3D Echo Introduction

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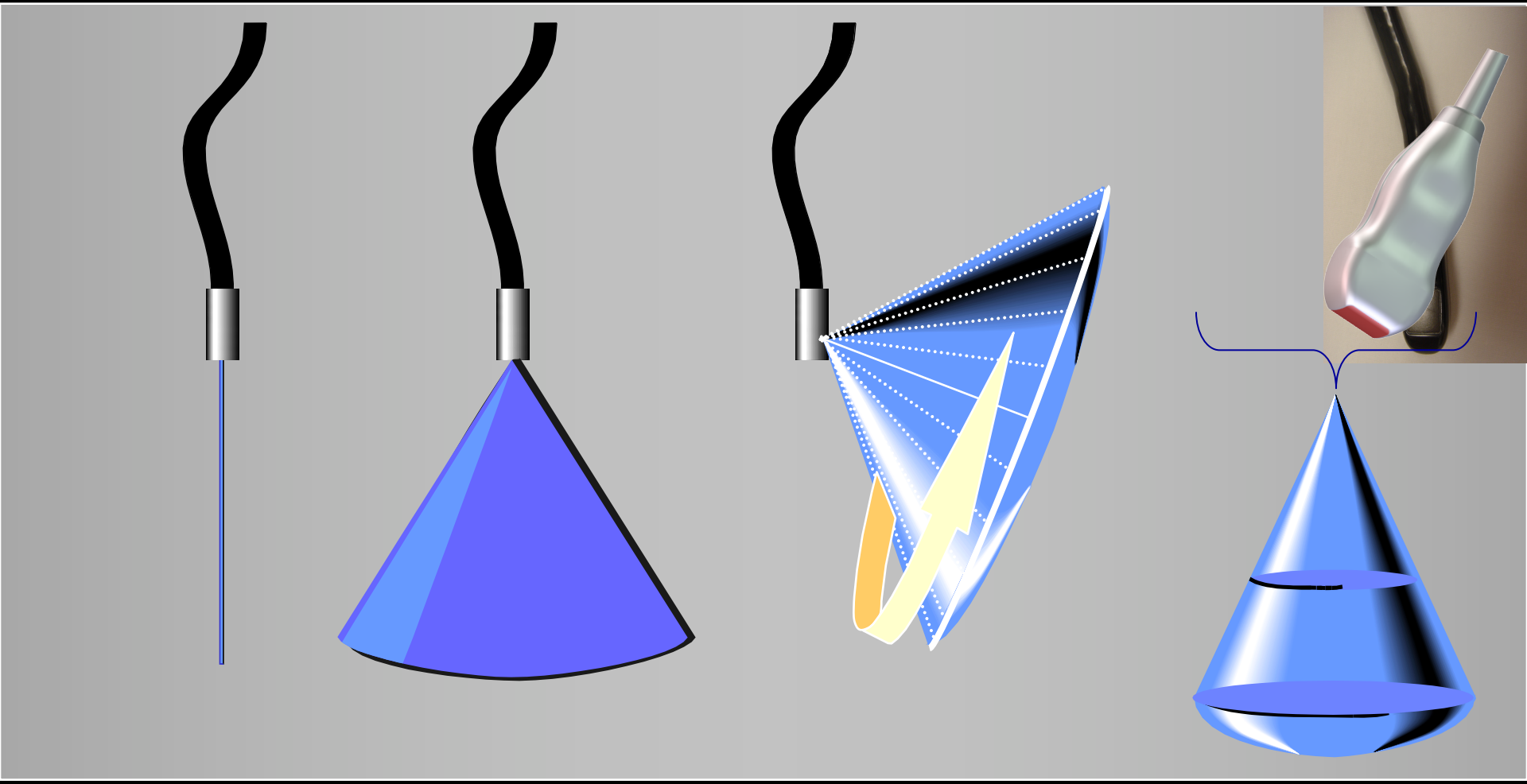
Toronto General Hospital – University Health Network

Outline

- Review developments in 3DE
- Acquisition modes and technological developments

Evolution of Echocardiography

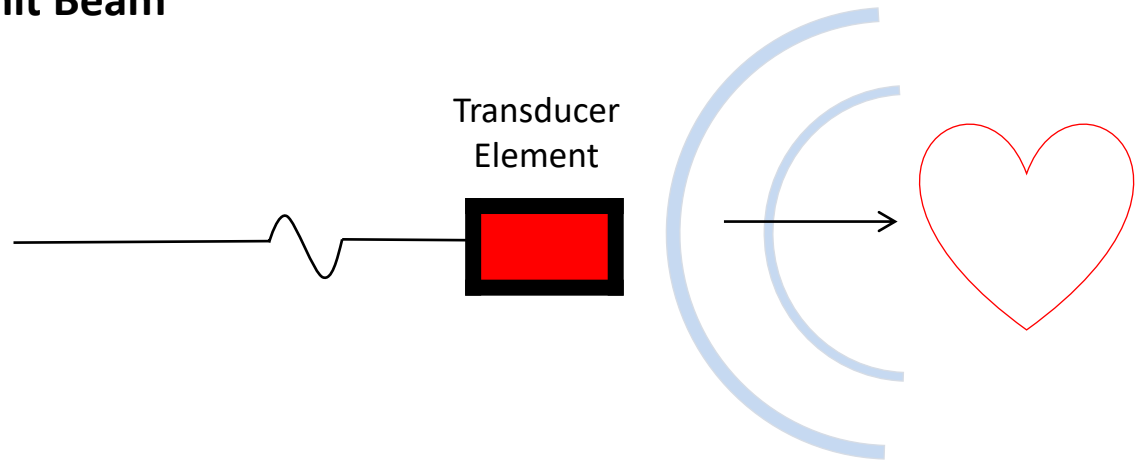


1D **2D** **3D**

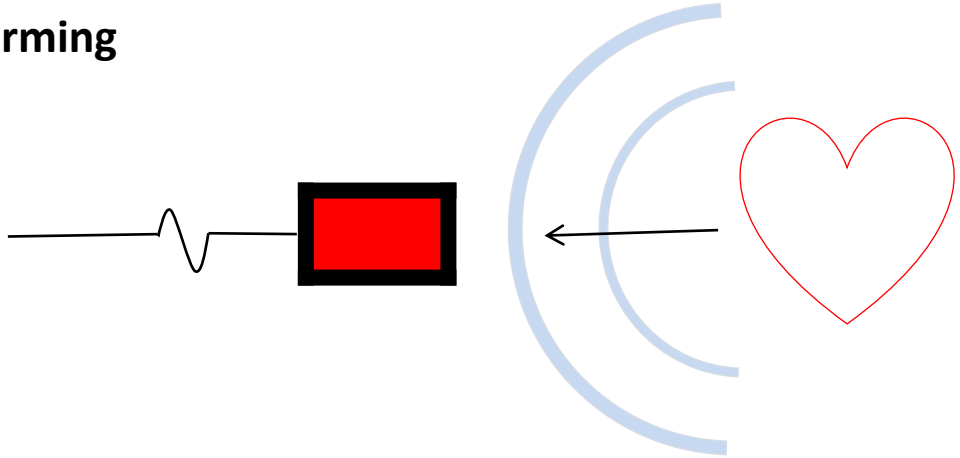
M-mode **Cut plane** **Reconstruction** **Real-time**

