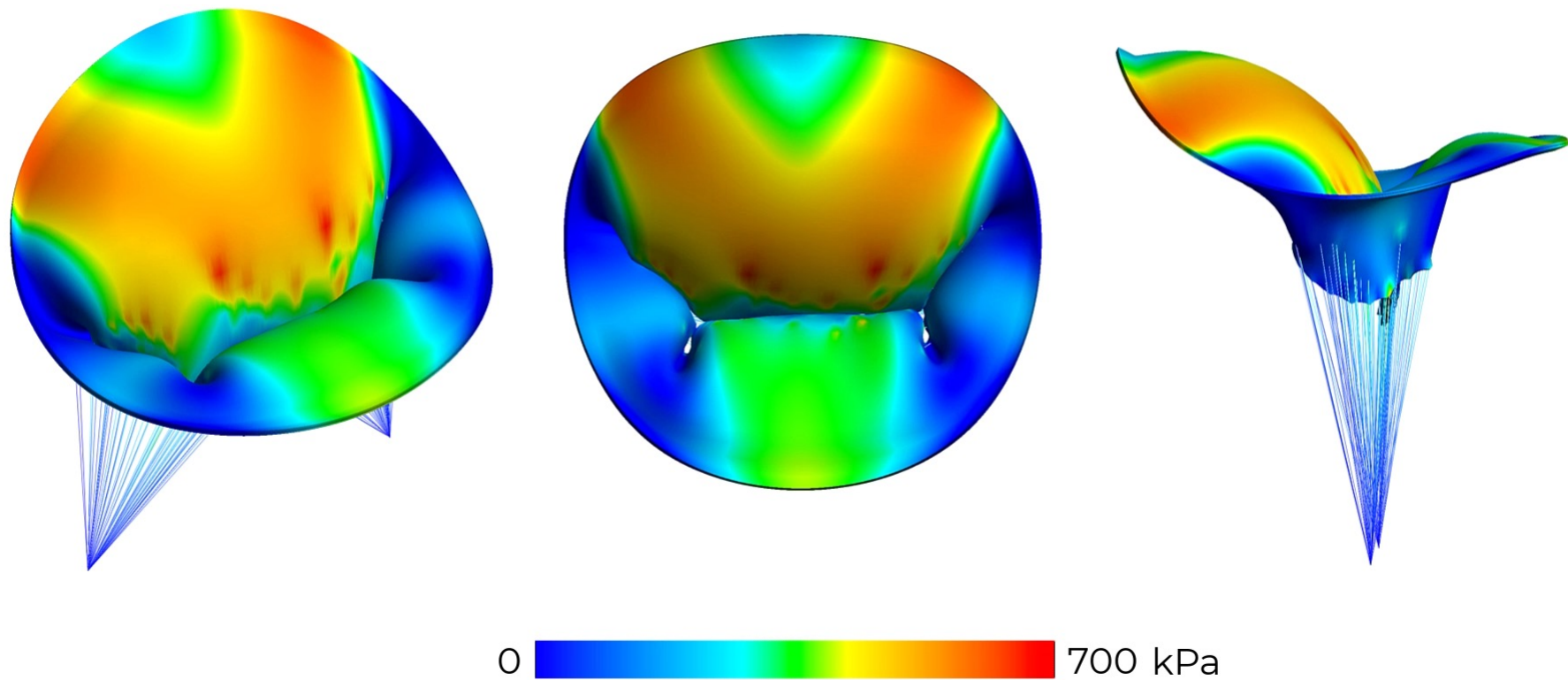


## Annulus



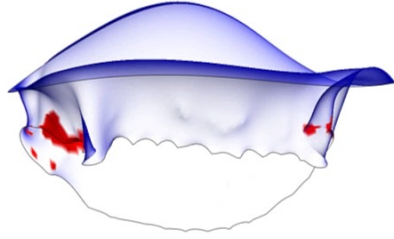
## Papillary Muscles



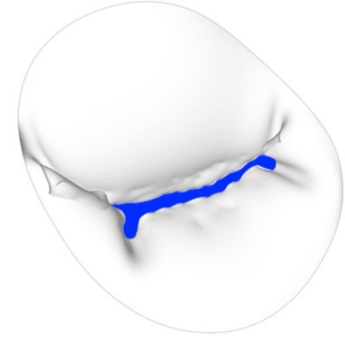


## Metrics of Valve Function

Contact  
Area

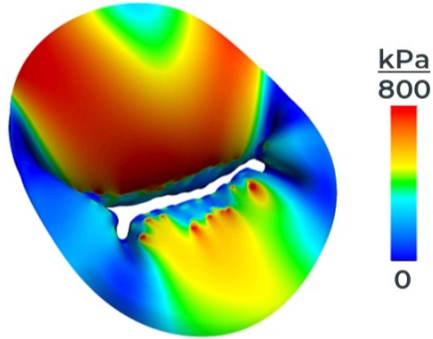


Regurgitant  
