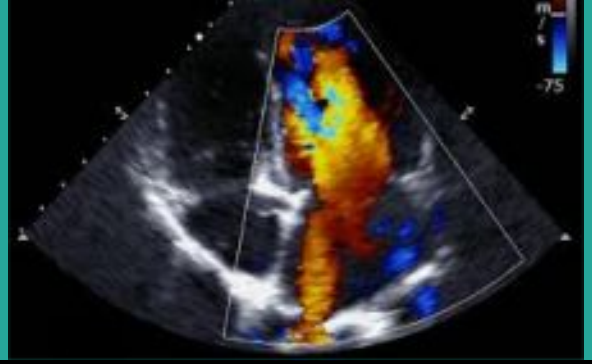


Using the Rate of Change of Cross-Sectional Area Slices of the Left Ventricle as a Means for Quantifying Sphericity in 3D Cardiac Ultrasound Images

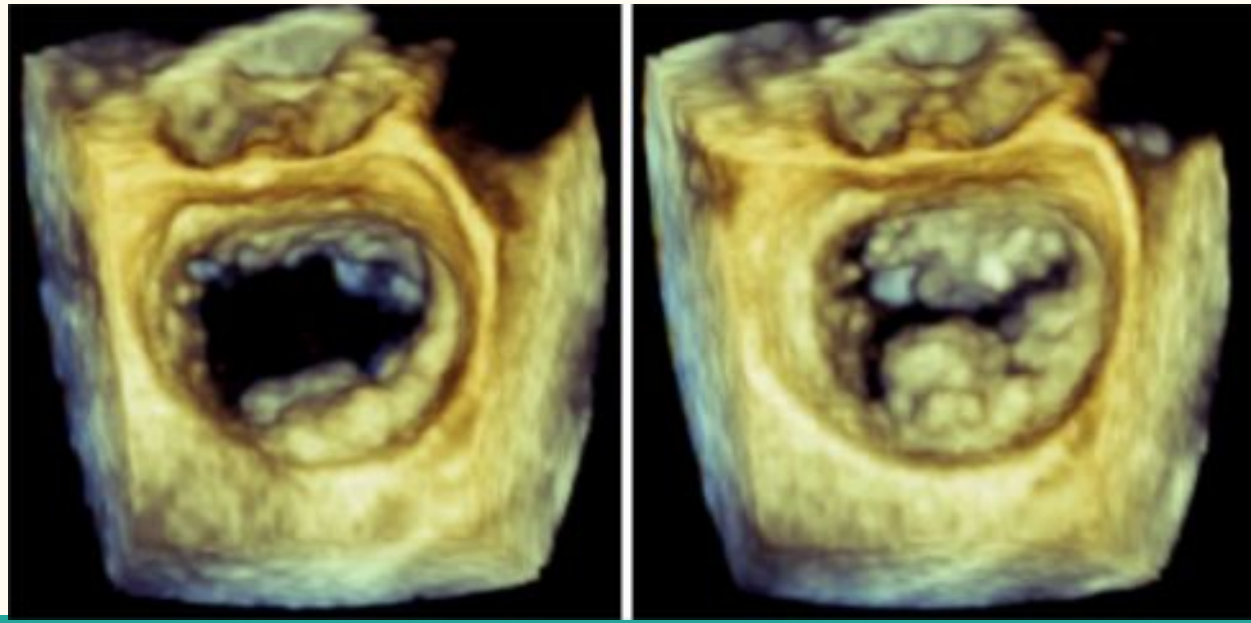
Tong Fu, Jose Rivera, and Kathleen Embury

Background

Importance of 3D/4D Echocardiography

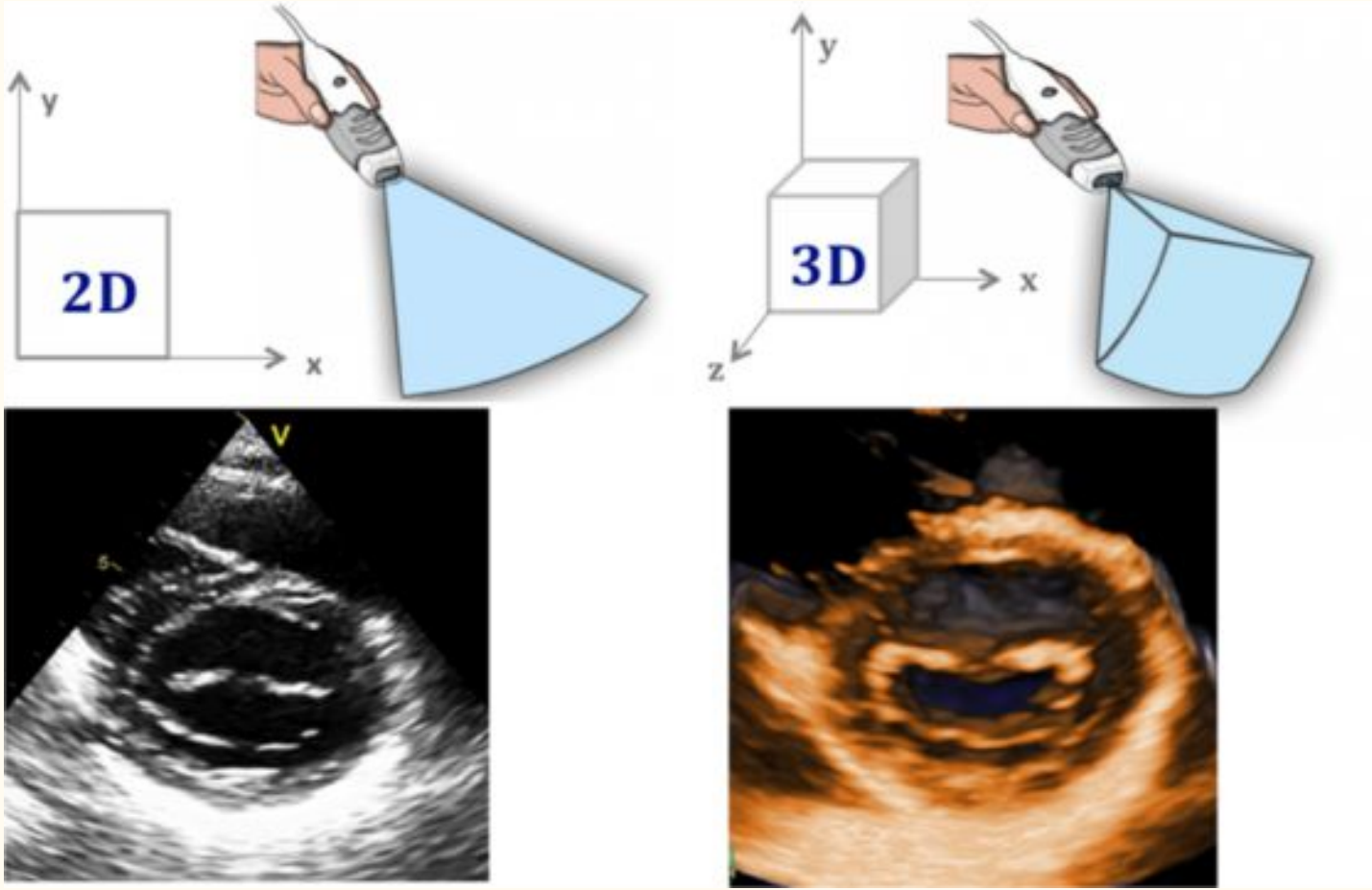
3D allows for...

- Realistic view
- Multiple perspectives
- “En face” slices
- Accurate volume calculation
- Real-time
- Diagnosis/prognosis



Shiota T. (2008) *J. Cardiol.*

2D vs. 3D Echocardiography



Lang (2012). *Eur Heart J Cardiovasc Imaging.*

Sphericity: What is it?