Basics of Ultrasound

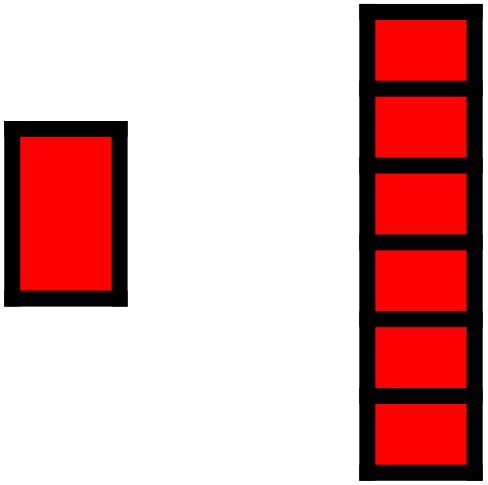
Transmit Beam



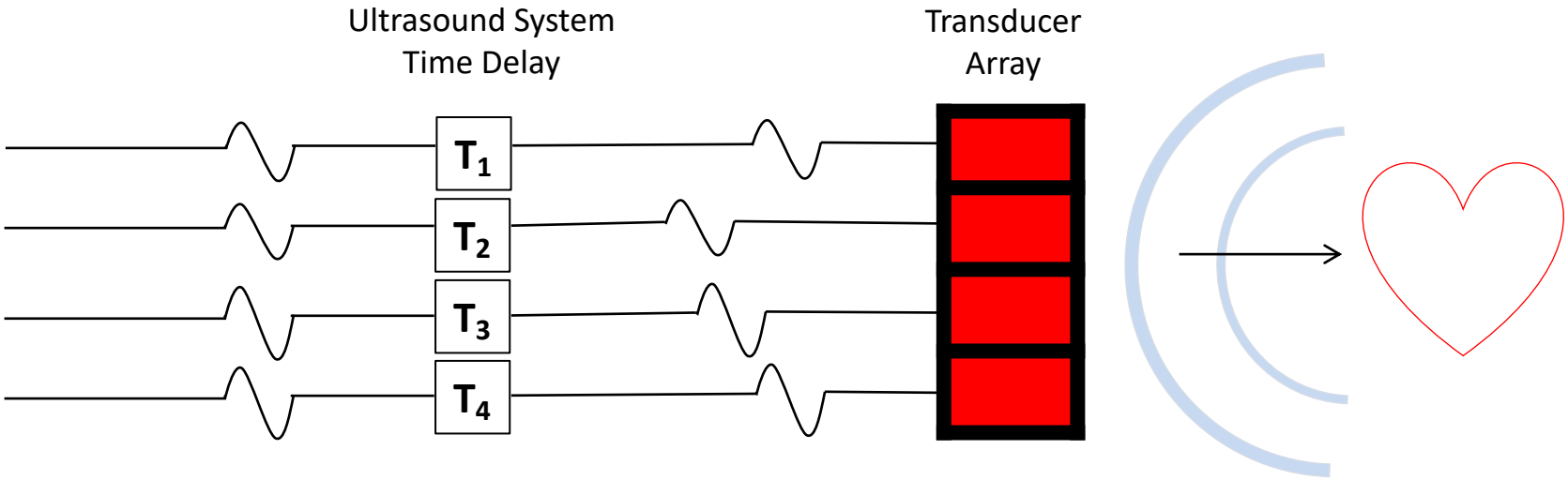
Receive Beamforming



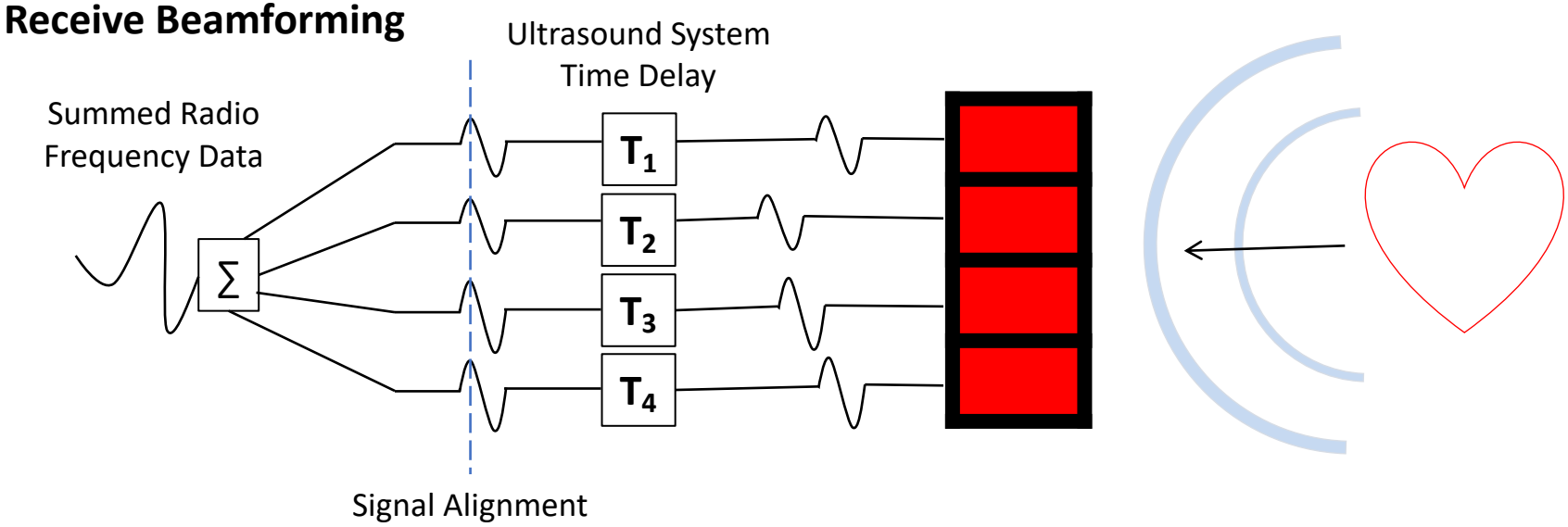
Transducers



Transmit Beamforming