Orifice Area

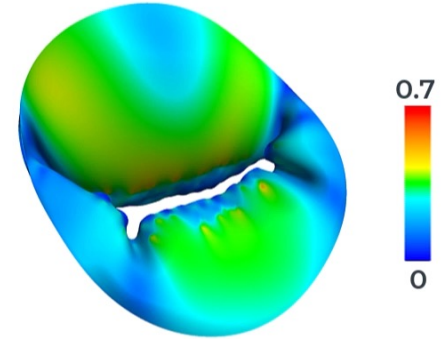


## Metrics of Durability

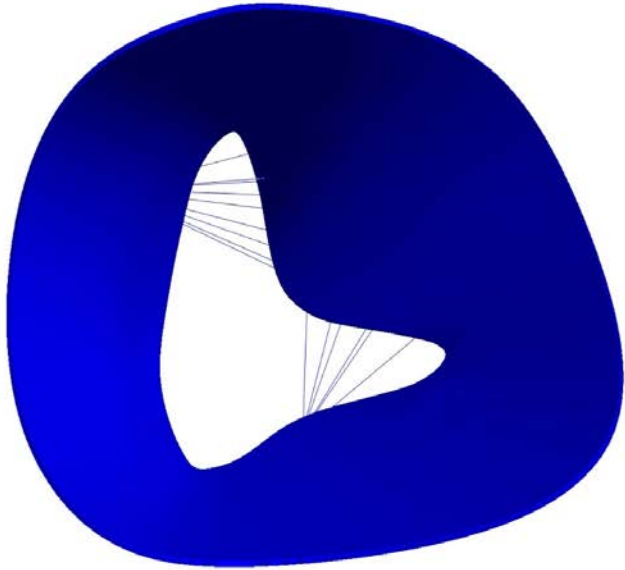
1st  
Principal  
Stress



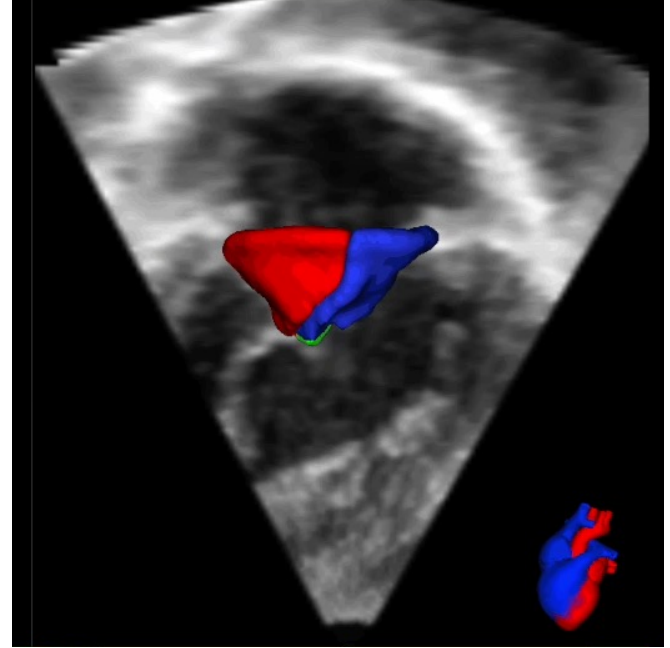
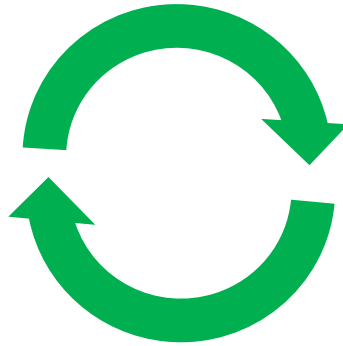
1st  
Principal  
Strain