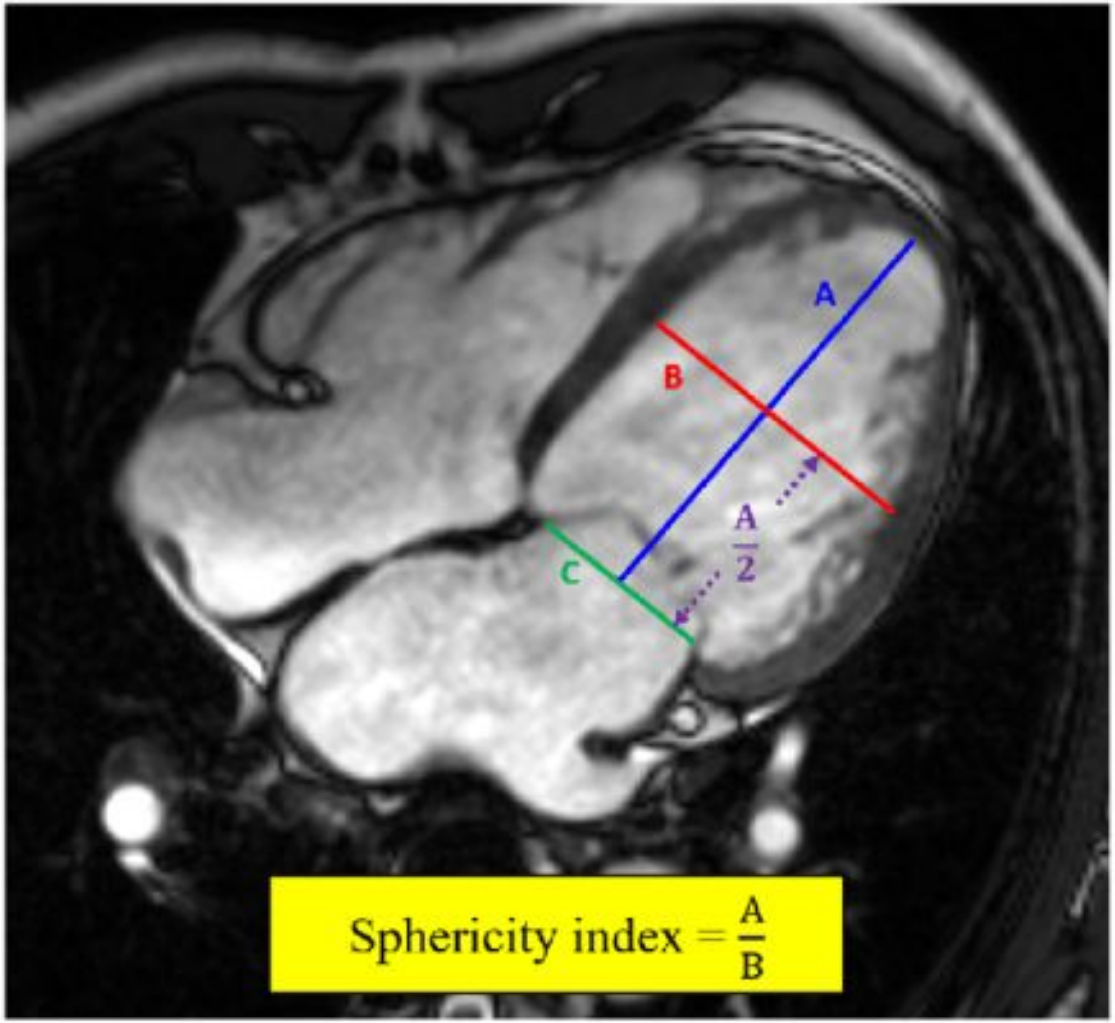
<u>Sphericity Volume Index:</u>

Real Volume vs. $4/3(\pi)(A^3)$

<u>Dimension Index:</u>

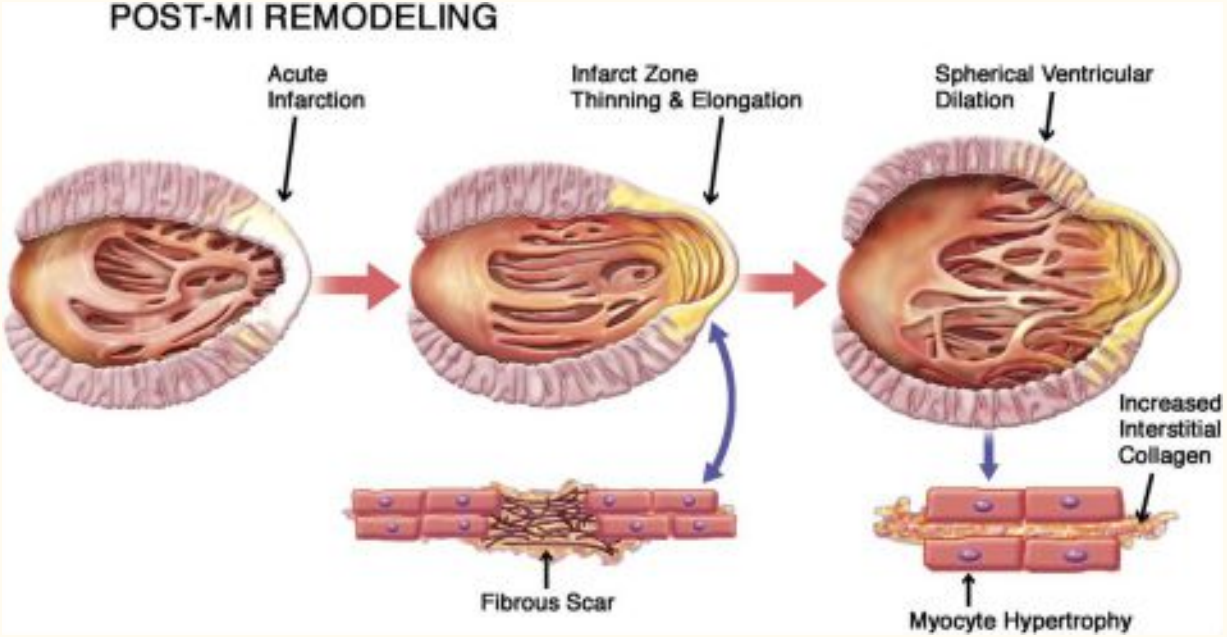
Short axis vs long axis ratio

Monaghan M. J. (2006). *Heart (British Cardiac Society)*.