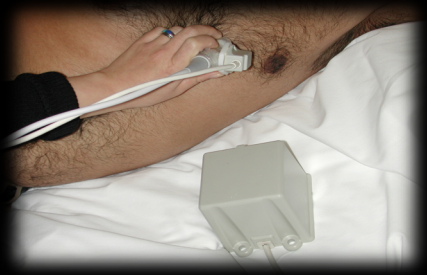


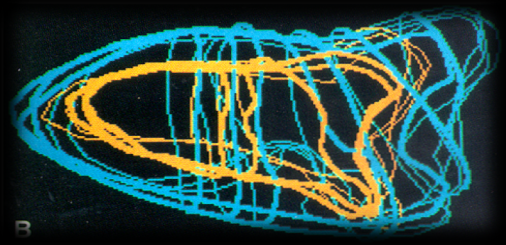
Receive Beamforming



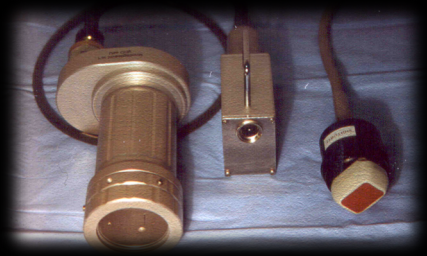
Reconstructive Methods

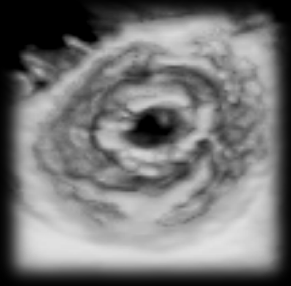
Spatial locators



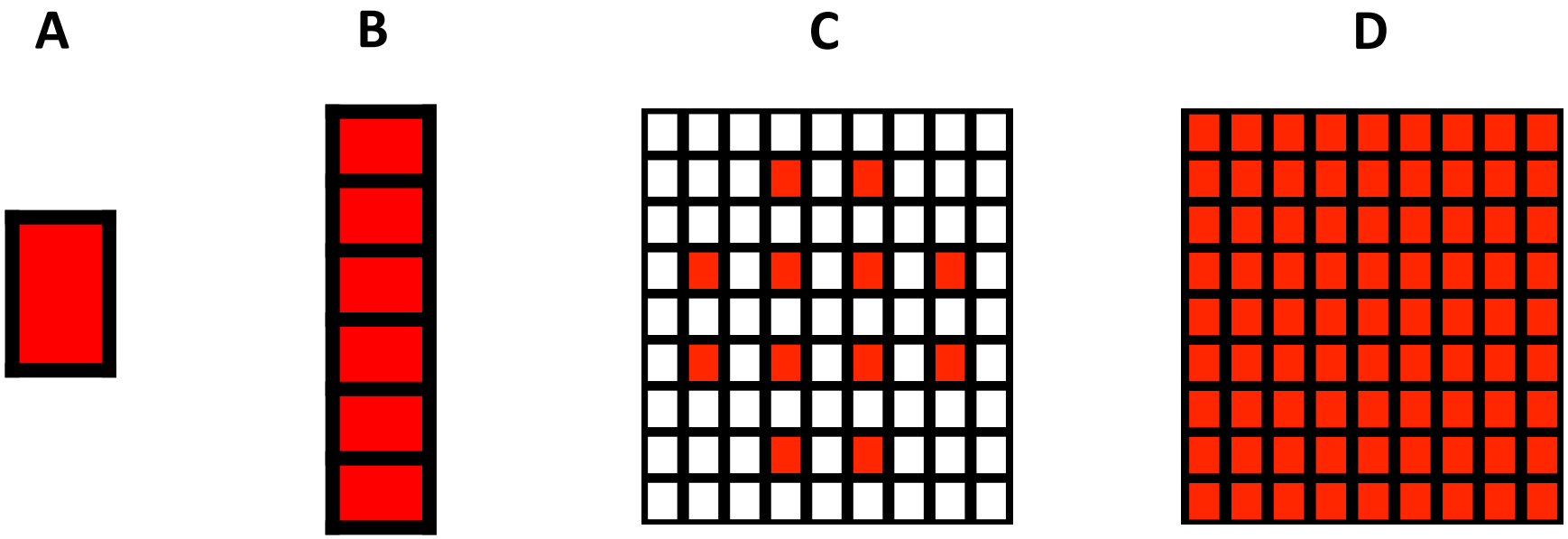