# VALIDATION



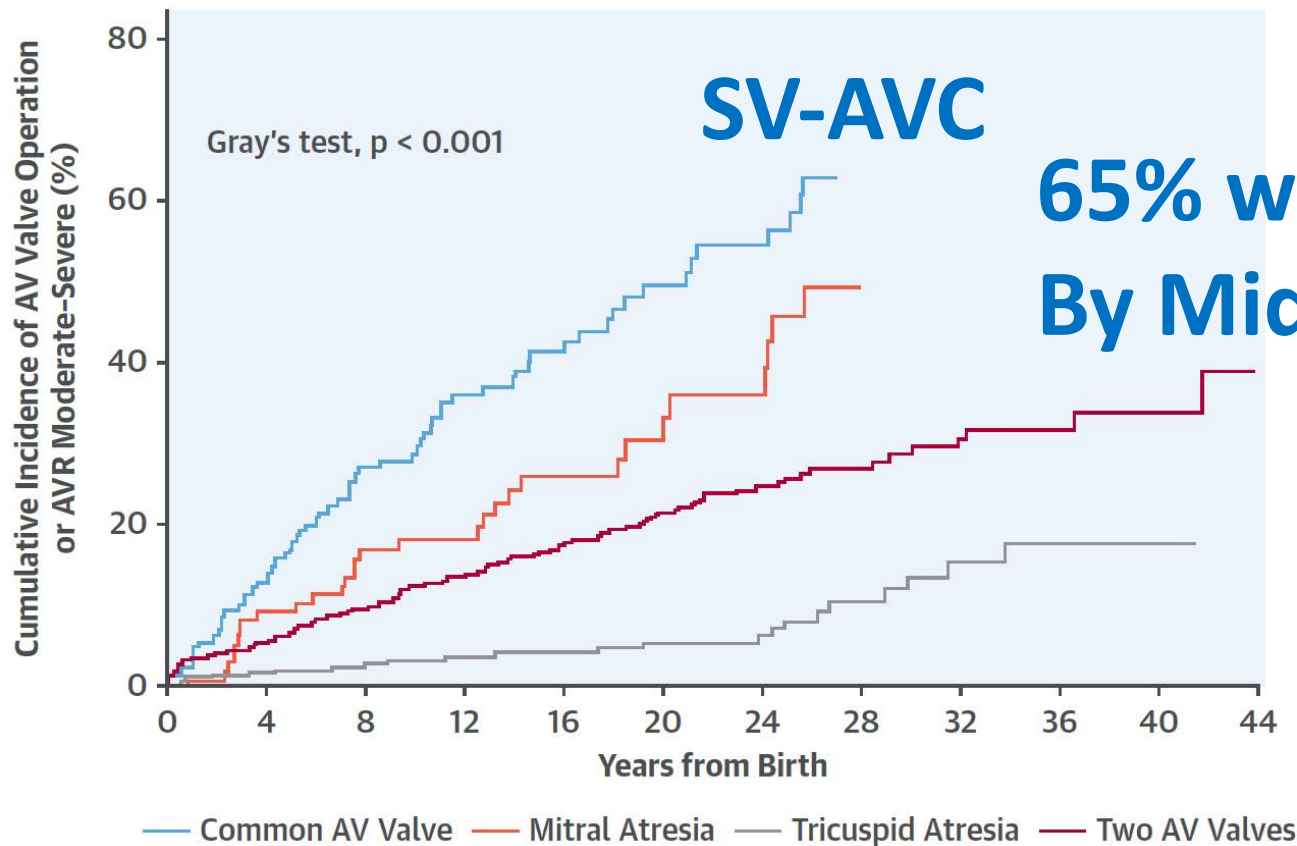
**Simulation-Derived  
Mechanics**



**Image-Derived  
Mechanics**

**B**

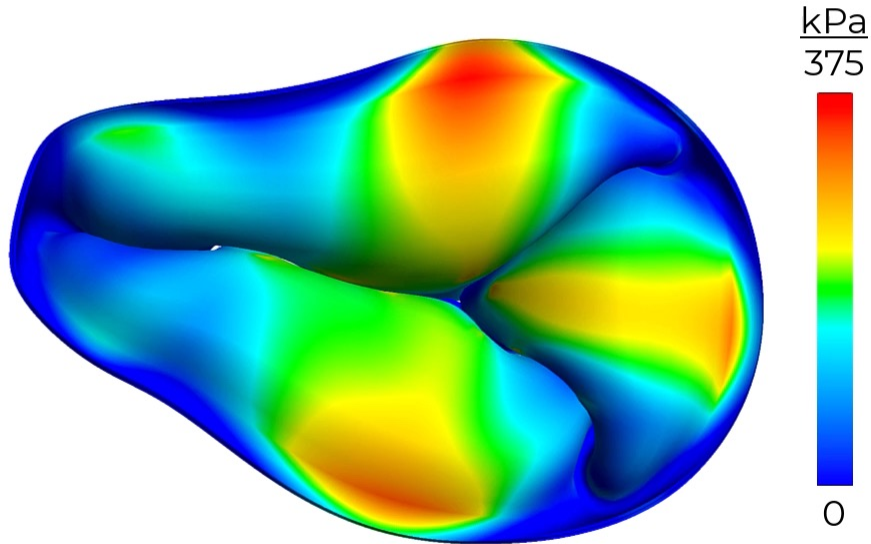
## Cumulative Incidence of Atrioventricular Valve Failure Stratified by Valvular Morphology