Sphericity: Clinical Application

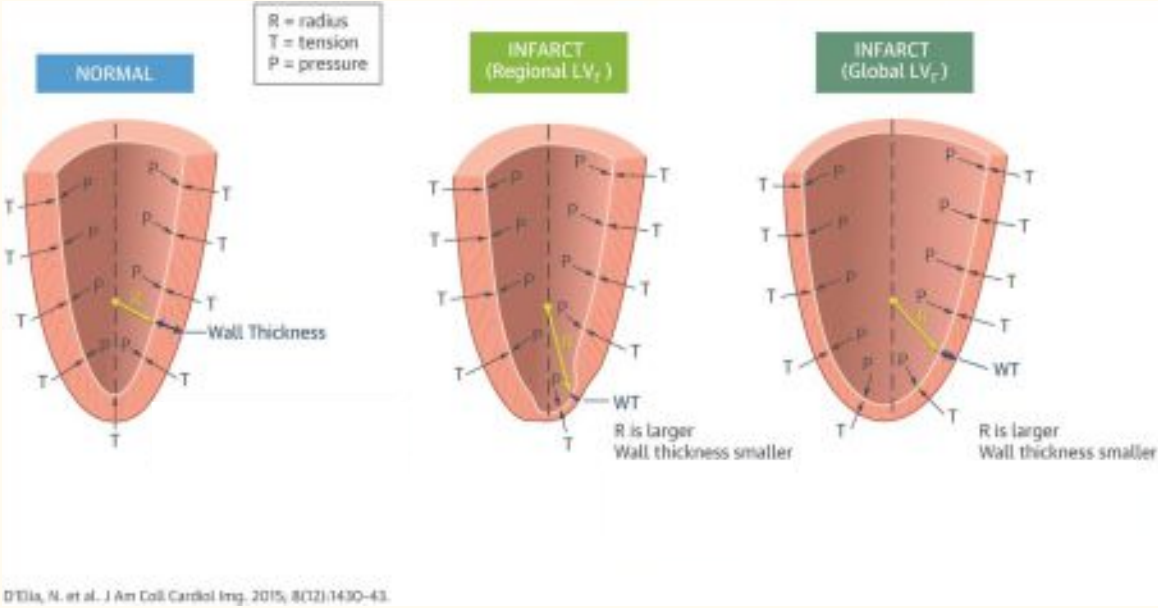
LV remodeling: ellipsoid to spherical



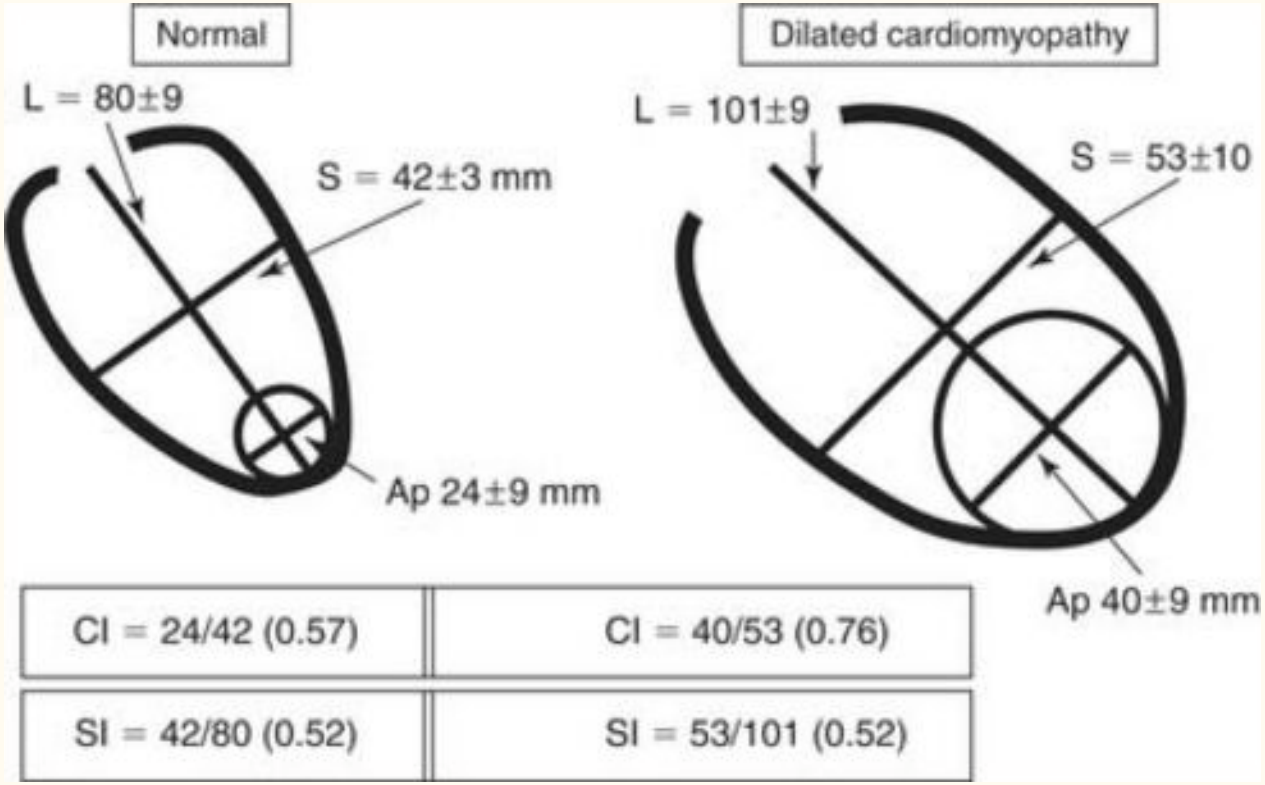
Limitations of Previous Work

Previous methods ignore...

- Standardized Quantification
- Regional reshaping
- Dilated ventricles
- 3D Echo
- Multiple planes
- Automation



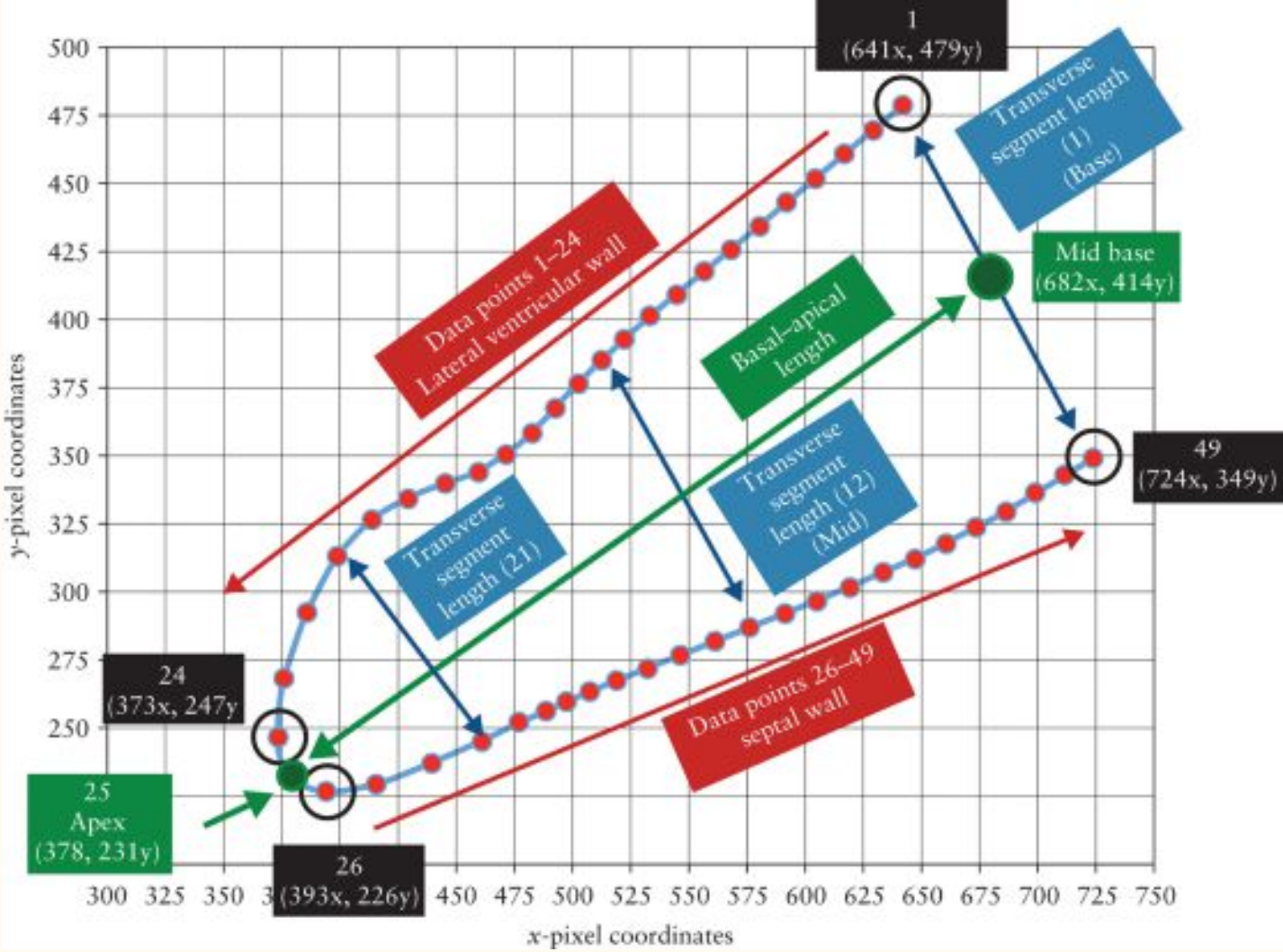
Conicity Index



Di Donato, M., et. al. (2006). *European Journal of Cardio-Thoracic Surgery*.

Previous Work

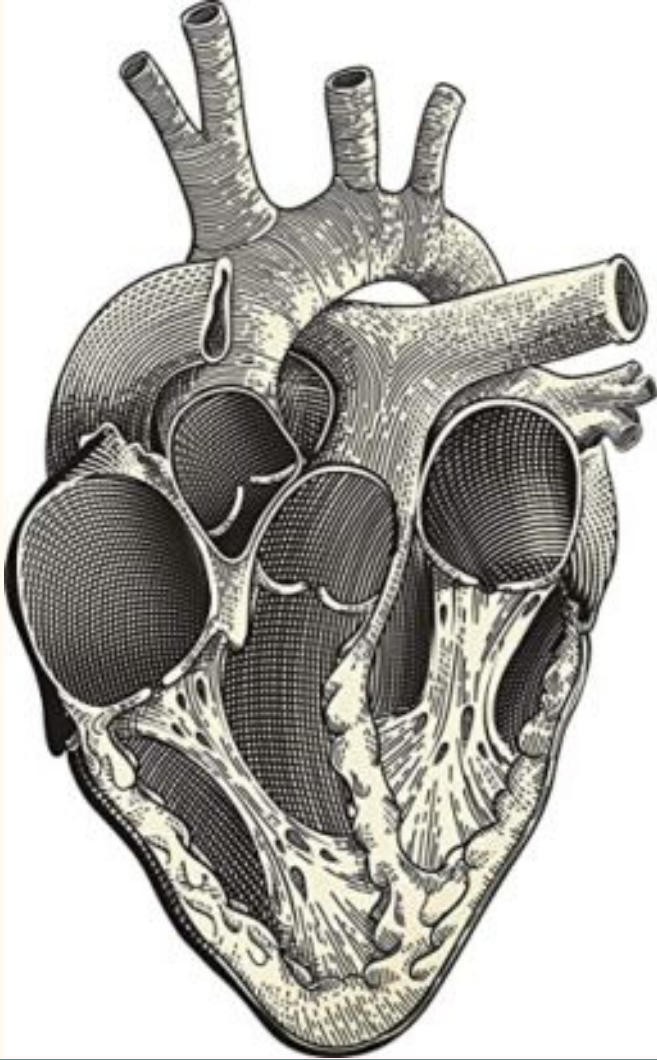
24-Slice Method



DeVore, G.R., et. al (2018). *Ultrasound Obstet. Gynecol.*

Our Plan

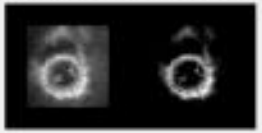
1. Process Images
2. 3 Plane Sphericity
3. Area Slices
4. Rate of Change Analysis
5. Automated System