Mechanically driven transducers



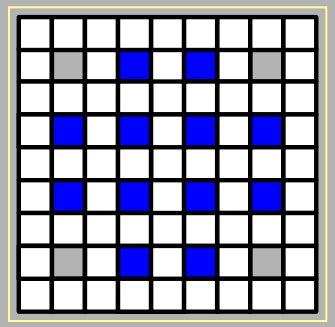


Transducers

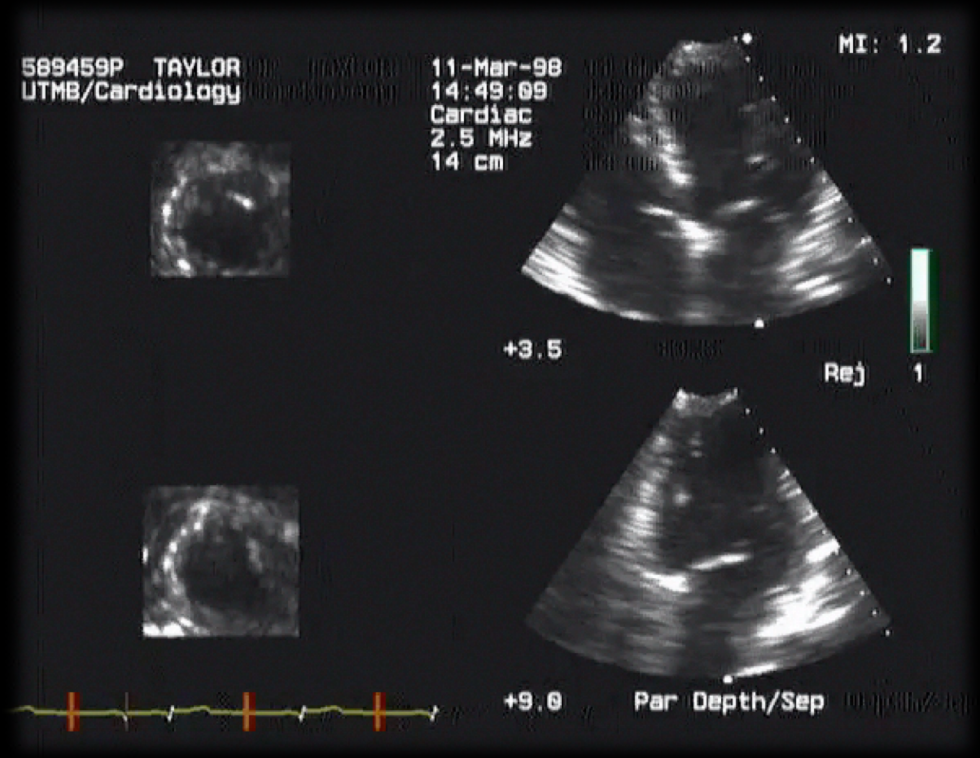


Sparse Array Transducer

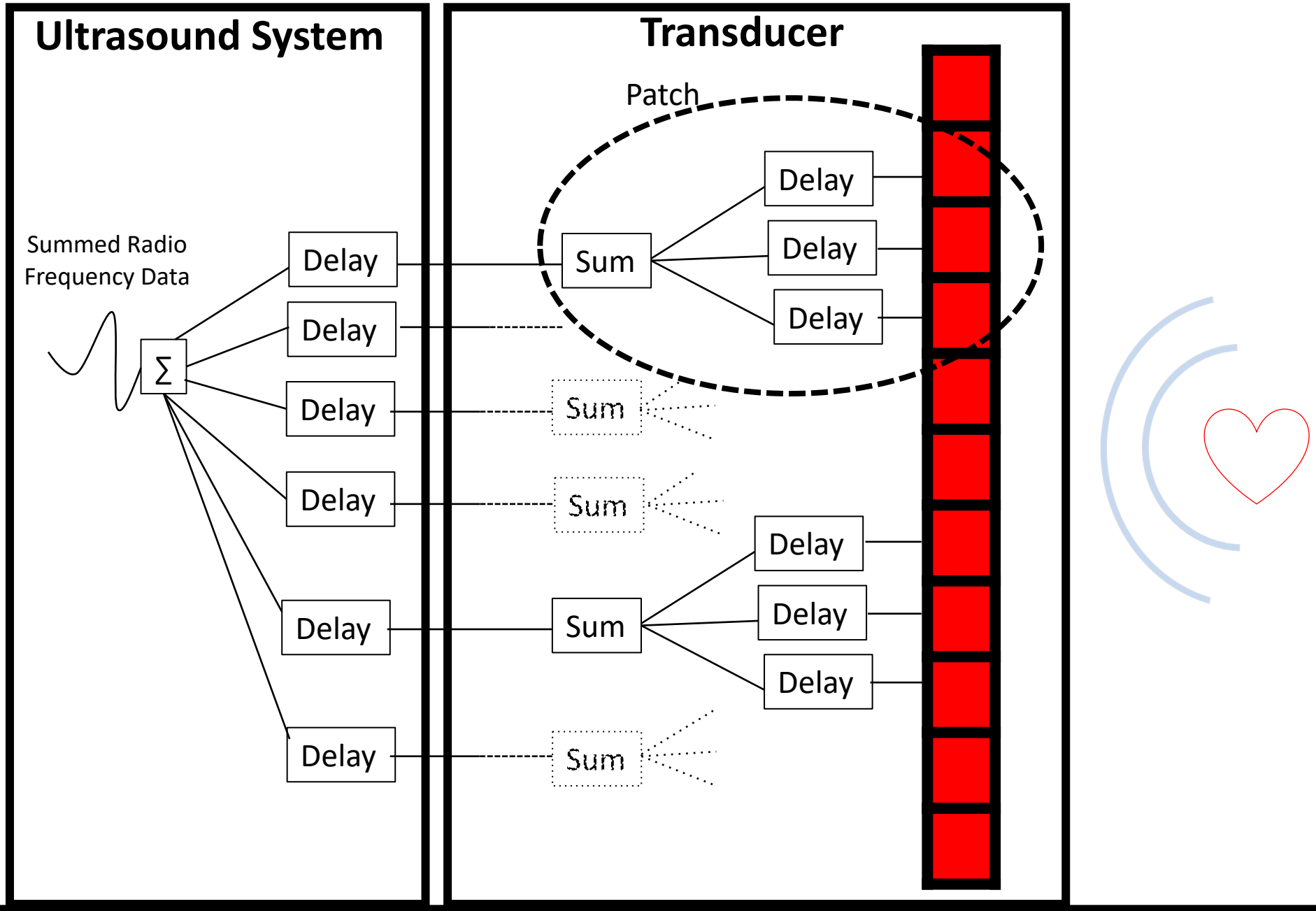
Sparse Array (~300 elements)