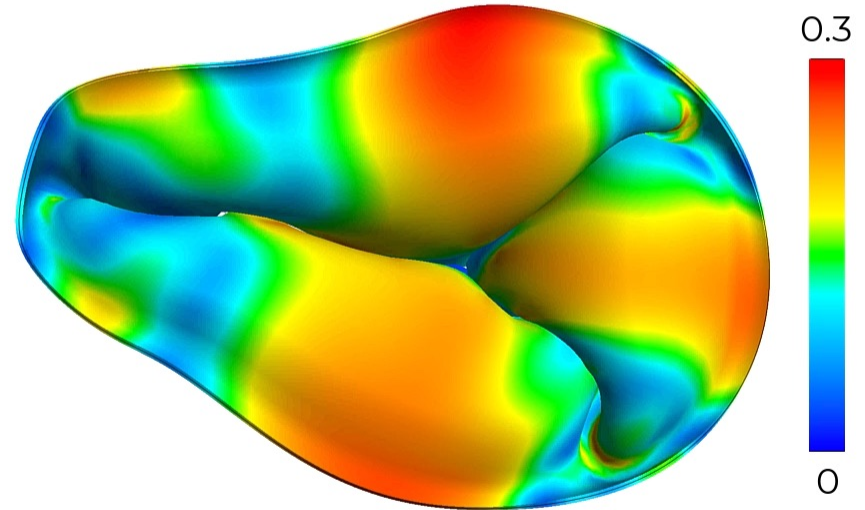


# Unbalanced CAVC

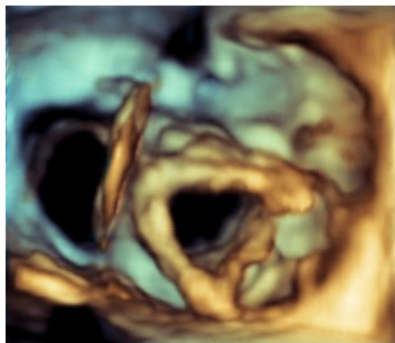
1st Principal Stress



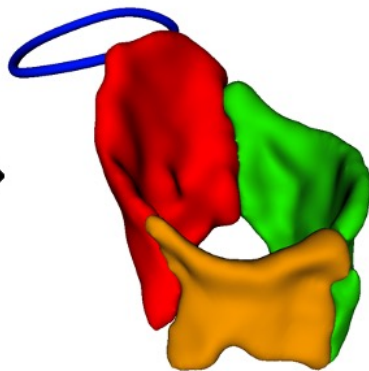
1st Principal Strain



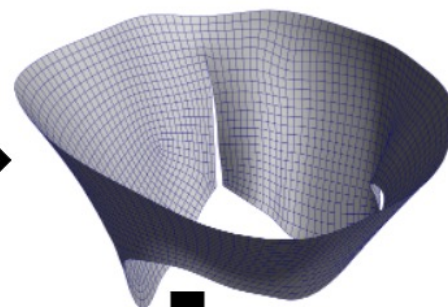
3DE



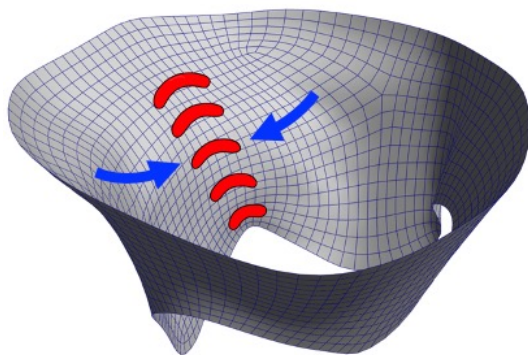
Segmentation