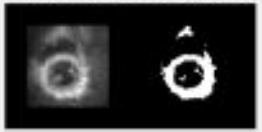
Methods

Image Processing

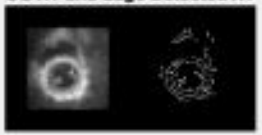
OG XY and Resized XY for Processing



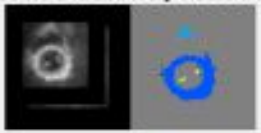
OG XY and Binarized XY



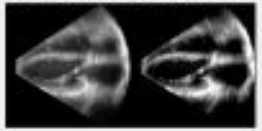
OG XY and Edge Detected XY



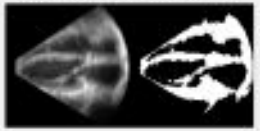
OG XY and Boundary Traced XY



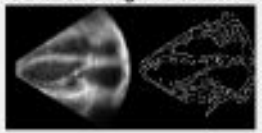
OG XZ and Resized XZ for Processing



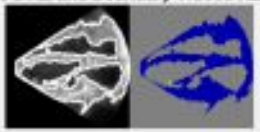
OG XZ and Binarized XZ



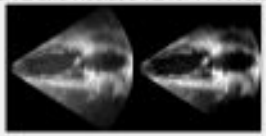
OG XZ and Edge Detected XZ



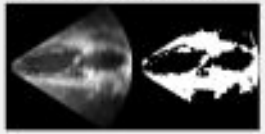
OG XZ and Boundary Traced XZ



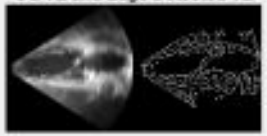
OG YZ and Resized YZ for Processing



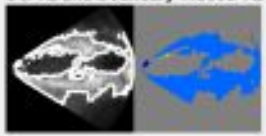
OG YZ and Binarized YZ



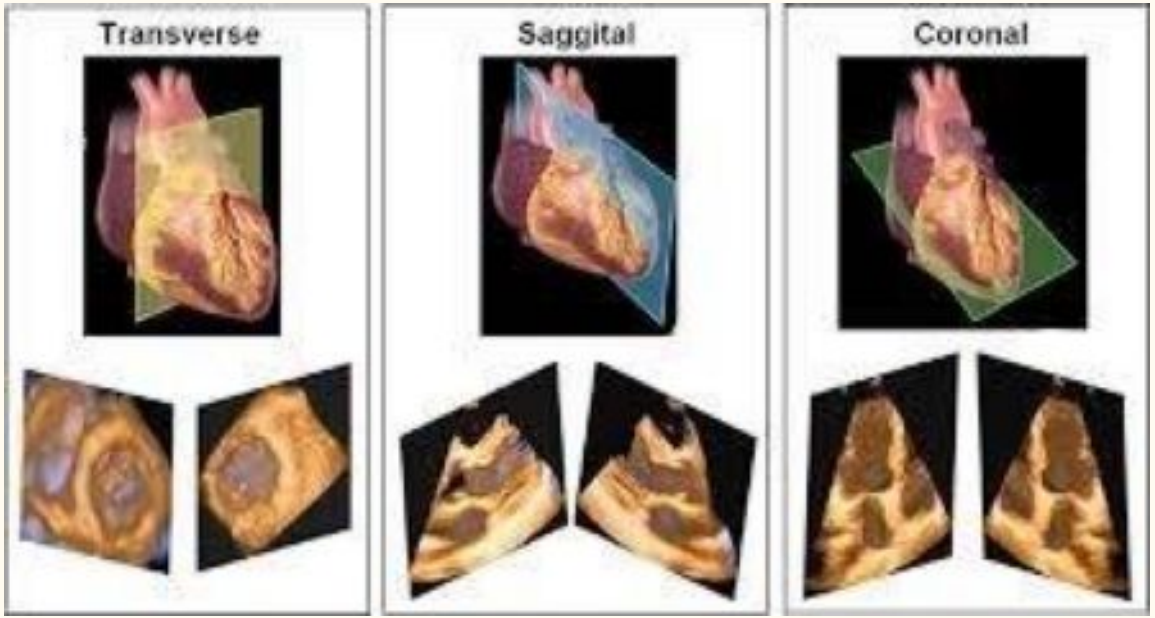
OG YZ and Edge Detected YZ



OG YZ and Boundary Traced YZ



1. Sphericity Index (an established method)

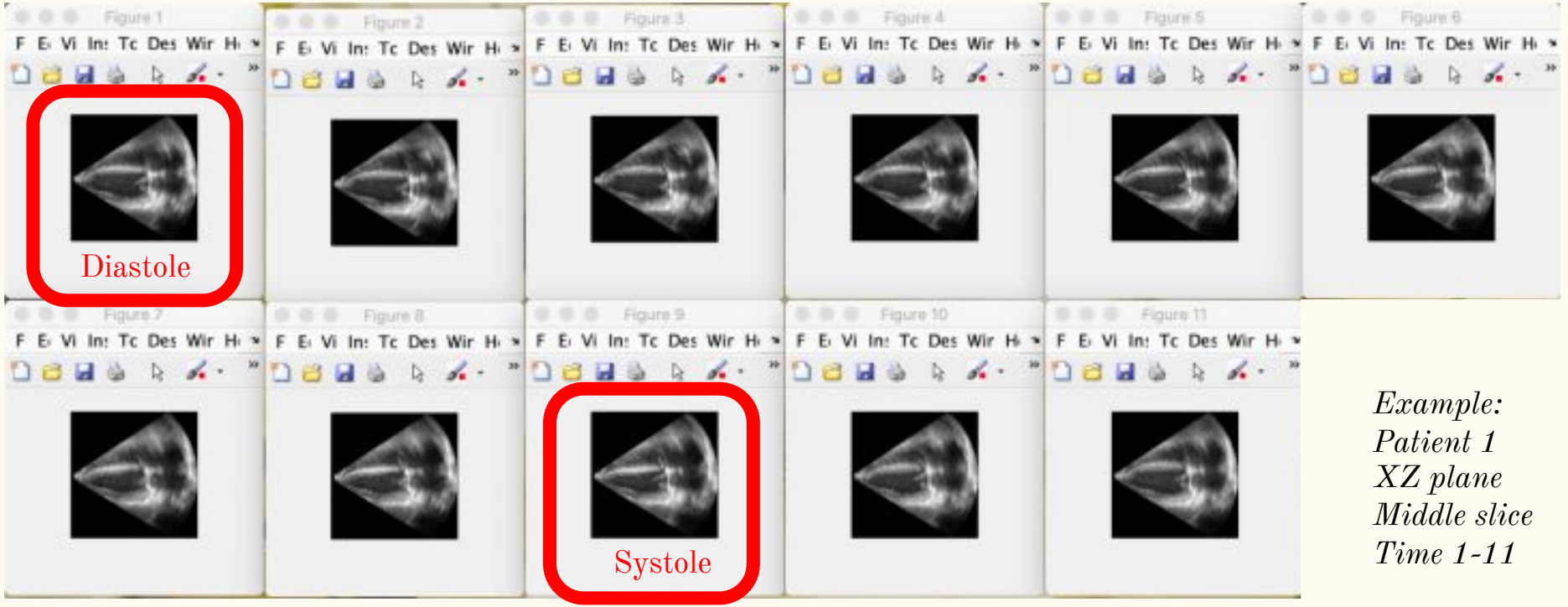


XY YZ XZ

Defining our Views

Lang, R.M. (2012).

Find the systole and diastole phase (middle slice)

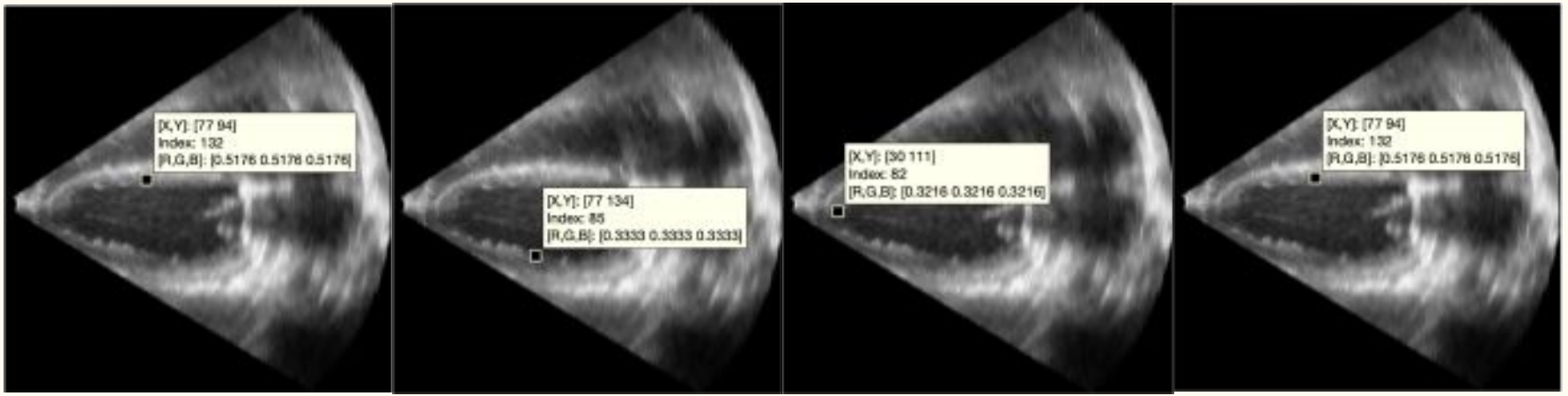


Example:
Patient 1
XZ plane
Middle slice
Time 1-11

Manually calculate **long axis : short axis** (3 planes)