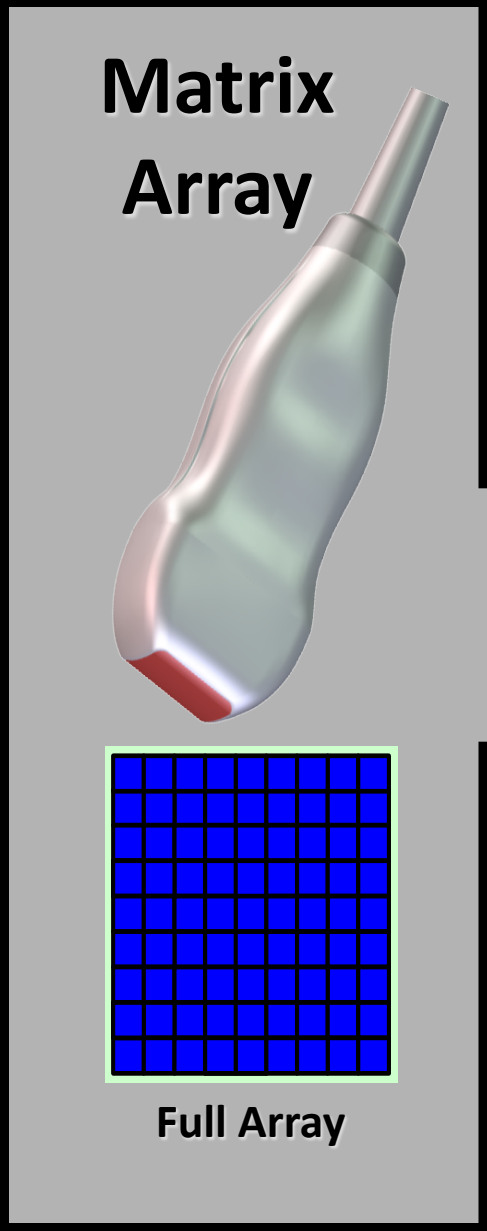
1997-2003

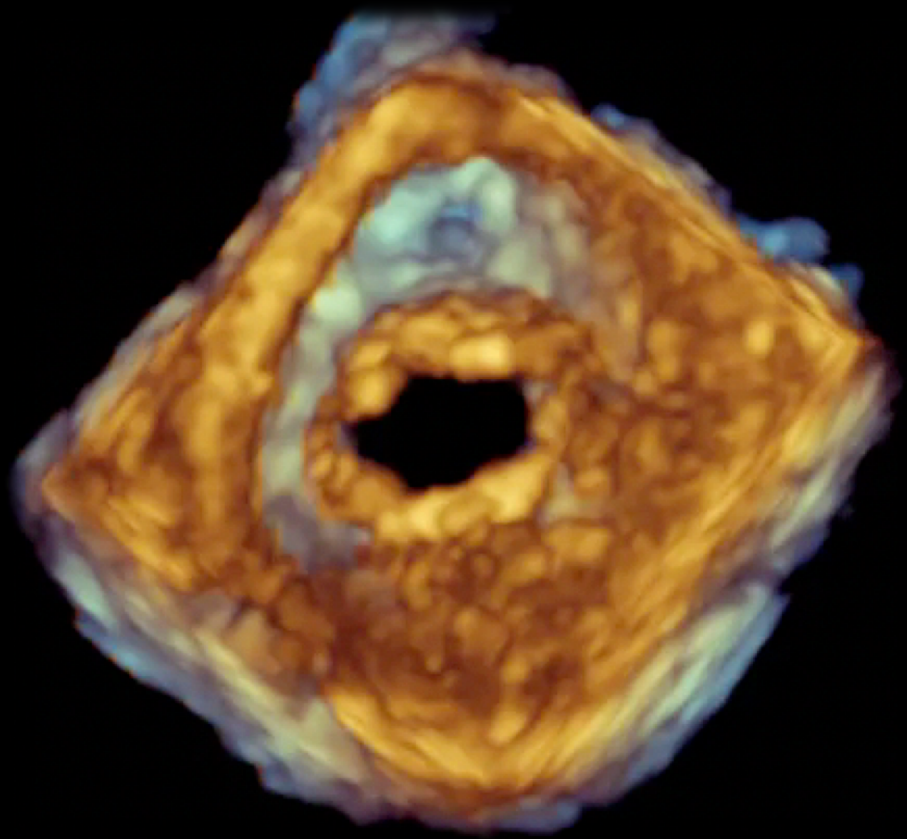


Courtesy Massod Ahmad

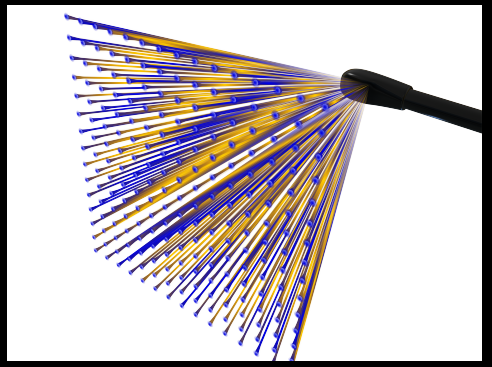

Ultrasound System
Transducer
Patch
Summed Radio Frequency Data
Σ
Delay
Delay
Delay
Delay
Delay
Delay
Sum
Sum
Sum
Sum
Delay
Delay
Delay
Delay
Delay
Delay

