Three Dimensional Echocardiography

Past, Present, and Future

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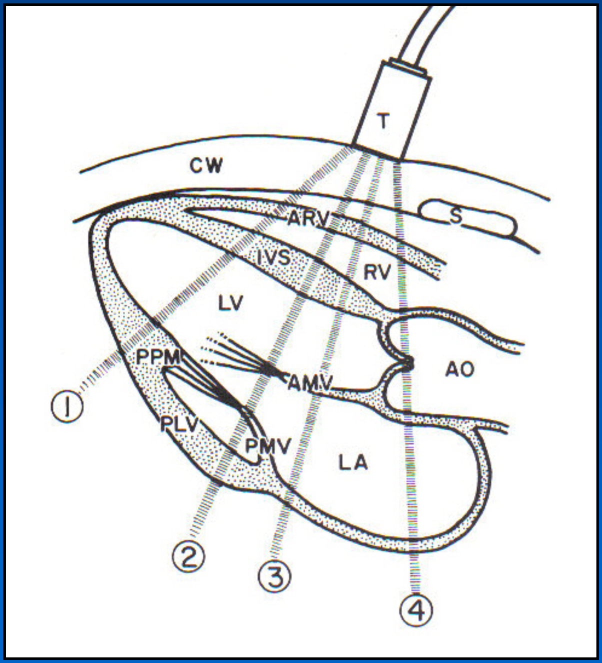
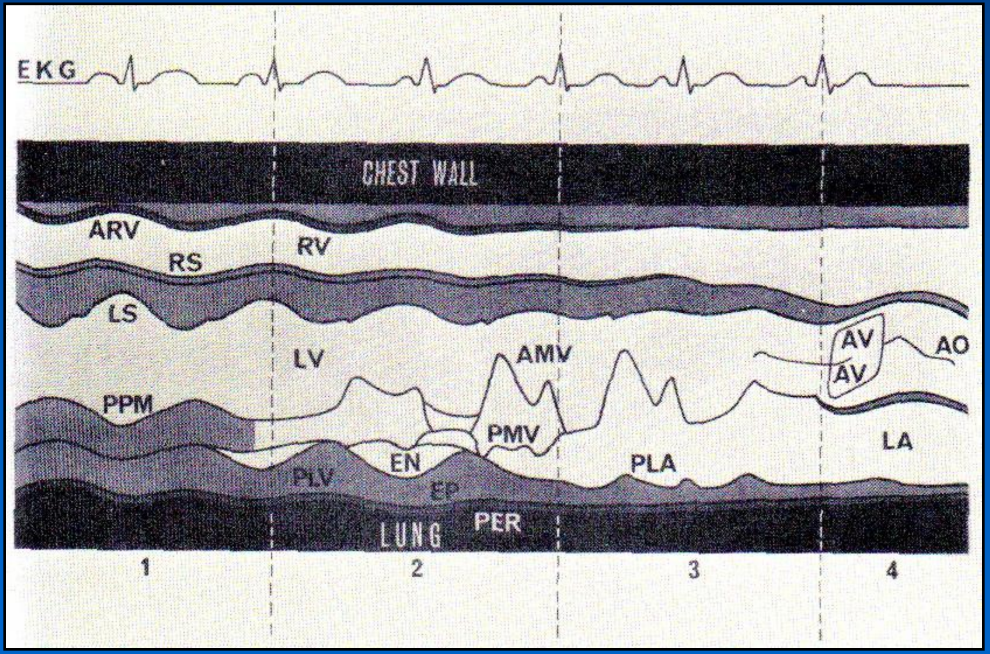
Overview

- History of echocardiography
- History of 3-D echo
- Current utility
- Specific examples
- Future directions

History of Echocardiography

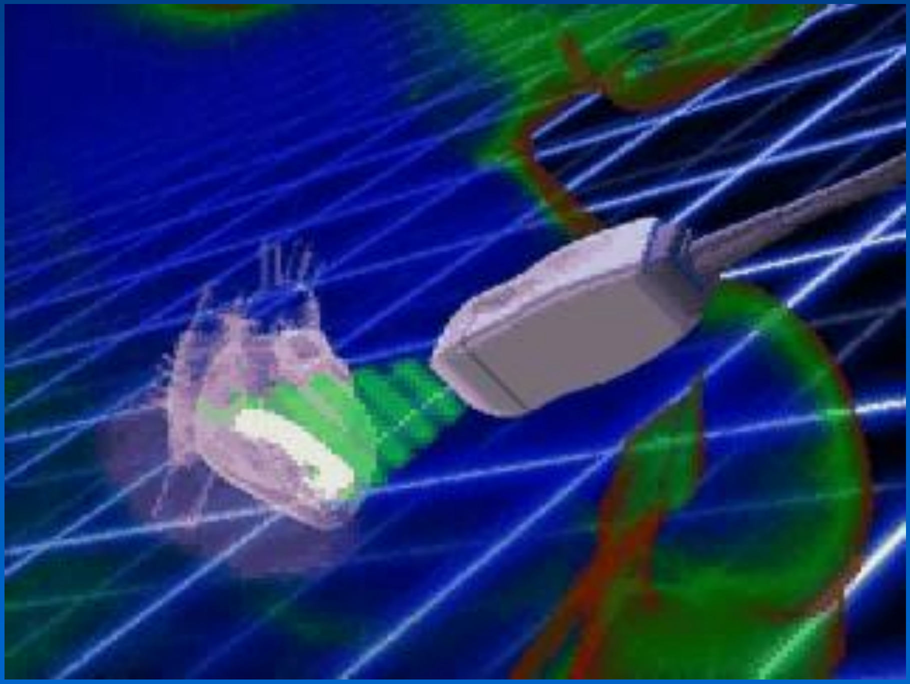
Single dimensional (M-Mode) Echo

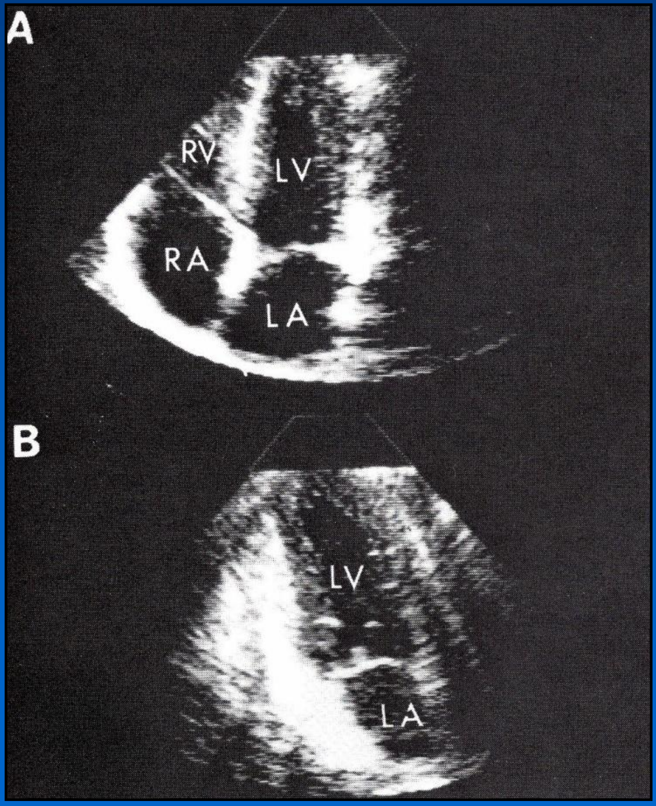




History of Echocardiography

Two dimensional Imaging
1980's-90's





Additional Historic Advances

- Doppler velocity tracings
- Color Doppler imaging
- Transesophageal imaging (TEE)
- Intravascular ultrasound (IVUS)
- Harmonic imaging
- Contrast perfusion imaging

Limitations of 2-D Imaging

- Limited acquisition windows
- Theoretically more time consuming acquisition
- Incomplete view of a single structure
- Loss of structural orientation/spatial relationships
- Lack of volume or mass measurements
- Poor quantification of regurgitant lesions
- Inherent increased learning curve

Art History

Pre Perspective

Initial word panel of Psalm--14th C.

Early

Renaissance

Post Perspective

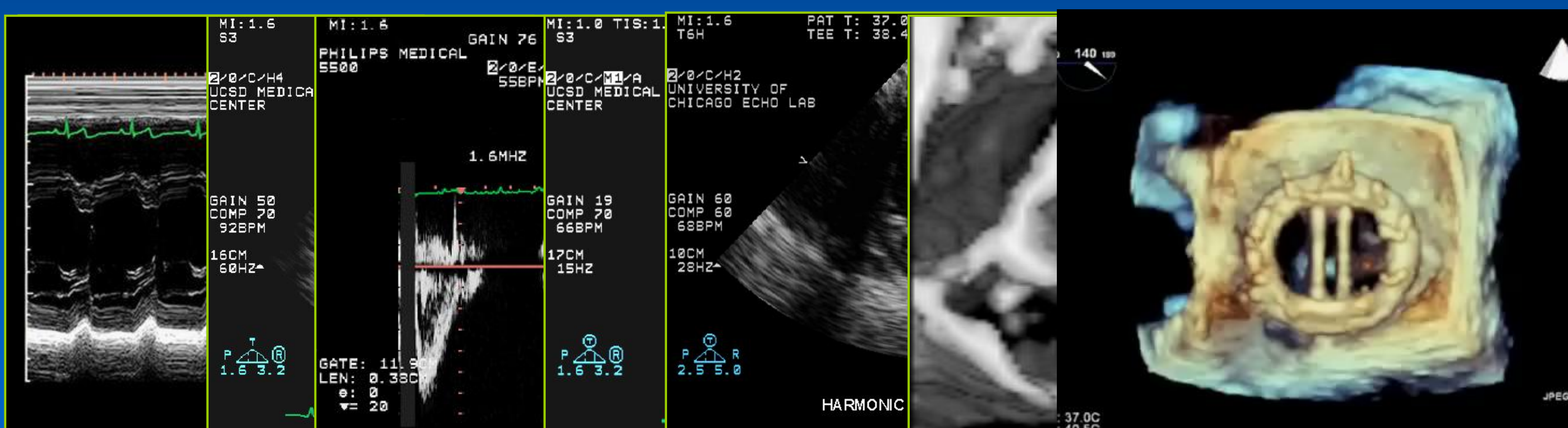
Raphael: School of Athens--15th C.