Short axis XZ: length in **pixel** * dW = length in **cm**

Long axis XZ: length in **pixel** * dD = length in **cm**



Top short axis

Bottom short axis

Left long axis

Right long axis

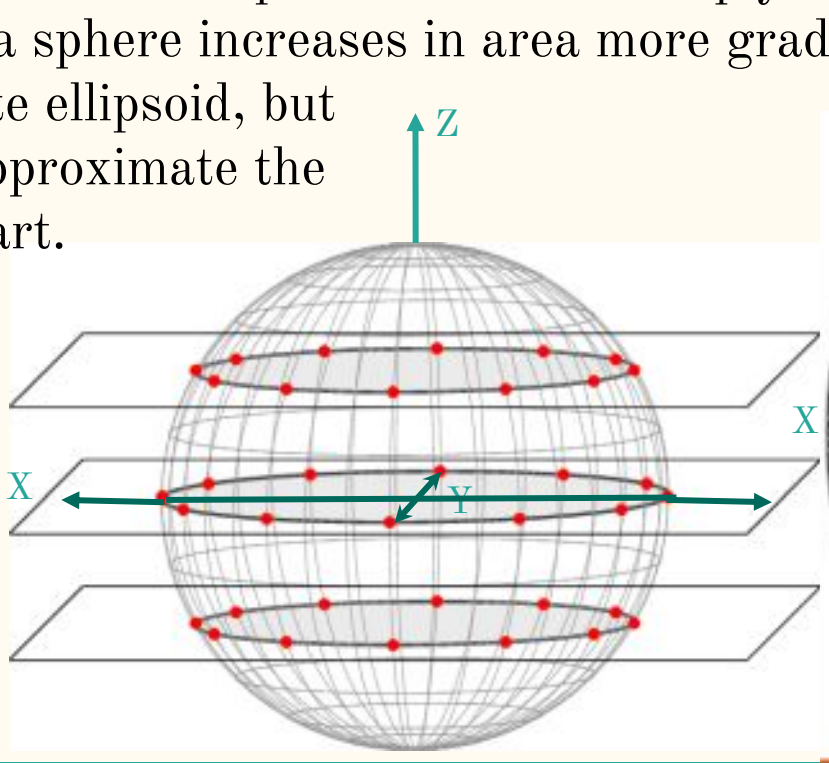
Difference

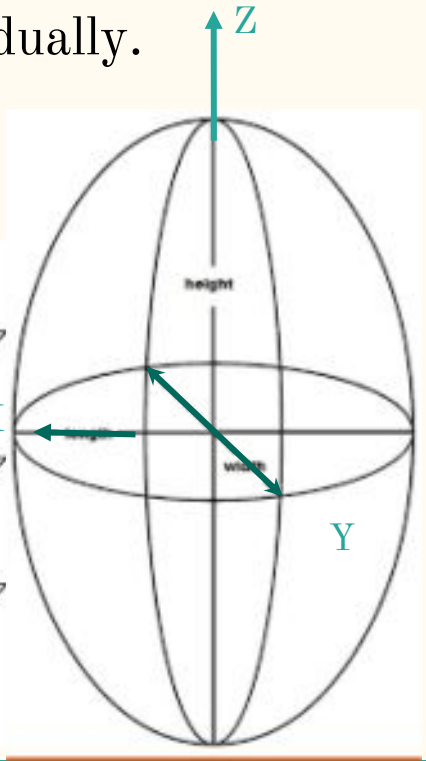
Short axis (40 pixel)

Short axis (90 pixel)

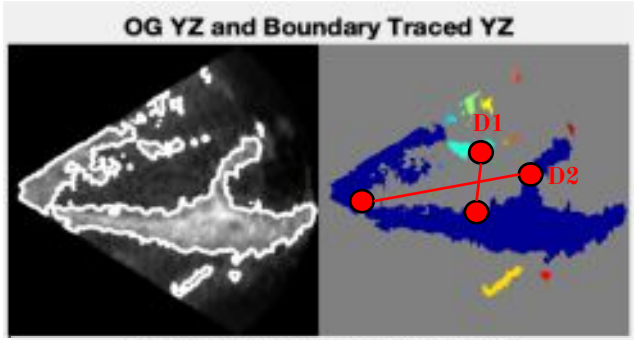
2. Area Rate of Change

- Rate of change in area for an ellipsoid increases sharply in the XZ and YZ planes while a sphere increases in area more gradually.
- Hearts aren't complete ellipsoid, but they can be used to approximate the shape of a healthy heart.





Finding the Area of a Cross Section of the Ventricle

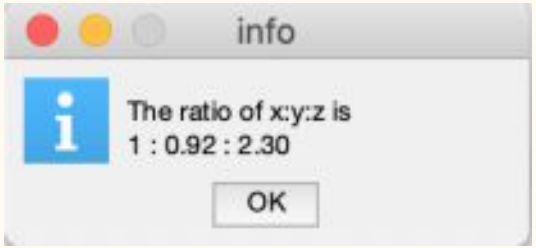


$\pi(D1)(D2)/4$

$\pi(D1)(D2)/4$

3. Automated Slicing

Display!

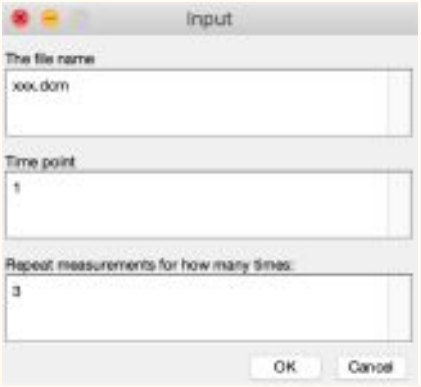


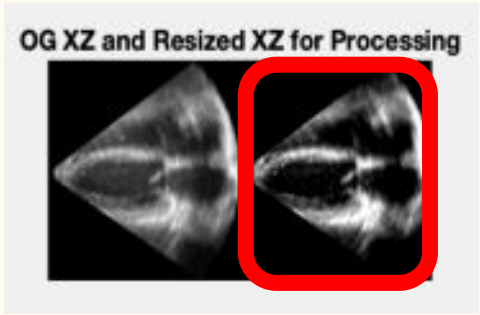
Message box ask for input

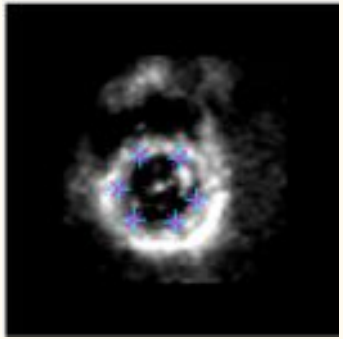
Pick the middle slice for all 3 planes & filtering

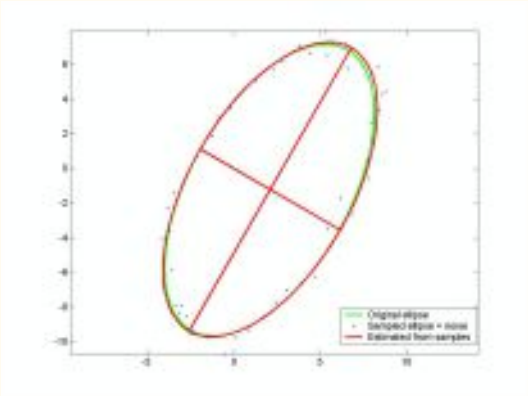
User select points on graphs

Ellipse fit & calculate SI



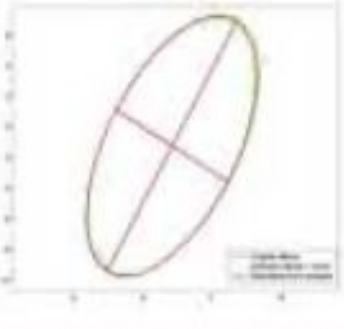






Ellipse Fit

Finds the best fit to an ellipse for the given set of points.



- fit_ellipse(x,y)
- **Least Square** estimation method done for the **conic representation** of an ellipse (with a possible tilt).
- Gives short and long axis of the best fit.