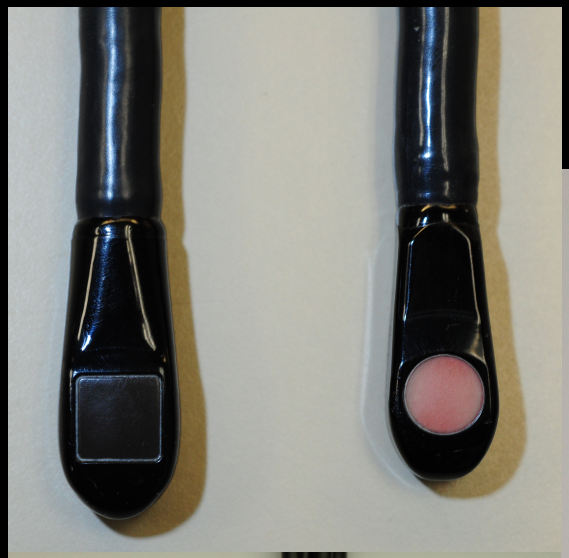
Matrix Array Transducer 2002



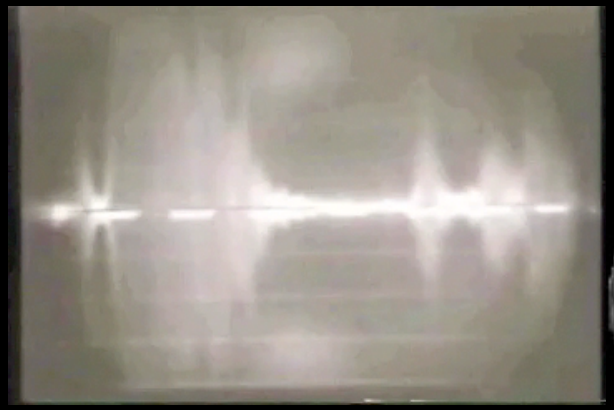


3D TEE 3D TEE Probes



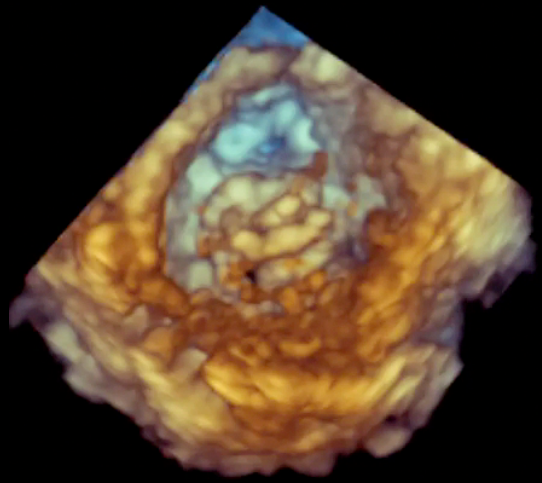


Evolution of 3D Echocardiography

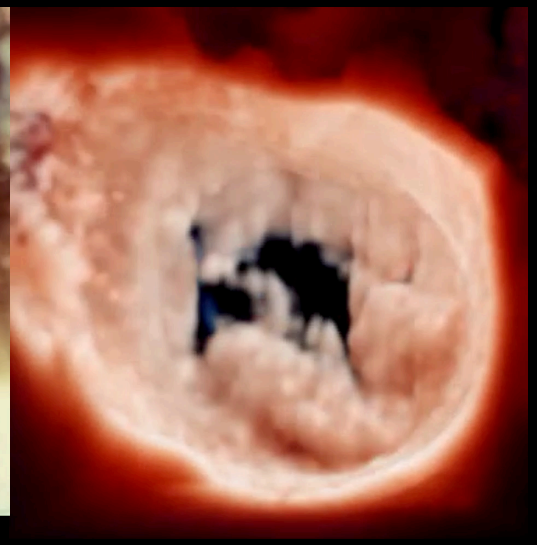


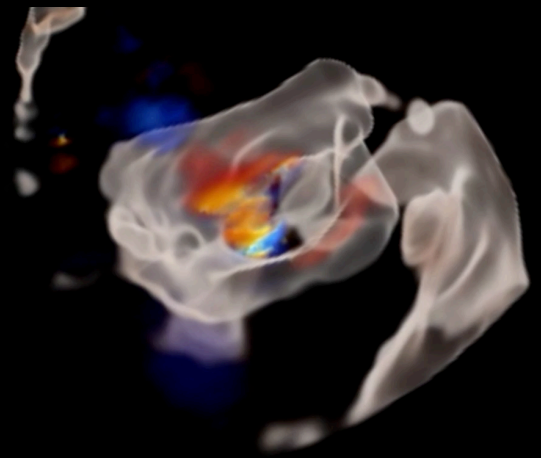
MV 1953

TEE 2003



TTE 2012





TEE 2019

ASE American Society of Echocardiography
Heart & Circulation Ultrasound Specialists

GUIDELINES AND STANDARDS

EAE/ASE Recommendations for Image Acquisition and Display Using Three-Dimensional Echocardiography

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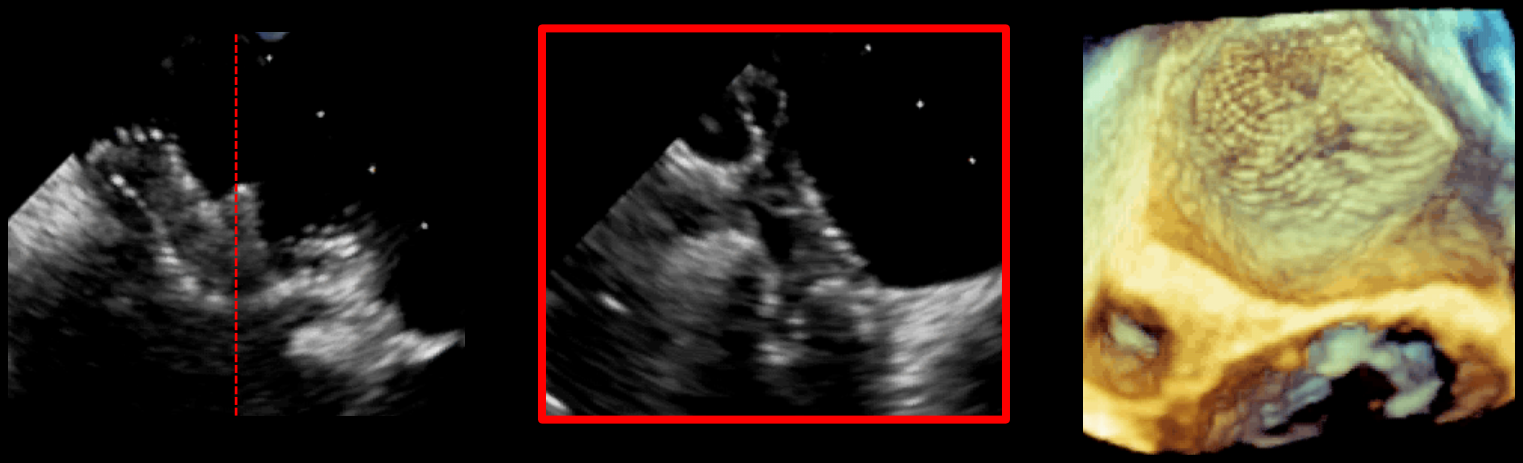
(J Am Soc Echocardiogr 2012;25:3-46.)

Bi- or Multi-plane Imaging is a 3D Mode



1. Image Optimization

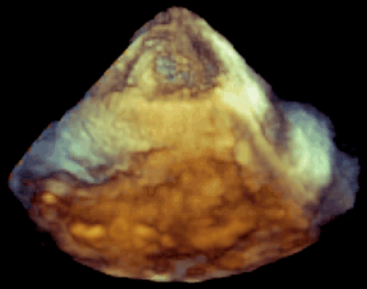
2. Acquisition Modes

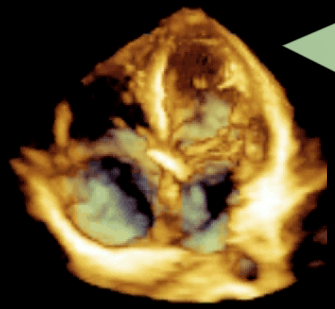
Spatial vs temporal resolution
Gating artifacts