Prince of Egypt

Live 3D Echo
Historical Perspective of Echo

A-mode B-Mode Doppler TEE Live 3D

M-Mode Real-time Color Gated-3D



History of 3-D Echocardiogaphy

Free-hand Scanning Method

- Developed in the early 80's
- Utilized multiple separate imaging planes
- Images aligned using acoustic locator system
- Acquired over several heart beats
- Reconstructed off-line with hand tracing
- Used for LV volume and mass measurements

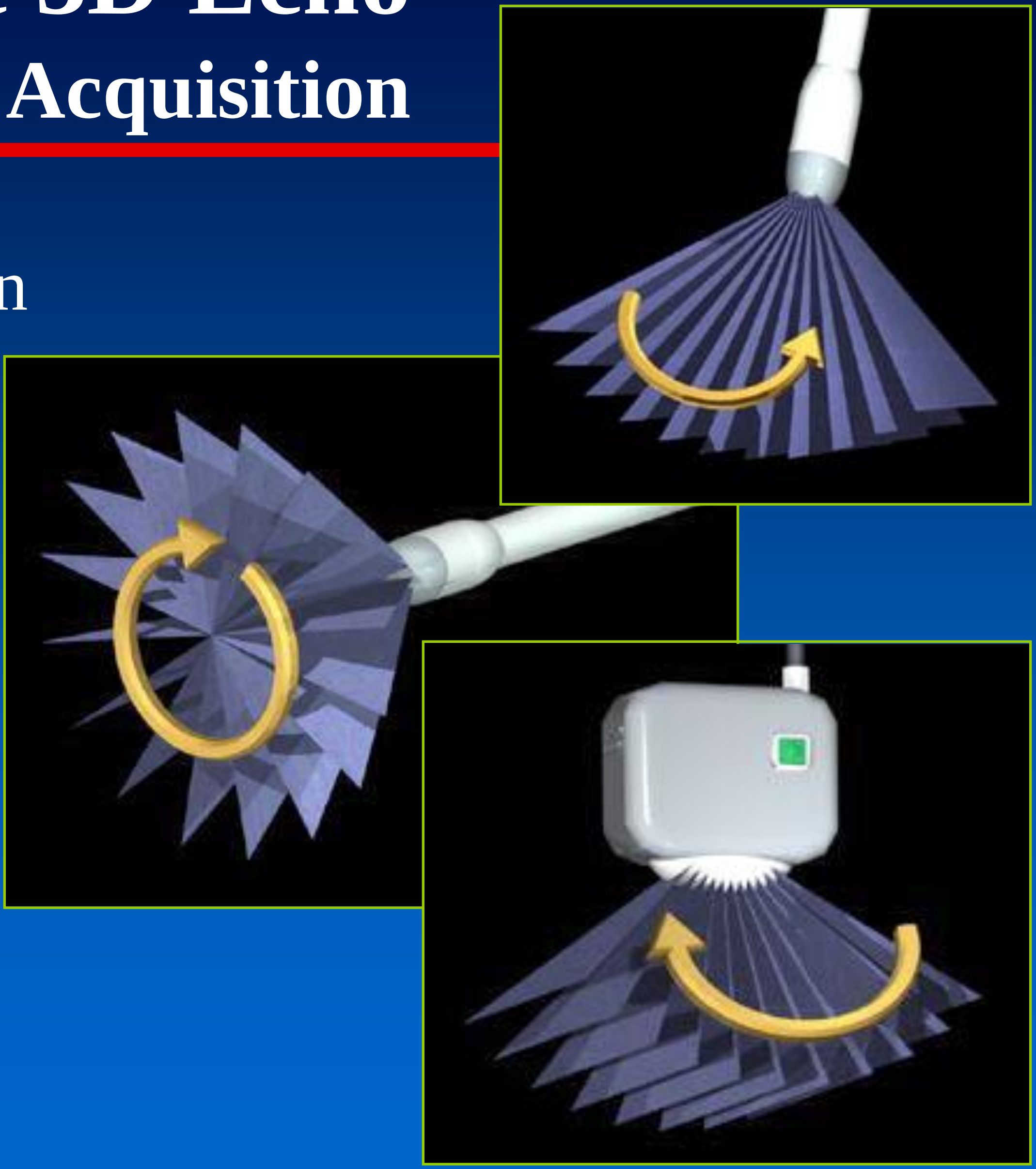
History of 3-D Echocardiography

Gated Sequential Scanning

- Developed in the early 90's
- Utilized a single acquisition window
- Mechanically rotated the transducer
- ECG/Respiratory gated
- Acquired over several heart beats
- Reconstructed off-line

Live 3D Echo
Data Acquisition

- Sequential acquisition
- Manual method
  - Parallel
  - Fan-like
  - Free surface
- Automated method
  - Rotational
  - Fan-like
  - Parallel



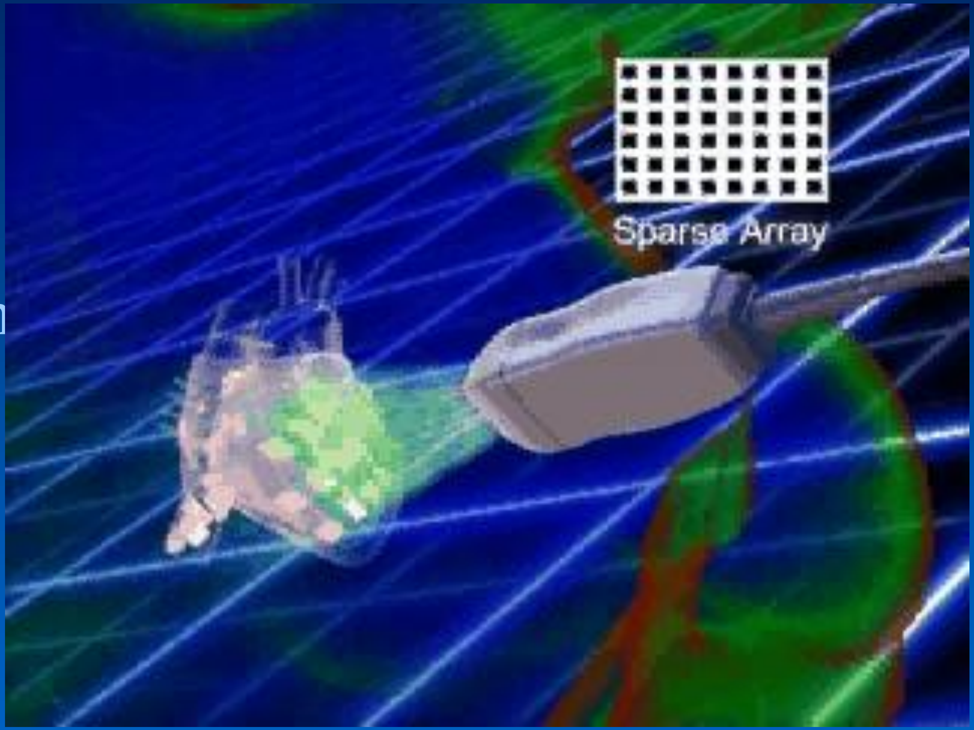
History of 3-D Echocardiography

Real Time (Live) 3-D

- Initial development in mid 80's
- Transducer technology
  - Sparse array: 256 elements
  - Full matrix array: 3000 elements
- Simultaneous image acquisition
  - Multiple planes simultaneously
  - Single heart beat
- Image processing on-line