Conic Ellipse representation =
a*x^2+b*x*y+c*y^2+d*x+e*y+f=0

Results


ΚΑΡΔΙΑΓΓΕΙΑΚΗΣ ΑΠΕΙΚΟΝΙΣΗΣ
ΣΤΗΝ ΚΛΙΝΙΚΗ ΠΡΑΞΗ
IN CLINICAL PRACTICE
LIVE
MEDIA

1. Sphericity Index Ratio

	Patient 1 (dilated)	Patient 2 (normal)
Systole	1: 1.15: 1.64	1: 1.43: 1.92
Diastole	1: 1	1: 1.49: 1.81

ROUNDER

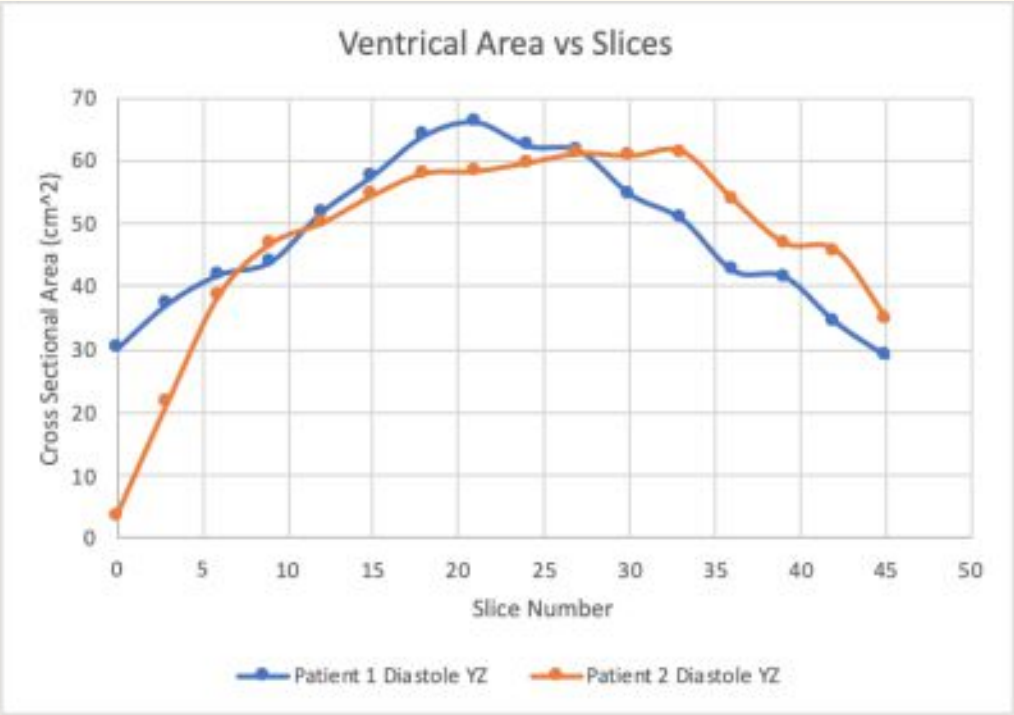
Systole: 0.52 (p2) vs. 0.61 (p1) ... ole: 0.55 (p2) vs. 0.72 (p1)

SI

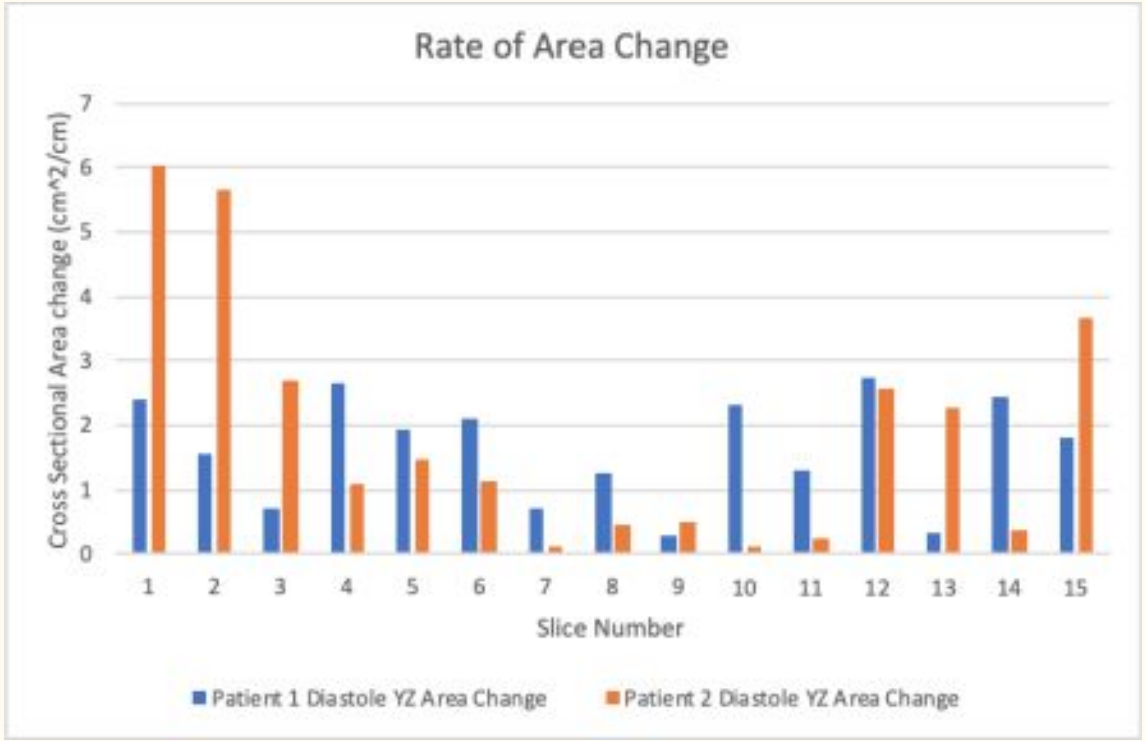
Rounder

- **Diastole vs. Systole**
  The diastolic left ventricle is rounder - filled with blood & muscle relaxes
  - Patient 1(dilated): **15.9%** rounder (SI **0.72 vs. 0.61**)
  - Patient 2 (normal): **5.7%** rounder (SI **0.55 vs. 0.52**)
- **X:Y close to 1**
- **Patient 1(dilated) vs. Patient 2 (normal)**
  - Patient 2's heart (normal) is more "elliptical" (SI **0.52 & 0.55**)
  - Patient 1's heart (dilated) is "rounder" (SI **0.61 & 0.72**)