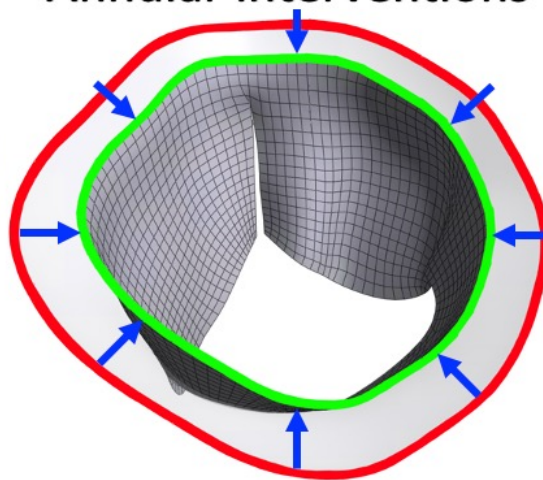
Shell Model



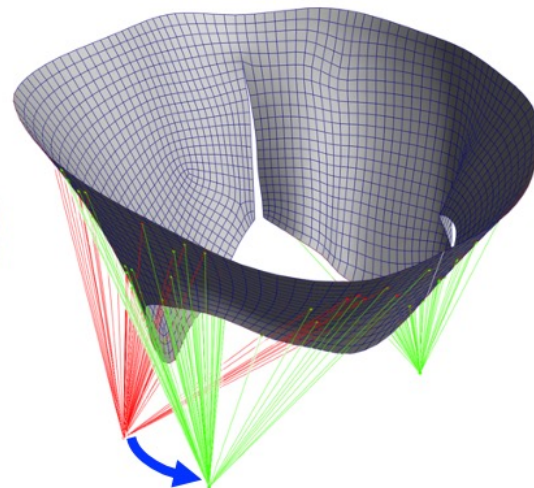
Leaflet Interventions



Annular Interventions

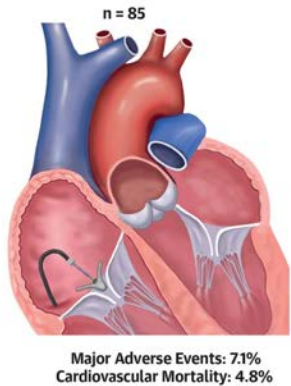


PM Redirection



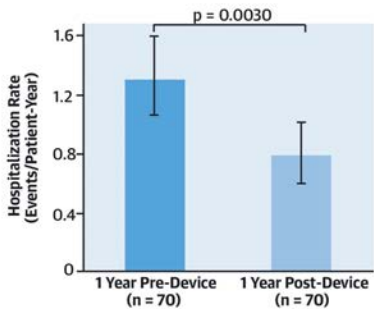
## CENTRAL ILLUSTRATION: 1-Year Outcomes From the TRILUMINATE Trial