- Zoom
- Narrow volume
- Wide volume
- Single beat
- Multi-beat
- Color Doppler

3. Rendering

- Cropping
- Thresholds

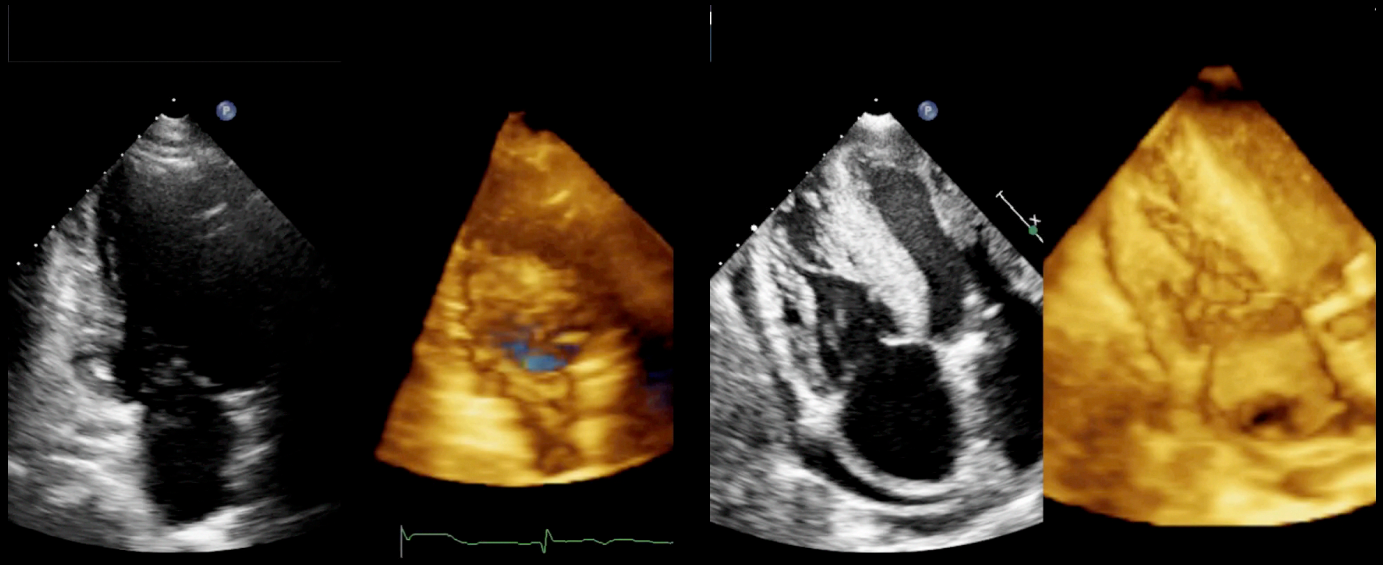




4. Final Image Display + Analysis

Acquisition: 2D Image Quality

- Before 3DE acquisition, the 2D image should be optimized
  - Poor 2D images, poor 3D images