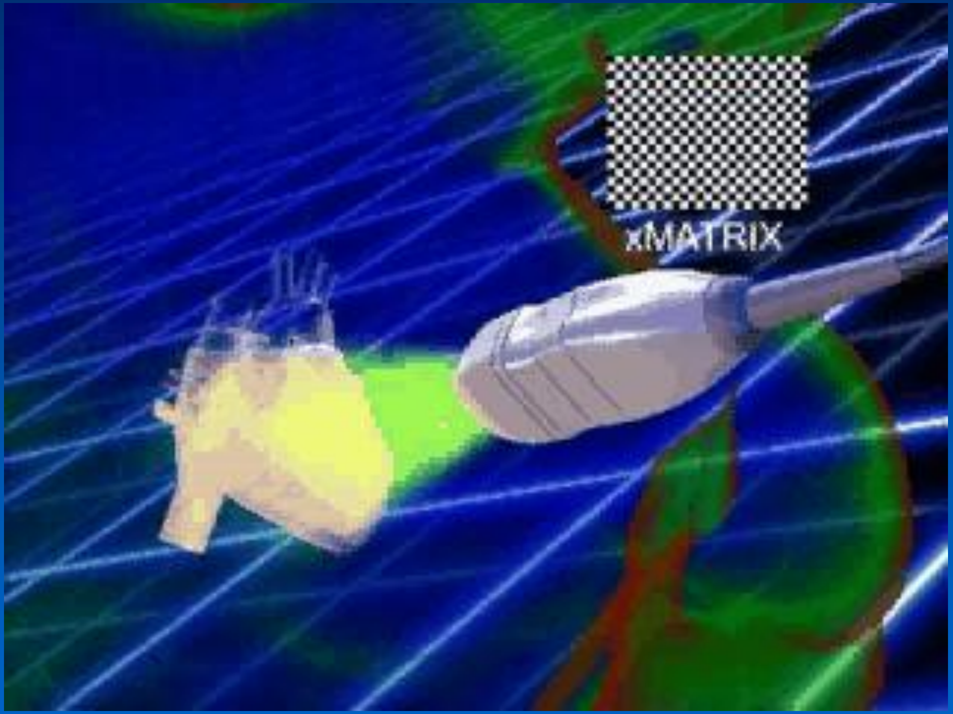
Live 3D Echo
Sparse Arrays

- Real-time
- Limited image quality
  - Weak sensitivity
  - Potentially poor resolution
- ~300 elements



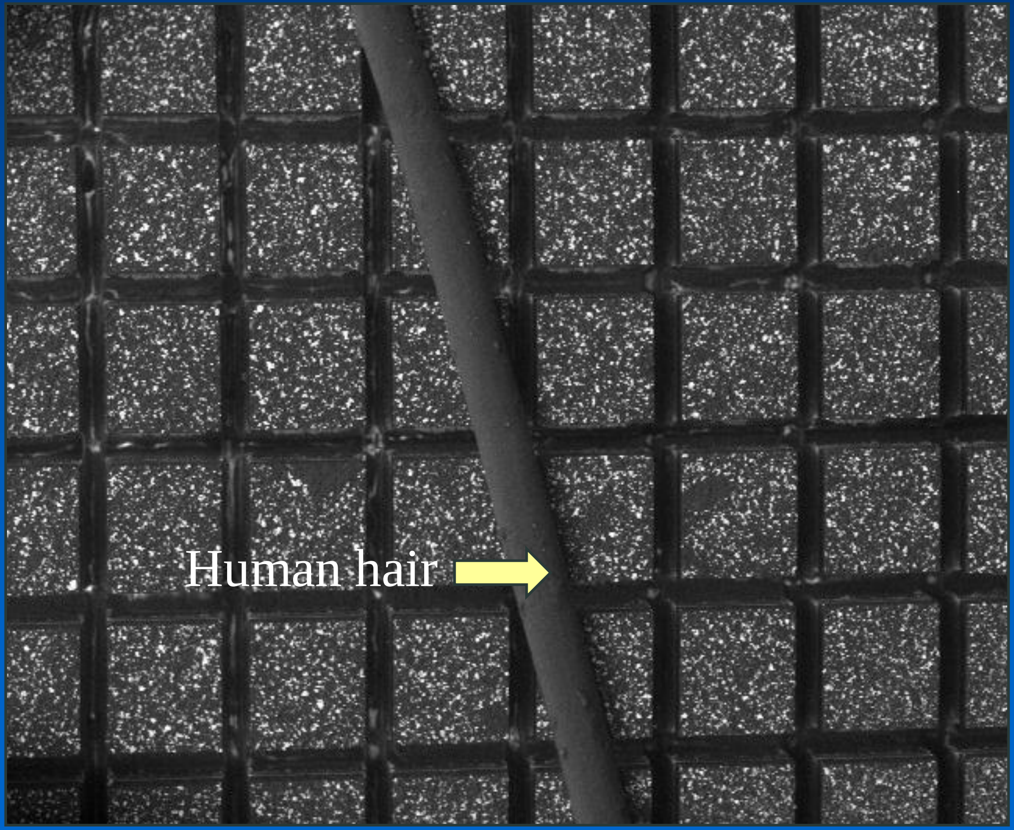
Live 3D Echo
X- Matrix Array

- Real-time volume acquisition
- Excellent image quality
- ~3000 elements and electrical connections



Live 3D Echo
X-Matrix Technology

- Sensor Fabrication



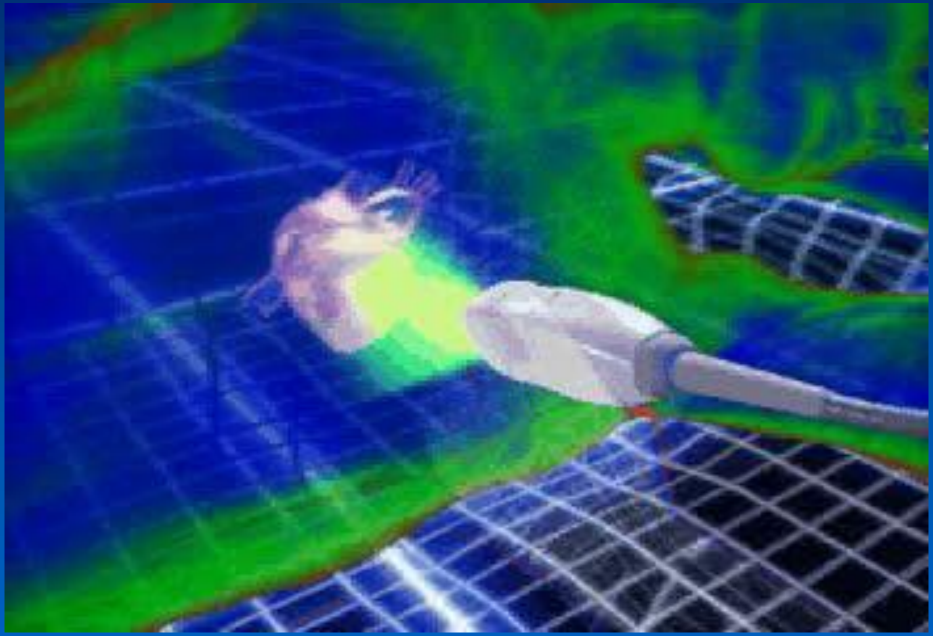
Microscopic photo of top view xMATRIX posts

Live 3D Echo

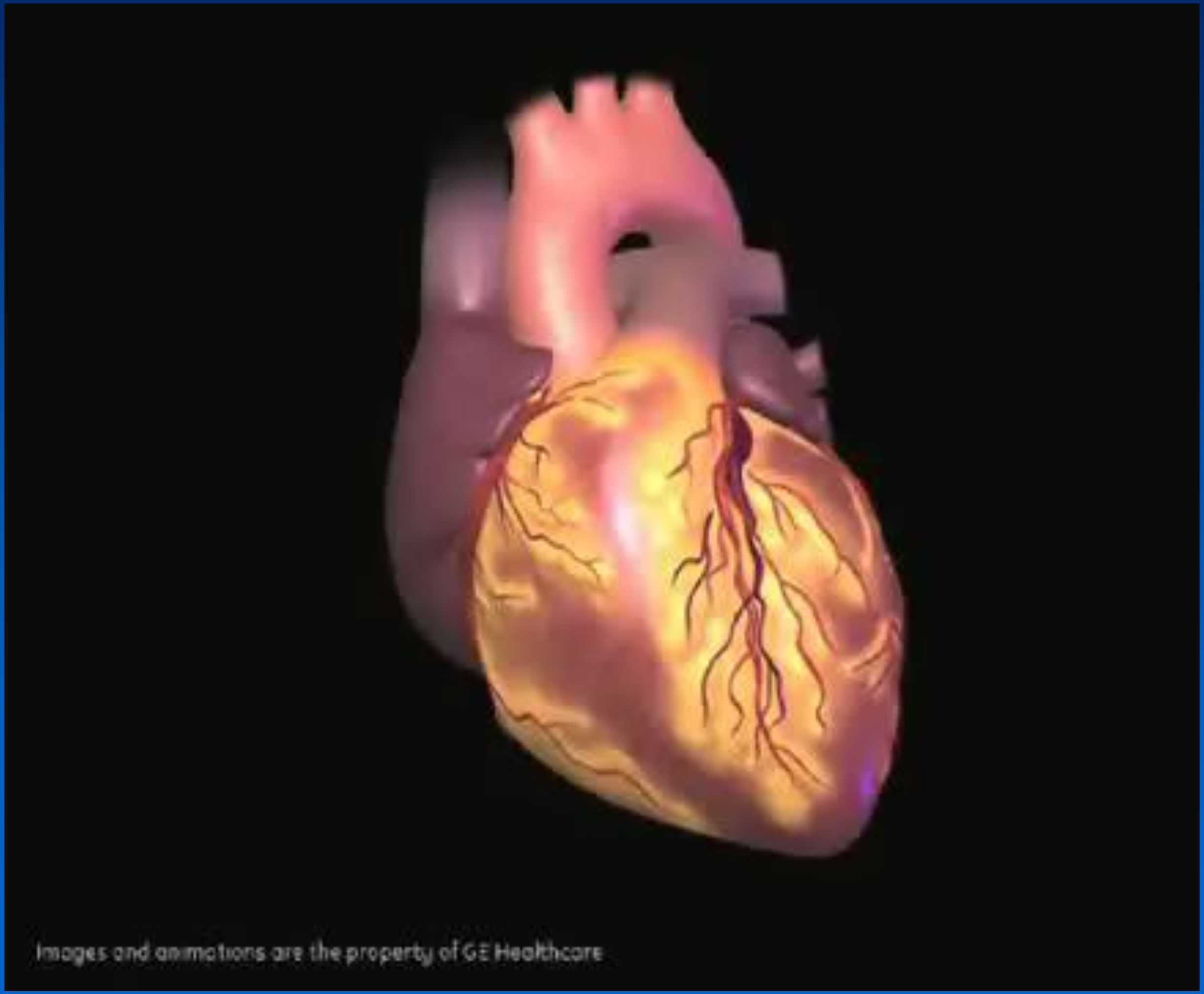
Technology

xSTREAM Architecture

- Super-computed processing
- Processes multiple data streams simultaneously
- Incorporates a processing environment capable of 250 billion operations per second