### TRILUMINATE Study



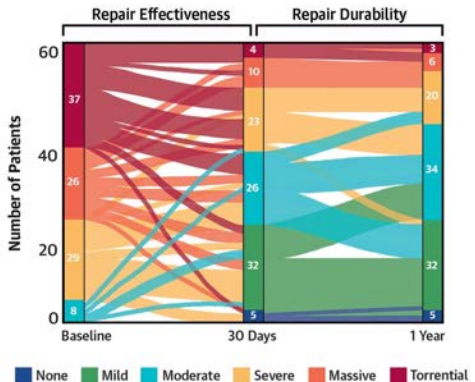
### Clinical Implications

40% Reduction in Hospitalizations

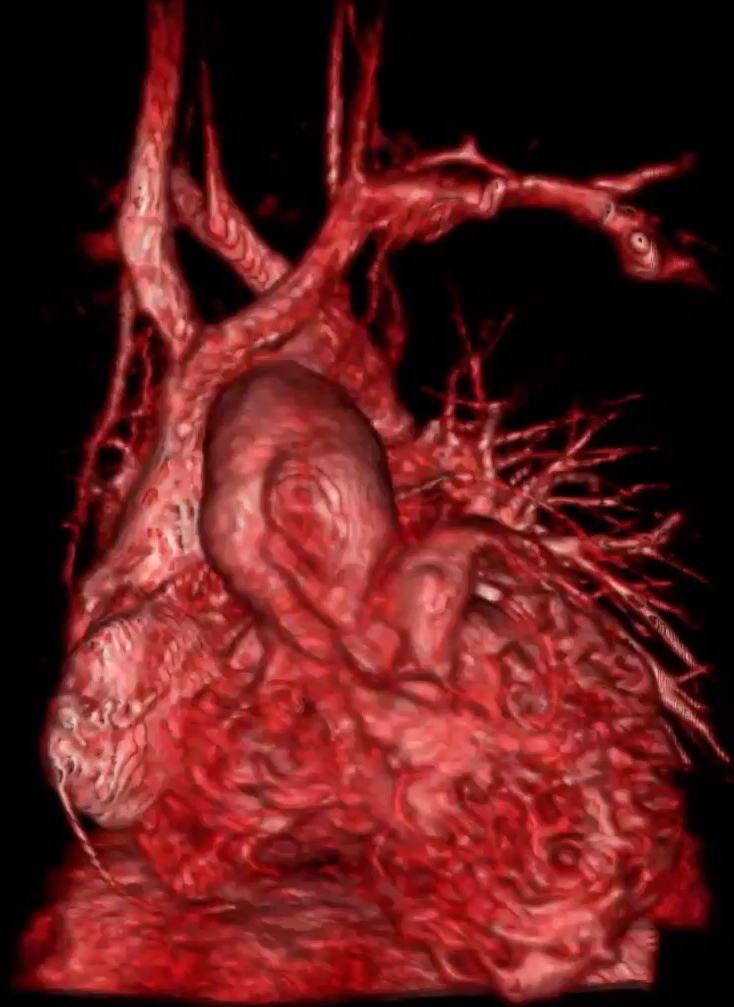


### Durability of Repair

TR Reduction at 1 Year  $\geq 1^\circ$ : 87%



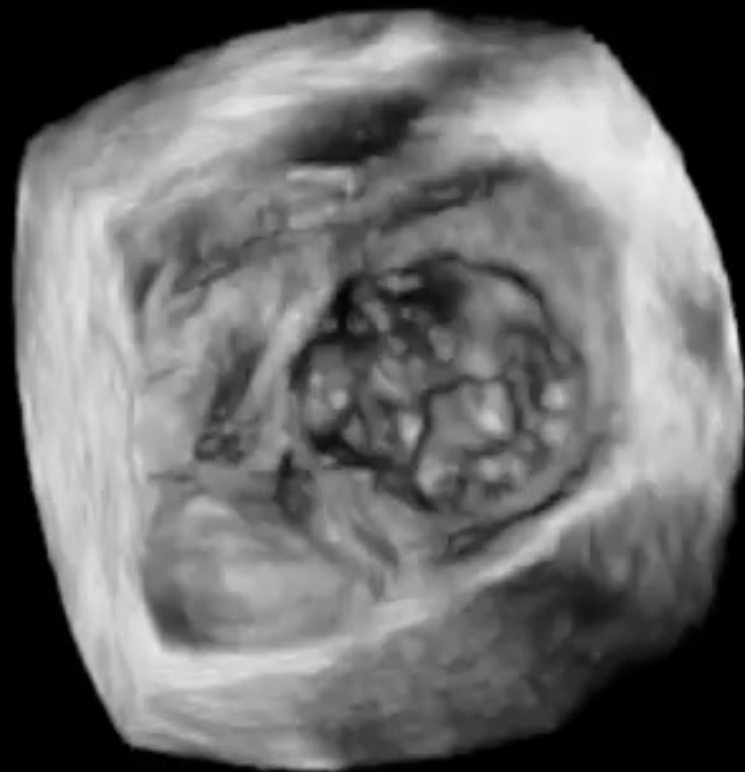
# Volume Rendering of Patient's CMR





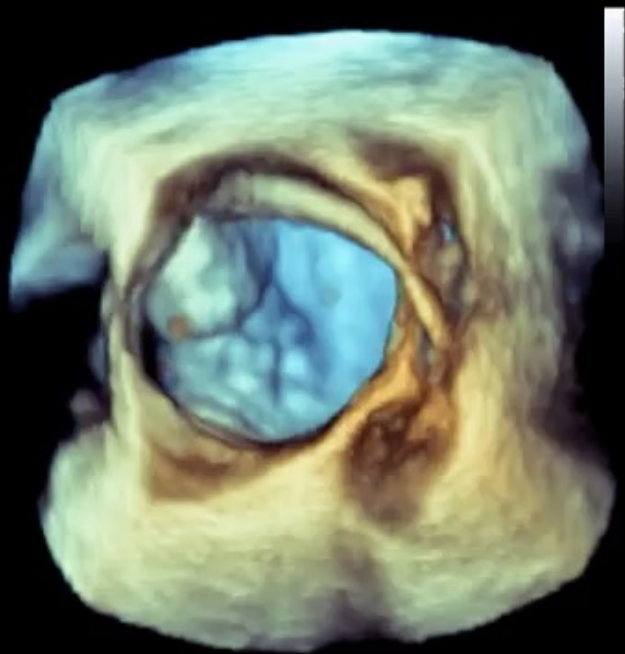


Atrial View



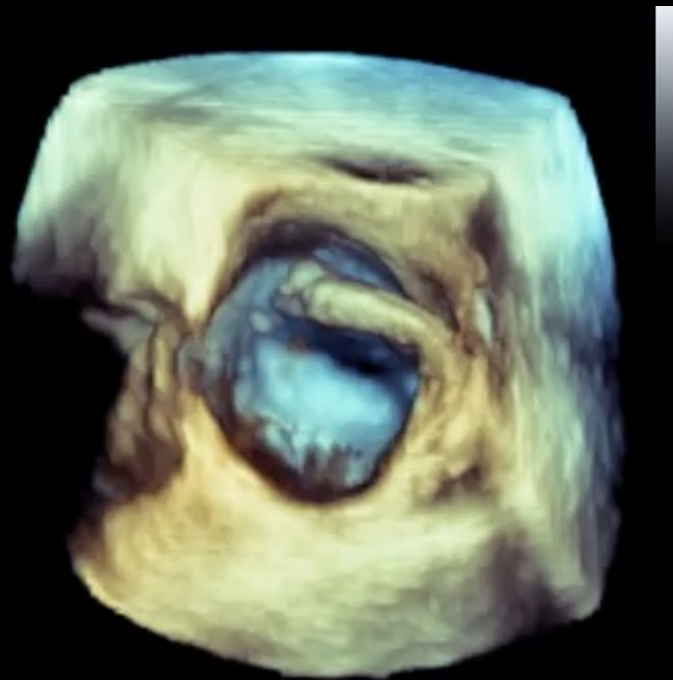
Atrial View

Access via Fenestration



Atrial View

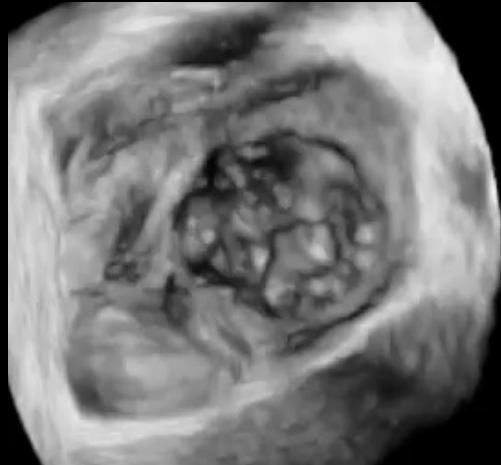
Delivery of Guide



Atrial View



# Pre-intervention



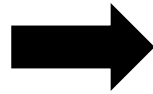
# Post-intervention



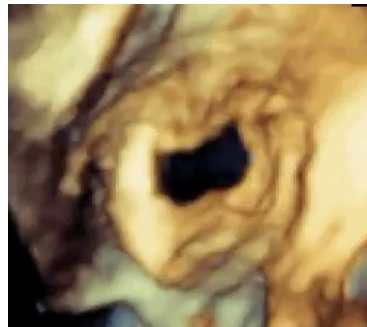
# Images + ML



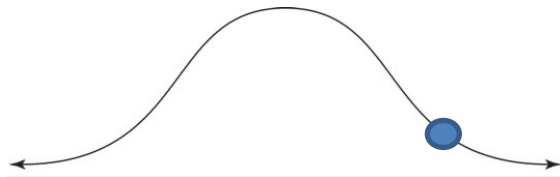