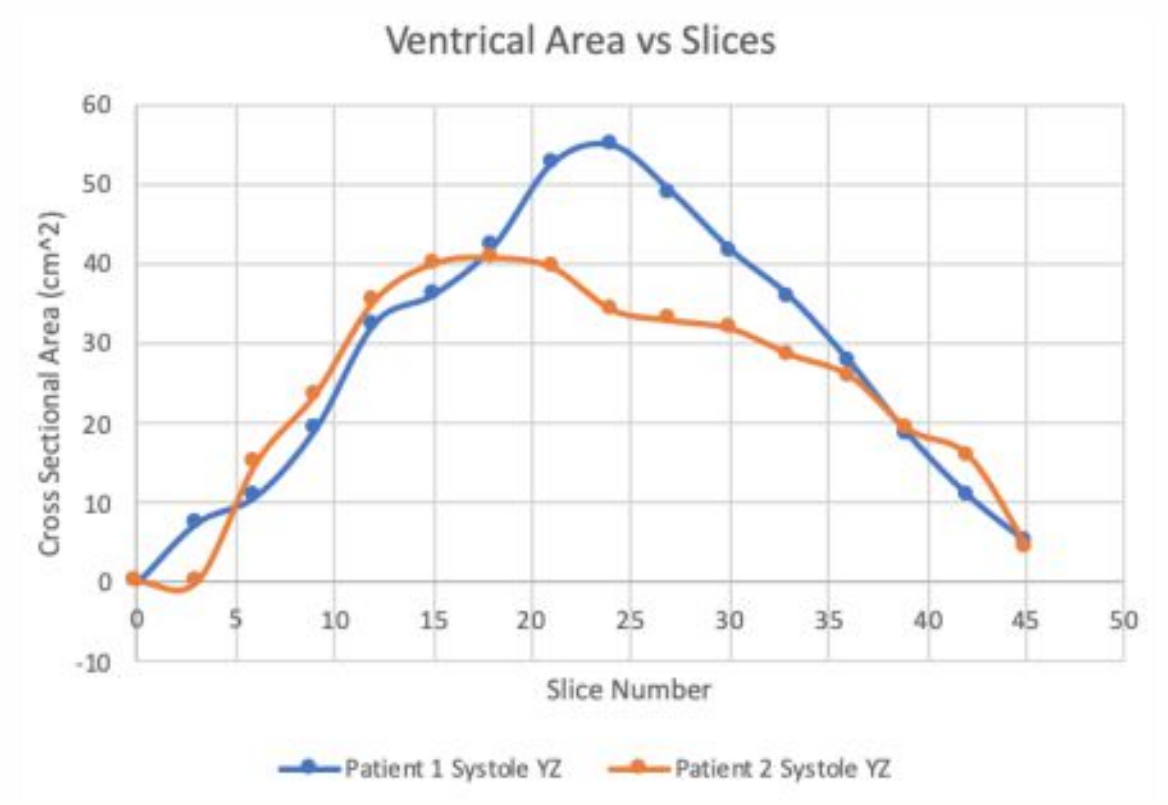
Diastole Plots for the YZ Plane



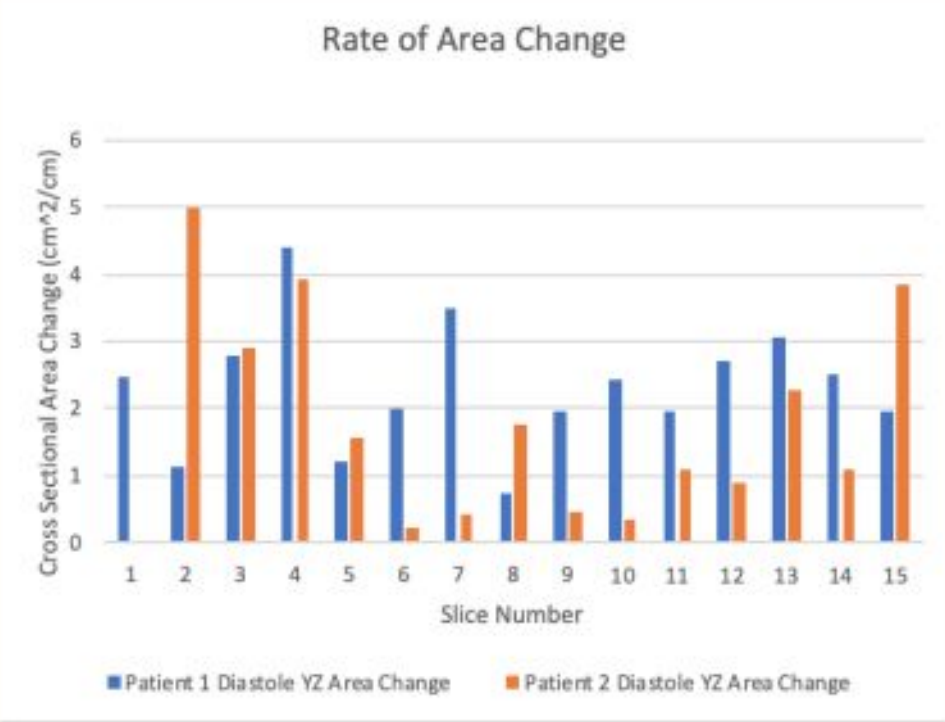
Diastole Plots for the YZ Plane



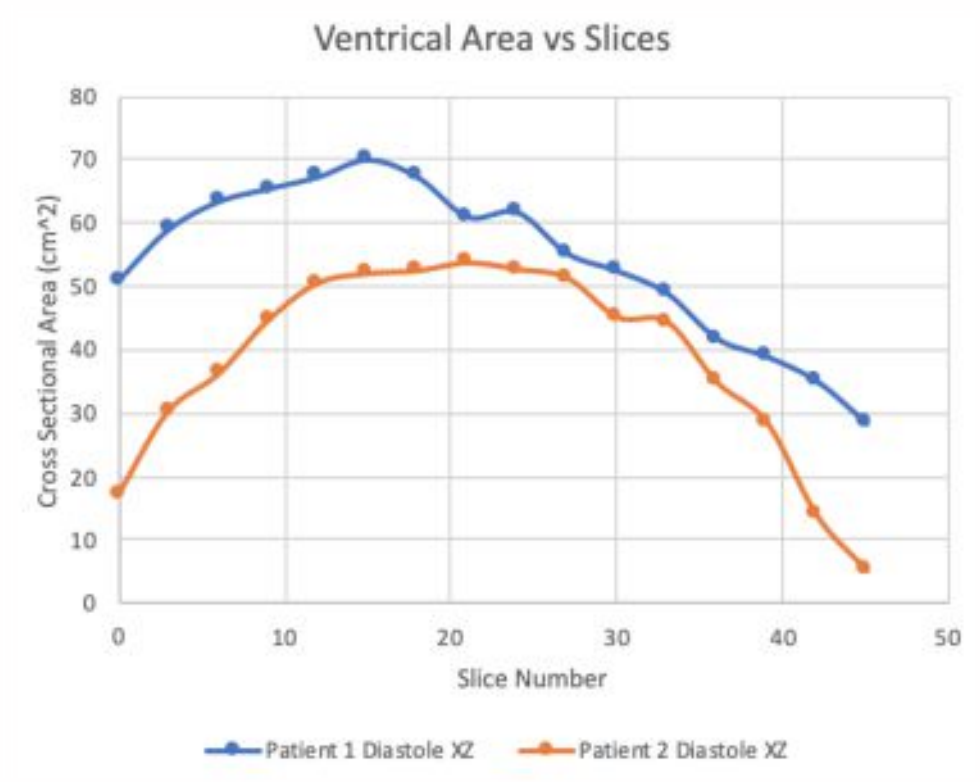
Systole Plots for the YZ Plane



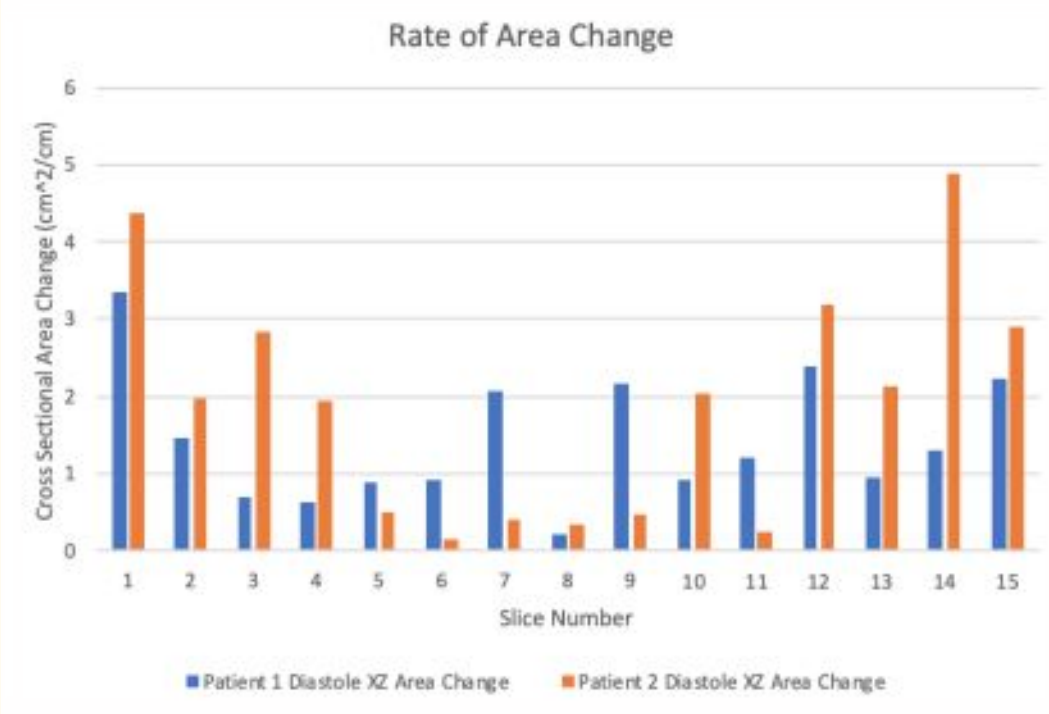
Systole Plots for the YZ Plane



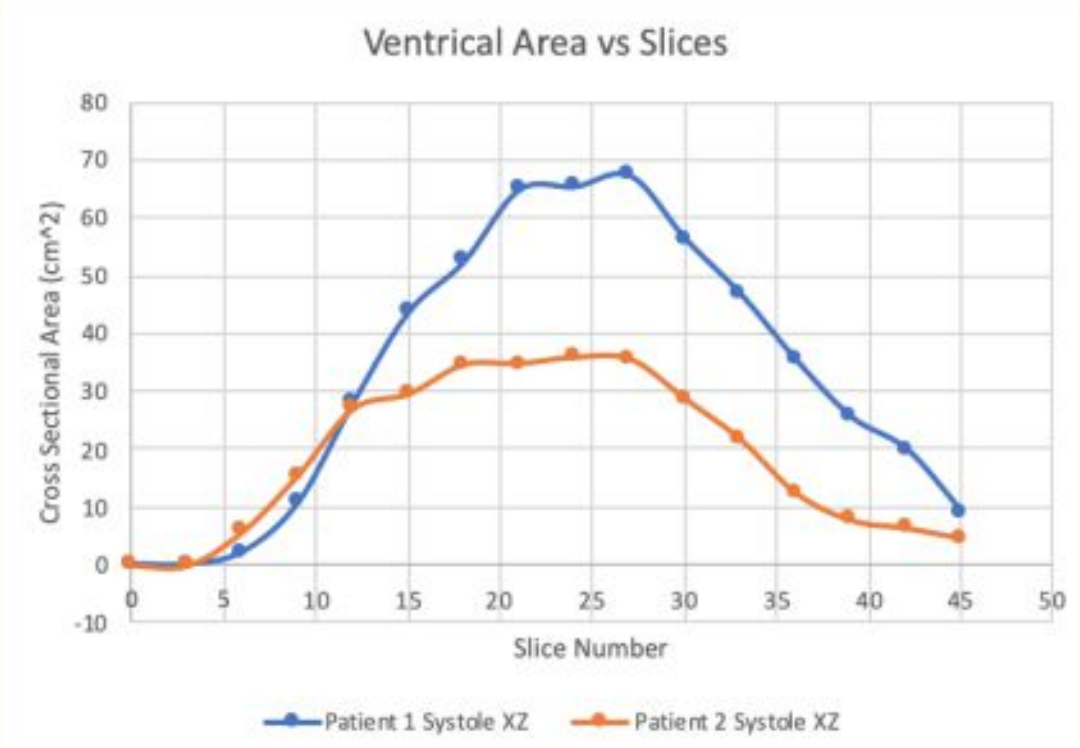
Diastole plots for the XZ plane



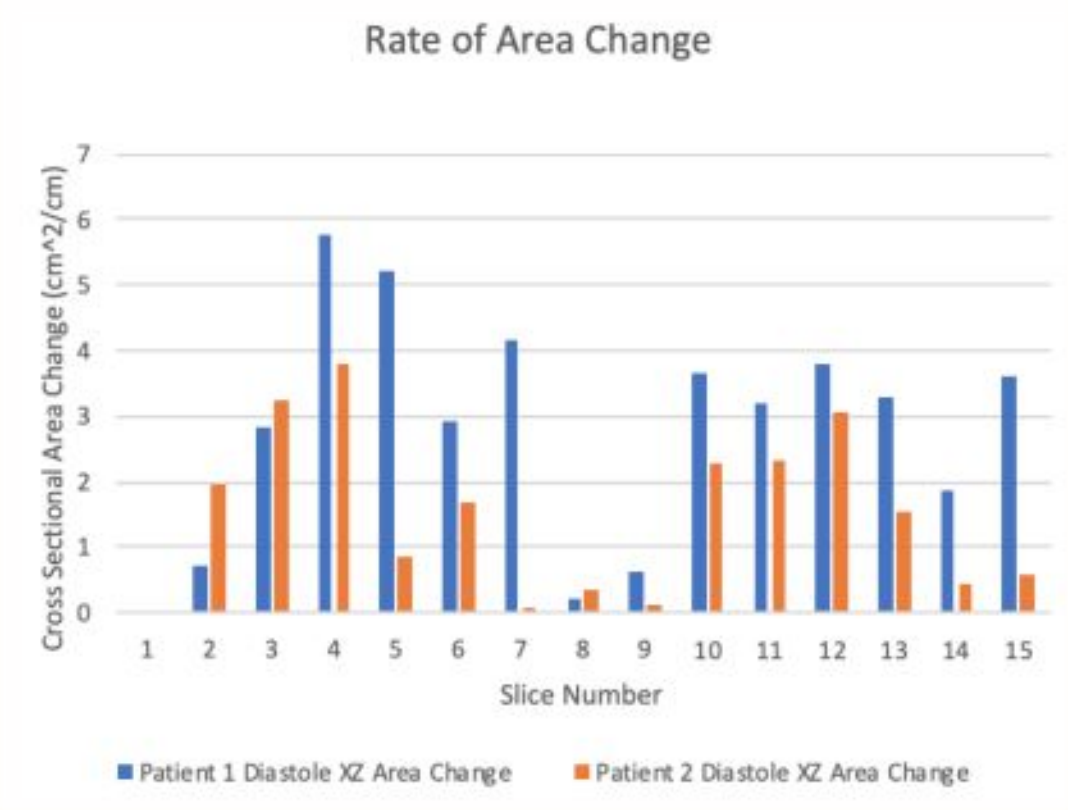
Diastole plots for the XZ plane



Systole Plots of the XZ plane



Systole Plots of the XZ plane



3. Automation

Patient1 (dilated)

	Trial 1			Trial 2			Trial 3				
	XY	XZ	YZ	XY	XZ	YZ	XY	XZ	YZ	average	ratio
x	66.35	50.97		59.03	46.91		60.98	49.8		55.6733333	1
y	58.74		52	58.04		53.38	58.37		67.53	58.01	1.04197102
z		118.98	105.25		103.64	104.11		121.09	133.32	114.398333	2.05481379
					x:y:z						
					1:1.04:2.05						

SI: 0.48

Patient 2 (normal)

	Trial 1			Trial 2			Trial 3				
	XY	XZ	YZ	XY	XZ	YZ	XY	XZ	YZ	average	ratio
x	74.46	62.87		80.22	65.89		75.19	59.62		69.708333	1
y	72.35		74.4	65.72		78.63	63.5		71.14	70.956667	1.0179079
z		194.25	158.22		179.33	154.53		186.84	163.33	172.75	2.4781829
					x:y:z						
					1:1.02:2.48						

SI: 0.40

Discussion

Comparison (the established method)

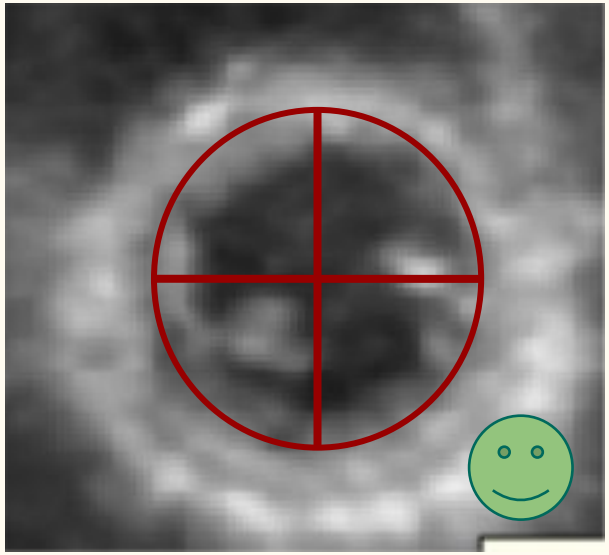
	Literature SI Values		Our SI Values	
	Diastole	Systole	Diastole	Systole
Normal	0.52	0.45	0.55	0.52
Dilated	0.58	0.51	0.72	0.61

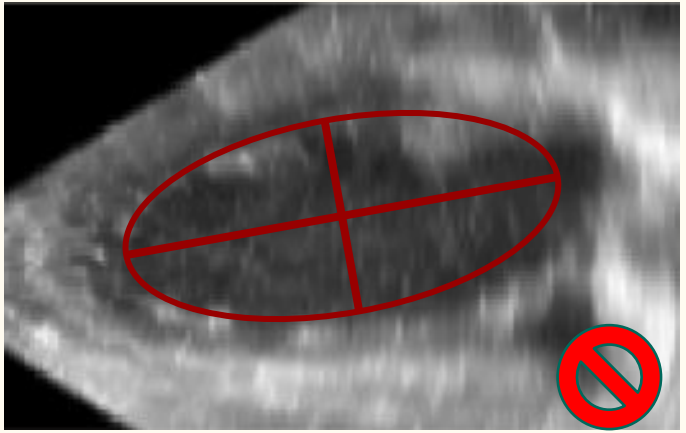
Large SI ← Small SI

Our SI to Literature Values

Di Donato M, et.al 2006