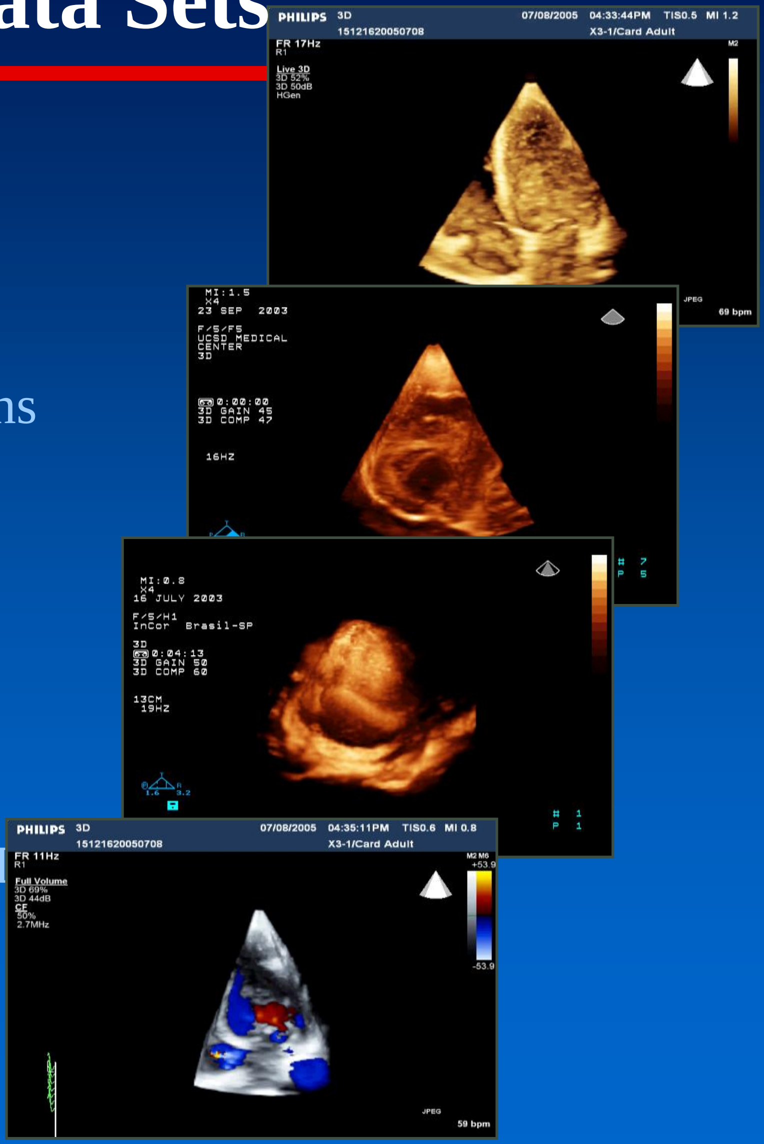
3-D Echo Acquisition



Live 3D Echo

Types of 3D Data Sets

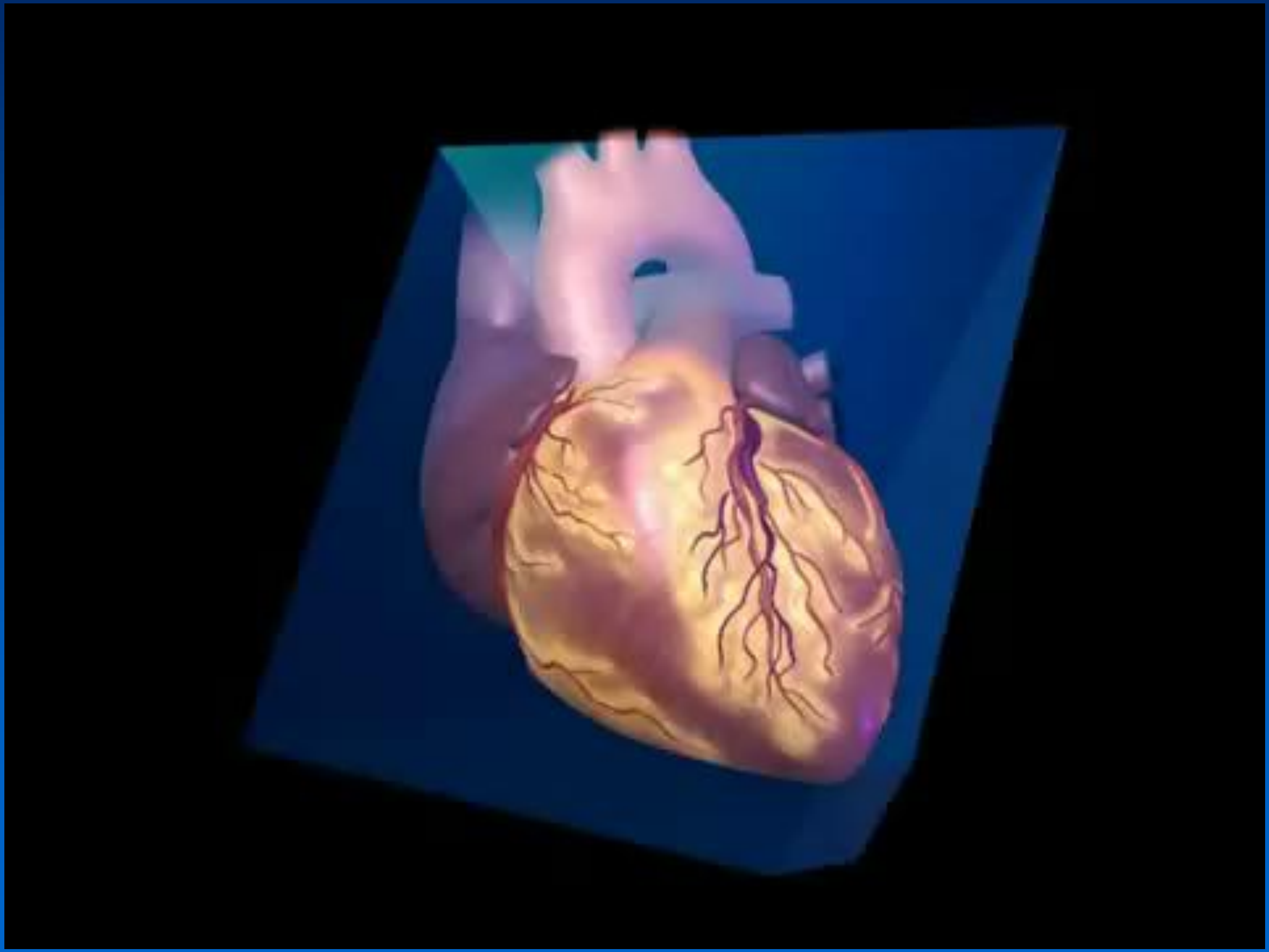
- Live 3D
  - ▸ A real-time mode allowing immediate acquisition and visualization in 3D
- 3D Zoom
  - ▸ A real time mode used for specific regions of the heart
- Full Volume (FV)
- Color Full Volume (FV)
  - ▸ Fast triggered mode to acquire high resolution anatomic structures in larger volumes
  - ▸ FV mode acquires high resolution color flow of hemodynamic patterns/shapes in 3D