# Modeling



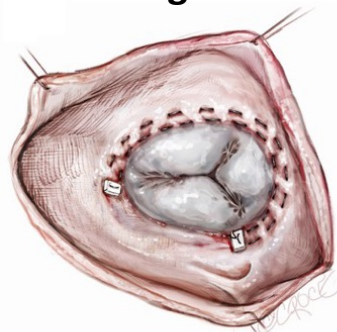
# Individualized Repair



## Multiparameter Assessment



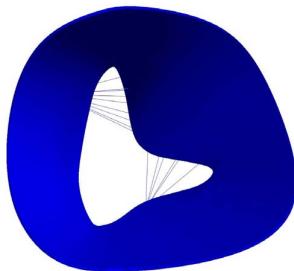
## Surgical



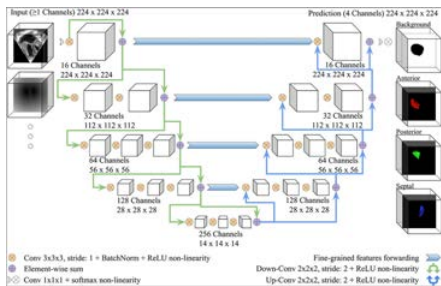
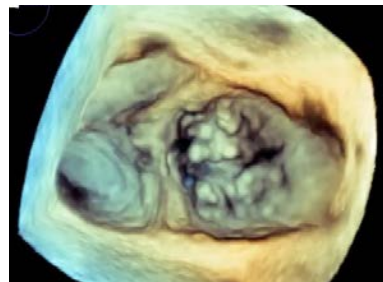
## Physical Simulation



## In Silico Simulation



## Transcatheter



**VALVES ARE IMPORTANT**

**VALVE REPAIR IS CHALLENGING**

**NEW TOOLS EVOLVING**

**VALVES MIGHT EVEN BE AS  
COOL AS THE MYOCARDIUM**

# Thank You

## JolleyLab

- Silvani Amin- Research Assistant
- Stephen Ching- Engineer
- Hannah Dewey- Undergraduate Student
- Christian Herz- Senior Developer
- Devin Laurence- Post Doc
- Hannah Nam- Med Student
- Patricia Sabin- Engineer
- Ana Sulentic- Research Assistant
- Wensi Wu- Post Doctoral Fellow
- Chris Zelonis- Undergraduate Student

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- Lindsay Rogers
- Yan Wang

## Cardiology Fellows

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- Mudit Gupta
- Yuval Corren

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- Gabor Fichtinger
- Kyle Sutherland

## Cath

- Matt Gillespie

## BWH/MIT

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Steve Pieper  
Danielle Pace

## Kitware

Beatriz Panigua  
Jared Vicory

## FeBIO(Utah)

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- Steve Maas

## Cardiac Surgeons

- Mo Nuri
- Jonathan Chen
- Constantine Mavroudis

## Ebatinica

Csaba Pinter

## UPENN

Alison Pouch