Method Limitations - established method





Limitations:

- Done manually
- Determined by only four points
- Tilted

Advantages:

- Easy to implement
- Accurate if the heart is not tilted

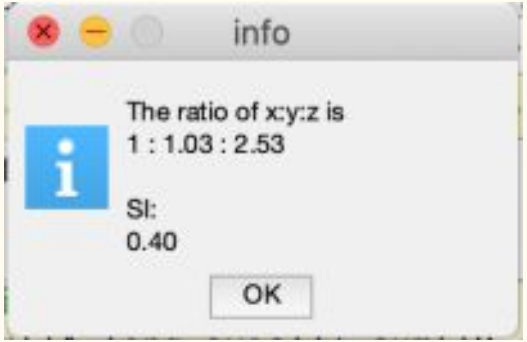
Method Limitations - automated slicing

Limitations:

- Highly subjective
- Good results requires the doctor to iterate the process for many times
- Time consuming if the doctor wants a unbiased and accurate result
- Depends on the Least Square fit method

Advantages:

- Efficient
- Automated process
- Straightforward by showing a number to the physicians



Our New Method vs. Other Methods

- This new method allows for the analyzation of the 3D data to move across the ventricle and actually visualize the sphericity in space and in time.
    - Previous methods only look at the comparison of the Radii in the center
- New method allows for clear distinction between a healthy and diseased hard in diastole when the heart has the greatest capability of becoming spherical.
- This new method also allows for local changes in heart to be viewed.
- Uses an automated version of the old method to increase precision in diagnosis.

Conclusions

Key Points

- Expanded sphericity definition with 3D data
- Developed a novel method using area rate of change
- Automation

Future Work

- Acquire More Data
- Clinical trials (relation to disease)
- Automation improvement
- More slices
- Image processing improvement

References

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Questions?