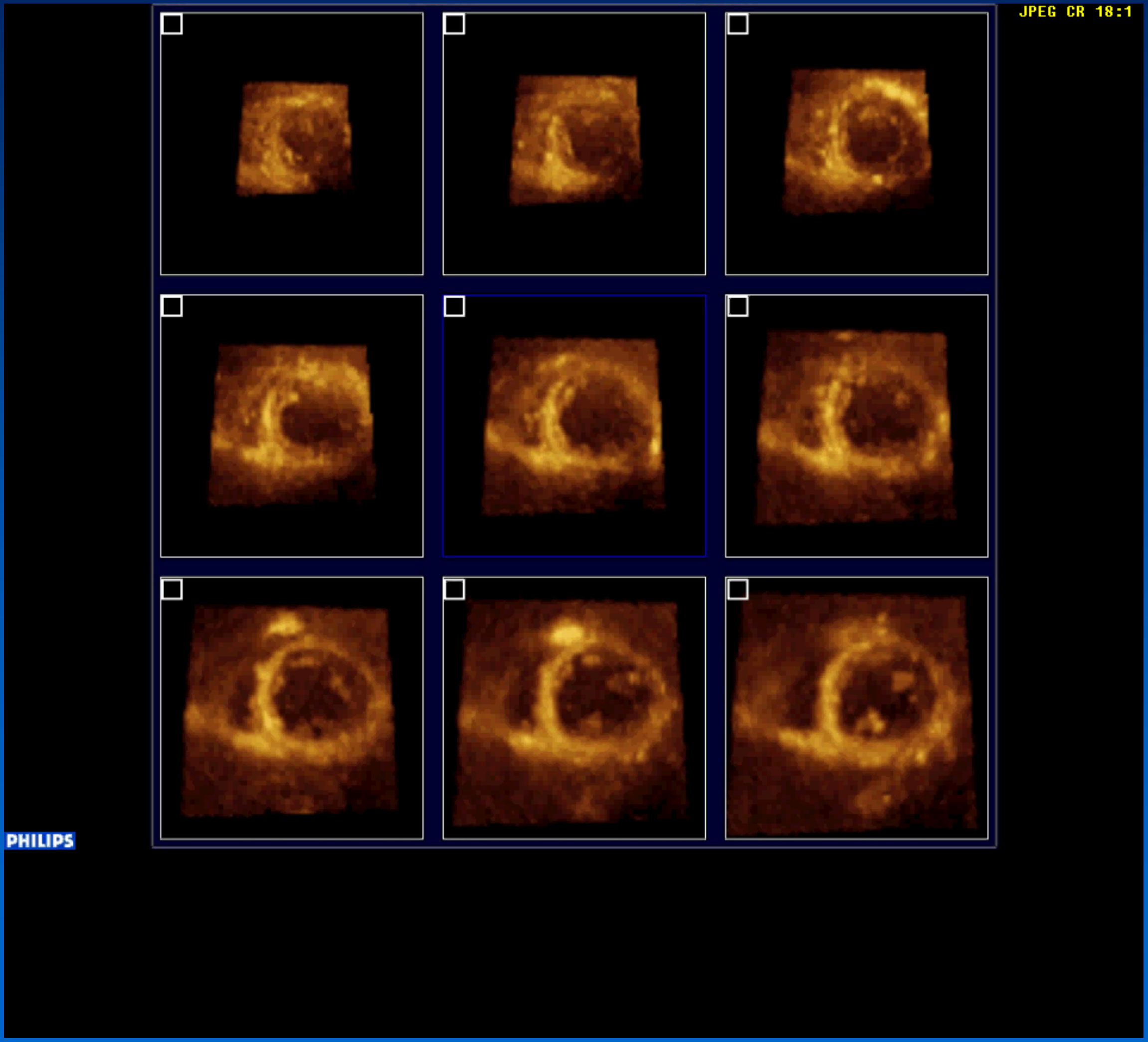
Current Applications

- Ejection fraction calculation
  - Prior M-mode/2-D techniques make assumptions
  - Accurate for both LV and RV measurements
  - Reproducible
- LV Mass
  - Risk stratification
  - Treatment response
  - Significance of valvular lesions

LV Volume Movie



i Slice for CAD



i Slice for CAD

Current Applications

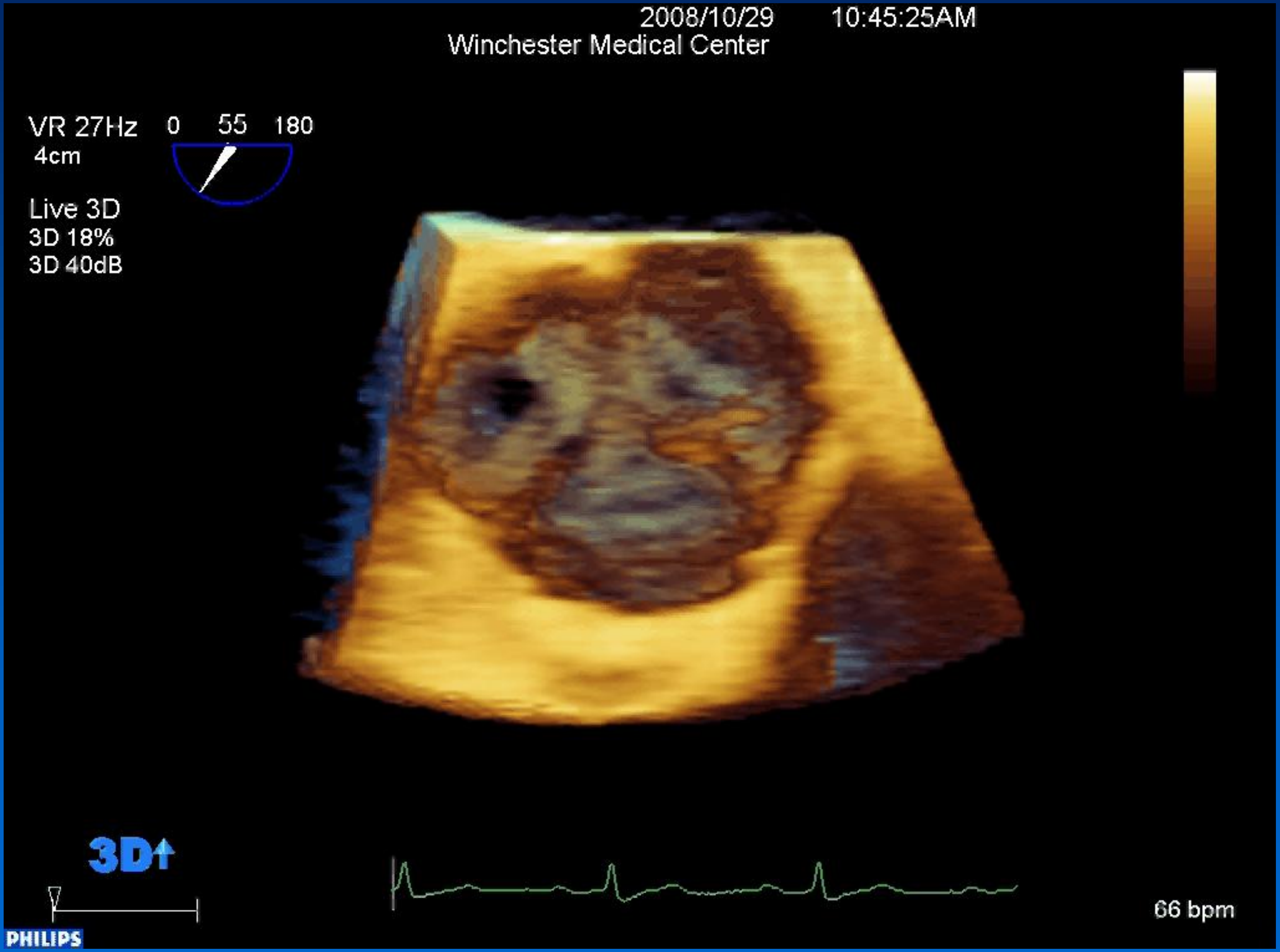
Valvular Heart Disease

- Mitral Valve
  - Mitral valve prolapse
  - Mitral stenosis
  - Mitral regurgitation
    - Ischemic v dilated
  - Endocarditis
  - Prosthetic valve function
    - Pre and post valve surgery

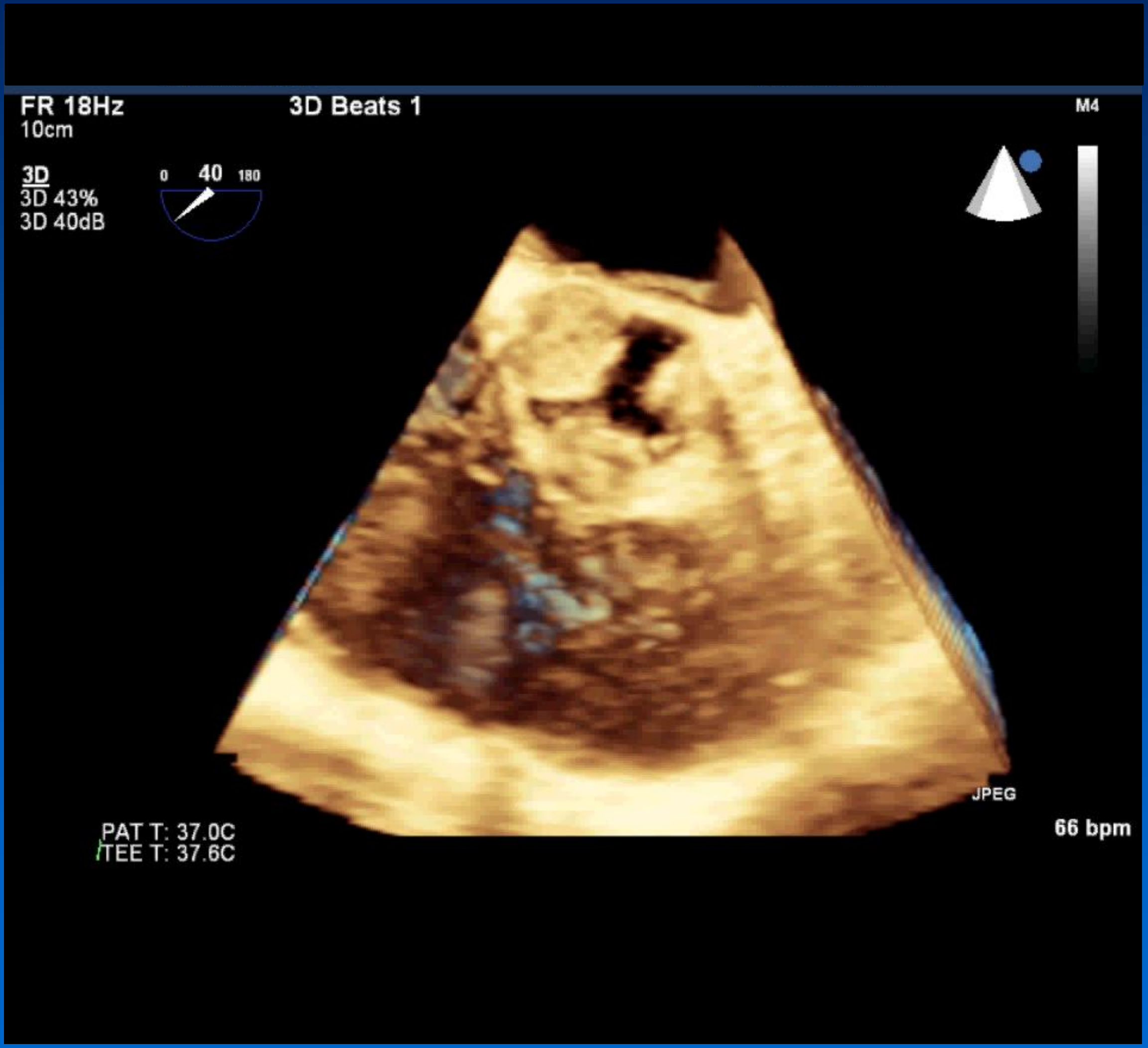
- Aortic Valve
  - Aortic regurgitation
  - Endocarditis
  - Bicuspid AV

- Tricuspid/Pulmonary Valves

Aortic Valve Vegetation



Aortic Valve Perforation



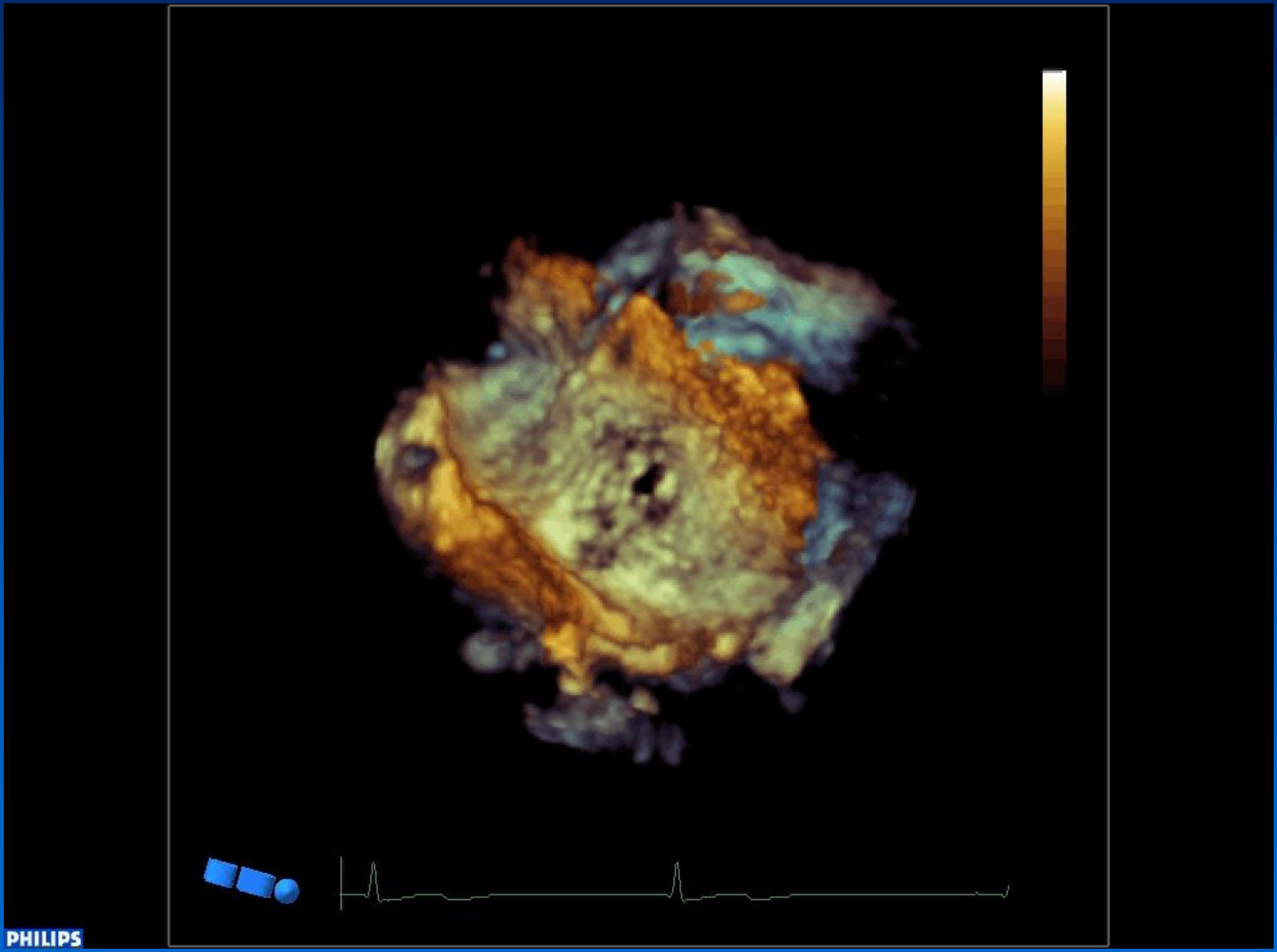
Example Valve Cases

Current Applications

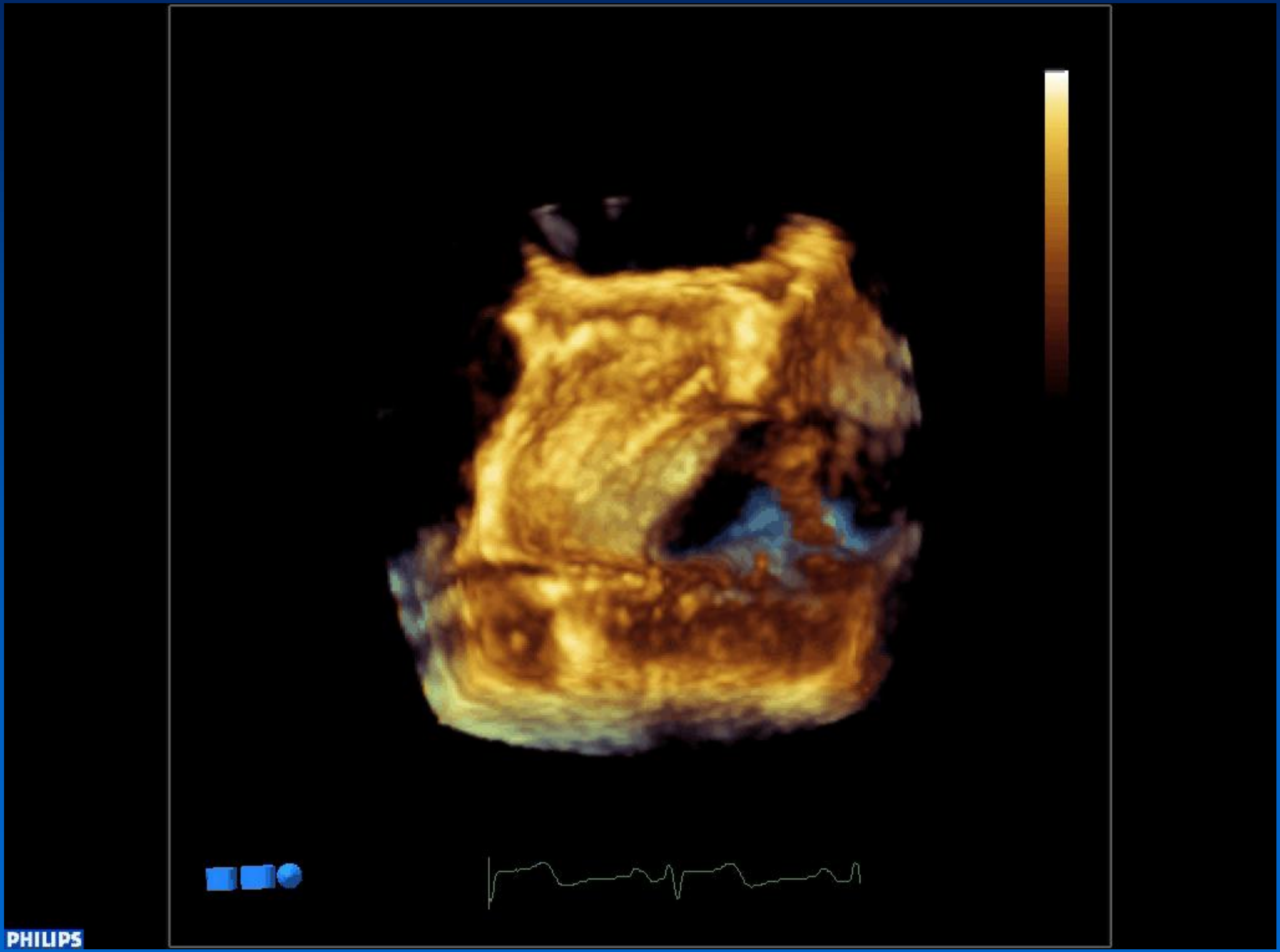
Congenital Heart Disease

- Atrial septal defects
  - Size and shape
  - Rim tissue assessment
- A-V septal defects
- Associated congenital defects
- Complex congenital defects (pediatrics)

Atrial Septal Defect



Sinus Venous Defect

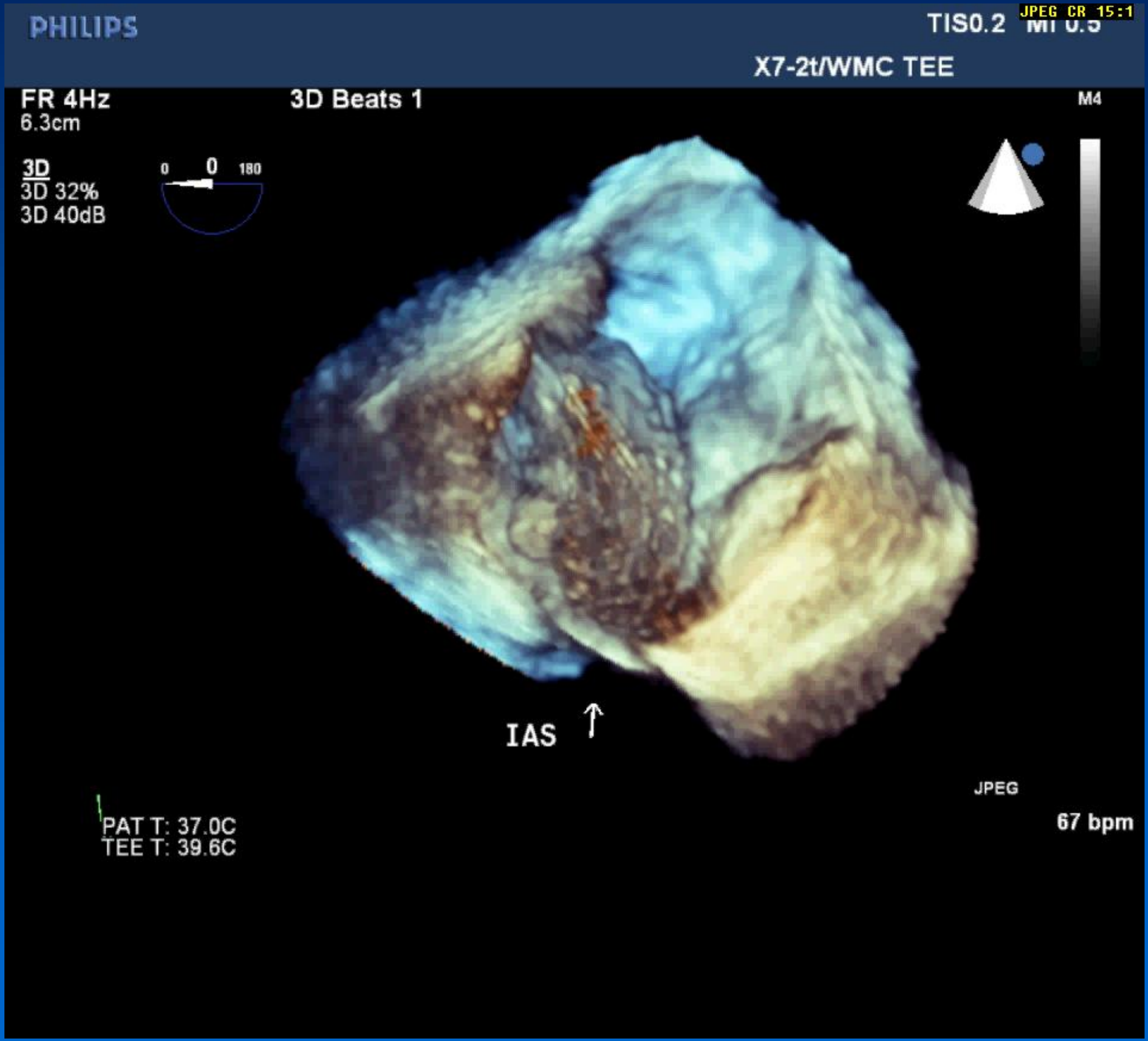


Current Applications

Cardiac Masses

- Assessment of size
- Tissue characterization
  - Smooth v irregular
  - Circular v irregular
- Attachment site
- Involvement of adjacent structures

Myxoma



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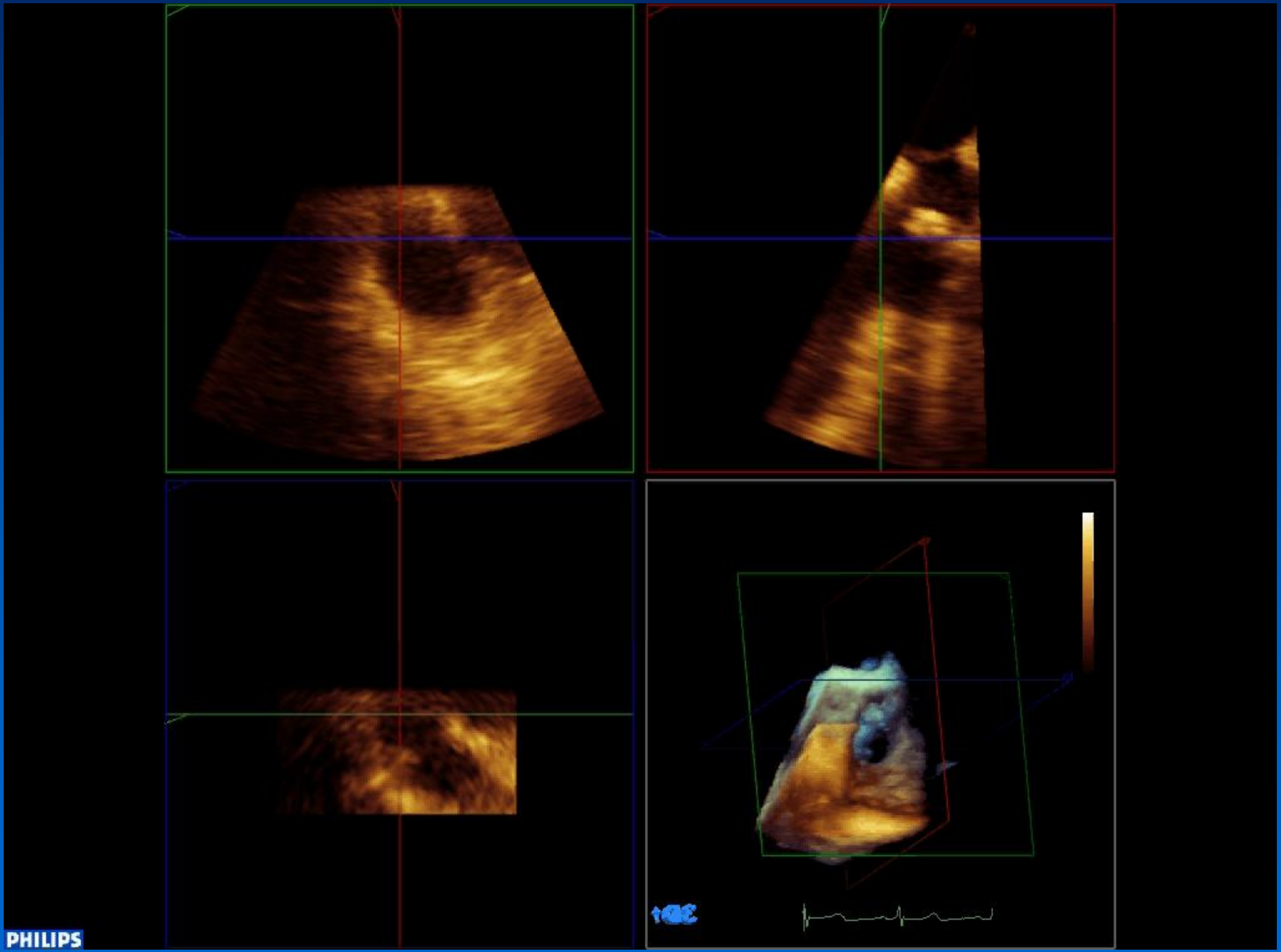
TIS0.2 MI 0.5
JPEG CR 15:1
X7-2t/WMC TEE
FR 4Hz
6.3cm
3D Beats 1
M4
3D
3D 32%
3D 40dB
0
0
180
IAS
JPEG
67 bpm
PAT T: 37.0C
TEE T: 39.6C

Right Atrial Mass

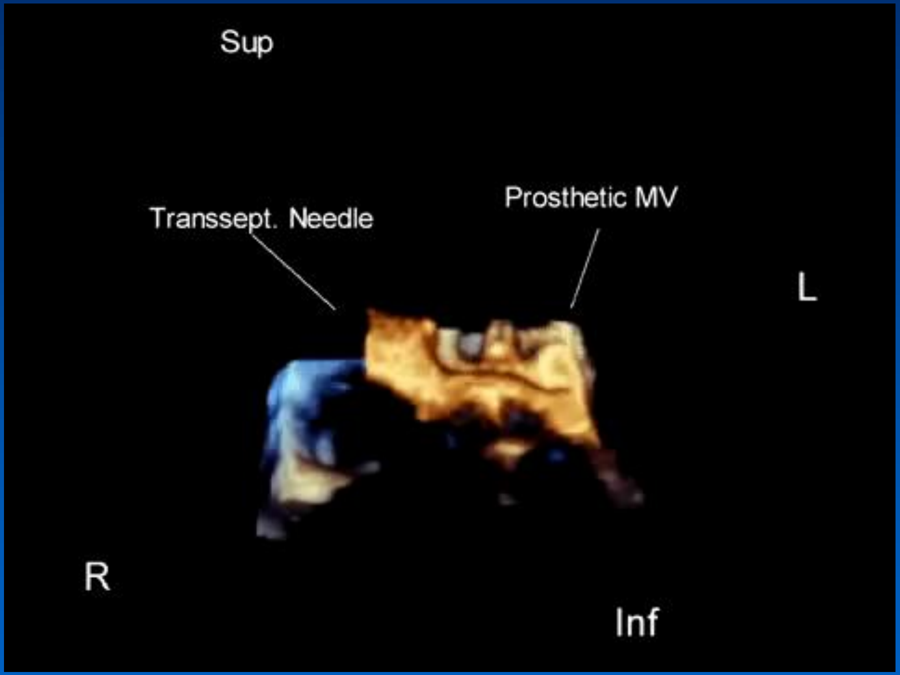
Right Atrial Mass

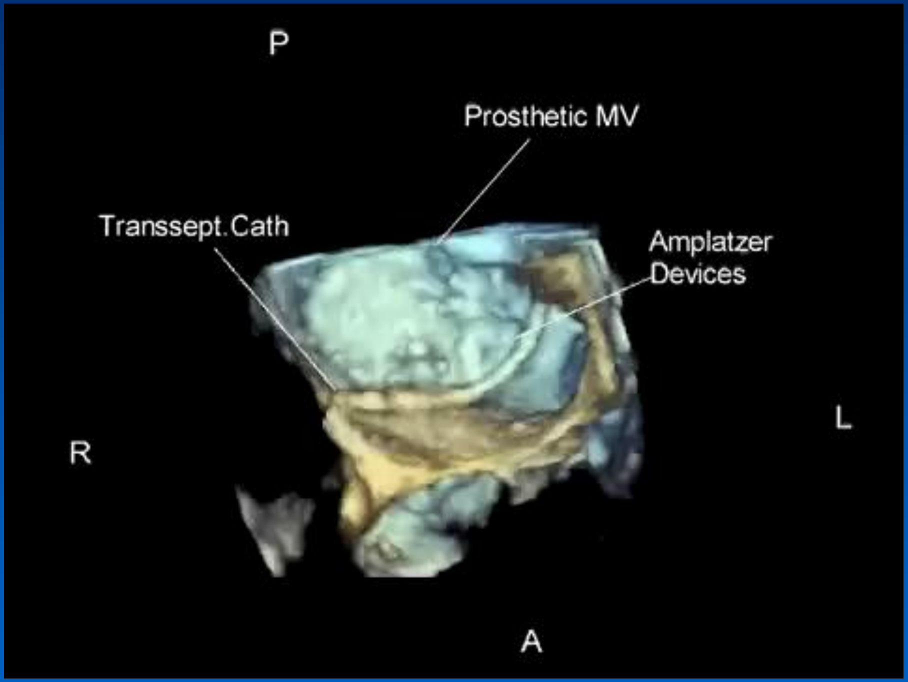


Echo Therapeutics

- ASD closure device placement
  - Assess position
  - Assess success of closure
- Guidance for right ventricular biopsy
- Mitral valvuloplasty
  - Pre-assessment of balloon placement
  - Post-assessment of success

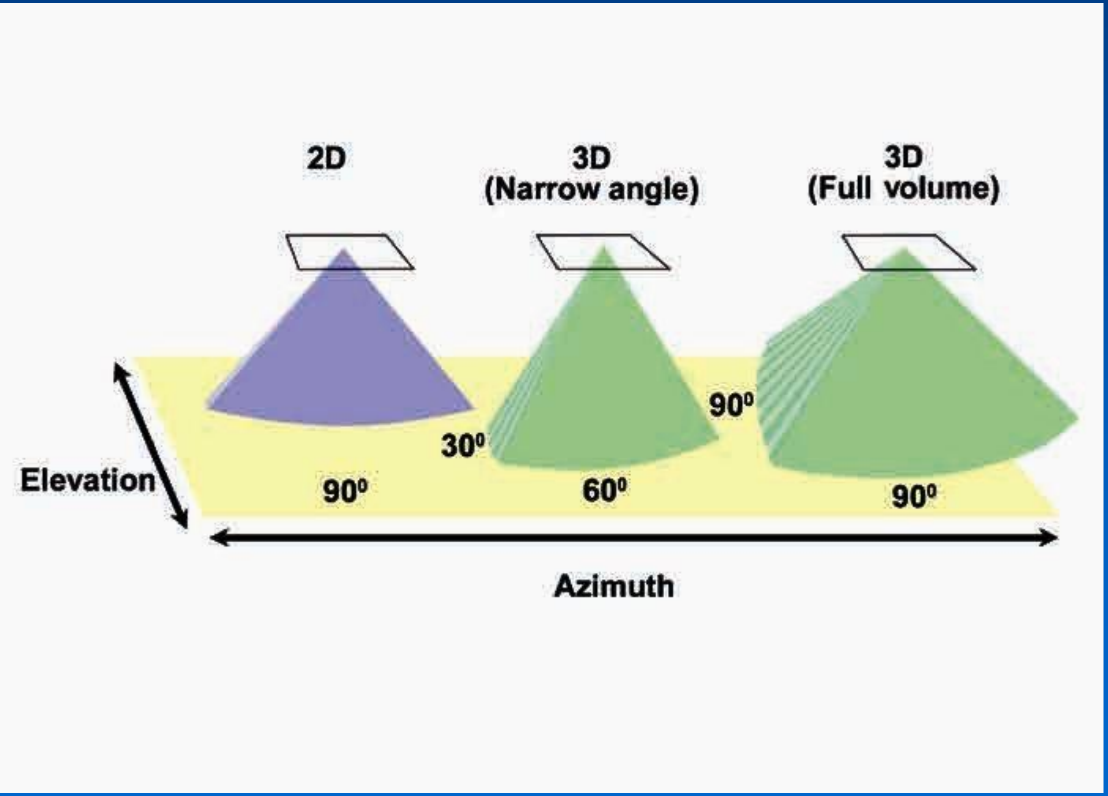
Trans-Septal Puncture





Live 3D Echo

- What 3D adds to the image



Comparison Study

Real-time 3-D Echo to Conventional 2-D

- 106 pts
- 2-D and 3-D echos
- Grading Scale

Grading Scale	#Cases
A: new findings	7 (7%)
B: additional info	19 (18%)
C: equivalent info	65 (61%)
D: missed findings	15 (14%)

Chan et al. J Am Soc Echocardiogr 2004;17:976-80.

Comparison Study

New Findings

- Depth of anterior mitral leaflet cleft
- Shape of ventricular septal defect
- Two pacer wires in venous ventricle
- Leaflet motion in a tissue prosthesis
- Improper tricuspid leaflet coaptation

Comparison Study

Additional Useful Information

- Visualization of myxomatous mitral valve
- Morphology of atrial septal defect
- Mass in left ventricular outflow tract
- Patency of main pulmonary artery
- Stenotic baffle in Mustard case
- Intra-atrial membrane location
- Ventricular septal patch dehiscence
- Location of epicardial fat in pericardial effusion
- Aortic valvular mass
- Aortic valvular morphology
- Mitral valvular mass
- Papillary muscle orientation
- Left ventricular wall-motion abnormality

Future Applications

Transcutaneous Therapy

- Atrial ablation
  - RA flutter ablation
  - Pulmonary vein isolation
- Cardiac resynchronization therapy (CRT)
- Delivery of gene therapy

Future Applications

Ischemic evaluation

- Stress echocardiography
  - Shorter acquisition time
  - Improved test sensitivity
  - Less respiratory artifact

Future Directions

- On-line analysis
  - Preset multiple 2-D slices from one 3-D data set
  - Wall motion analysis
- Transducer improvements
  - Smaller foot plate for better acoustic window
- Improved image resolution
- Larger image window
- Incorporation into 2-D exam

3-D Limitations

- Image acquisition
  - Larger footprint limits acoustic window
  - Heavy transducer
- Image processing
  - Still time consuming for in depth structural analysis
  - Standardization needed
- Image analysis
  - Cardiologists need more exposure

Questions?