Acquisition: Image Optimization Multiplane Viewing

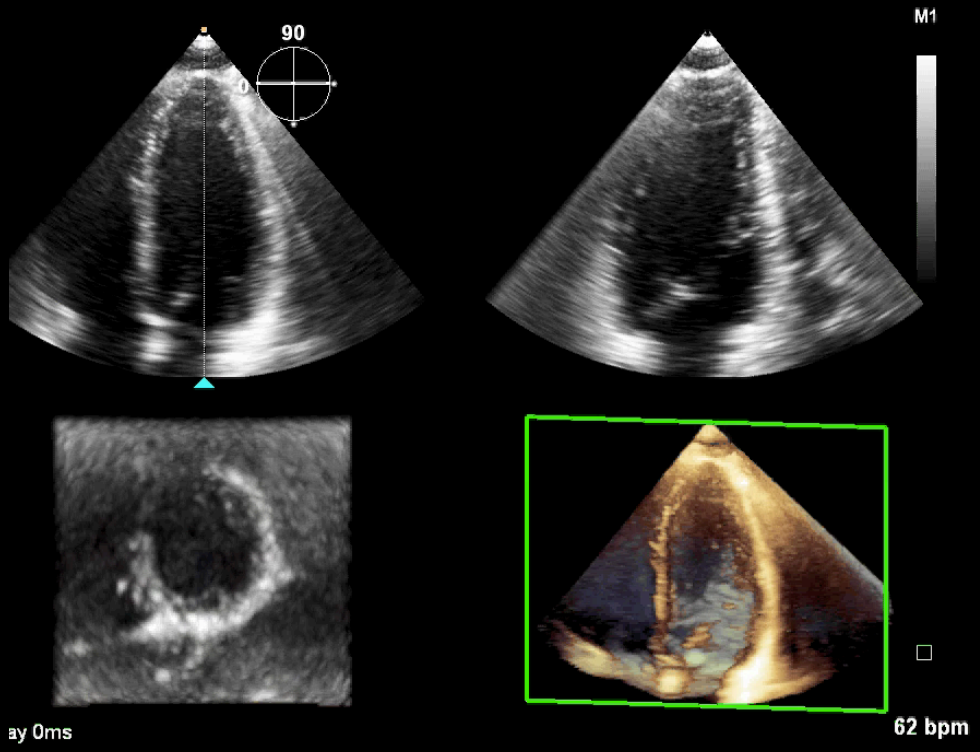


Image Resolution

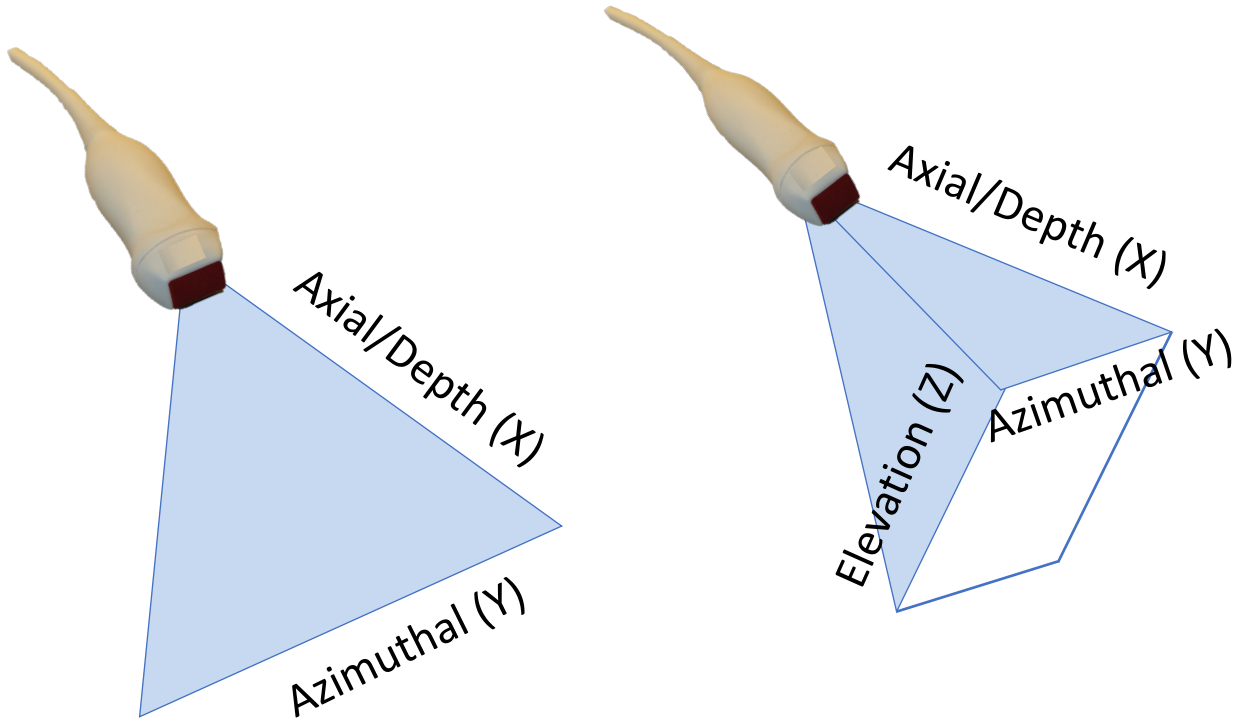
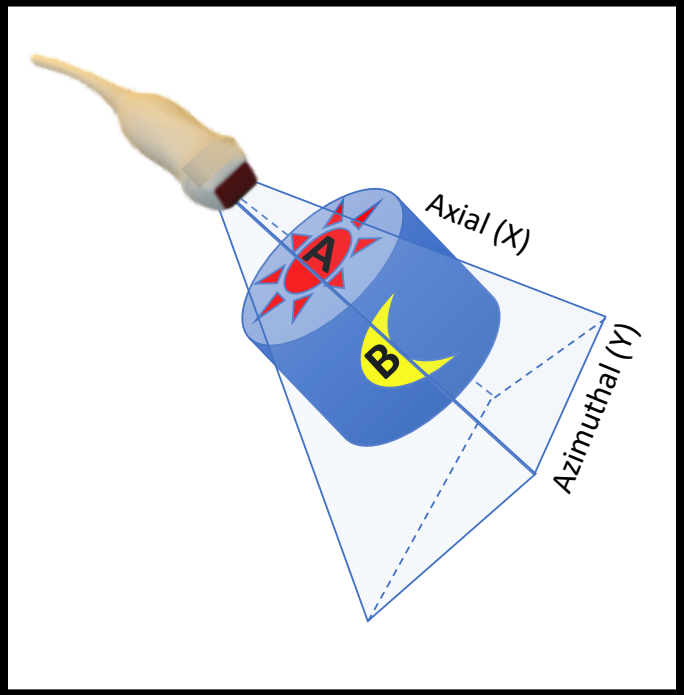
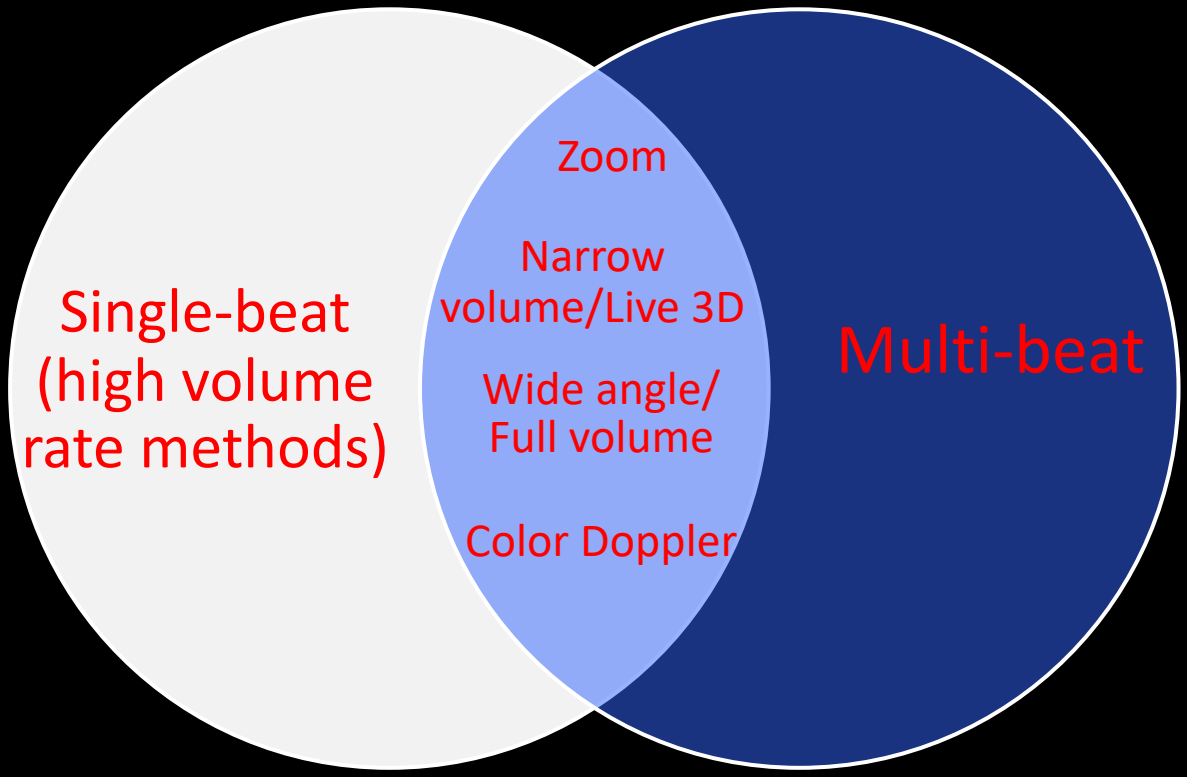


Image perpendicular to the beam for the best image

Image Quality

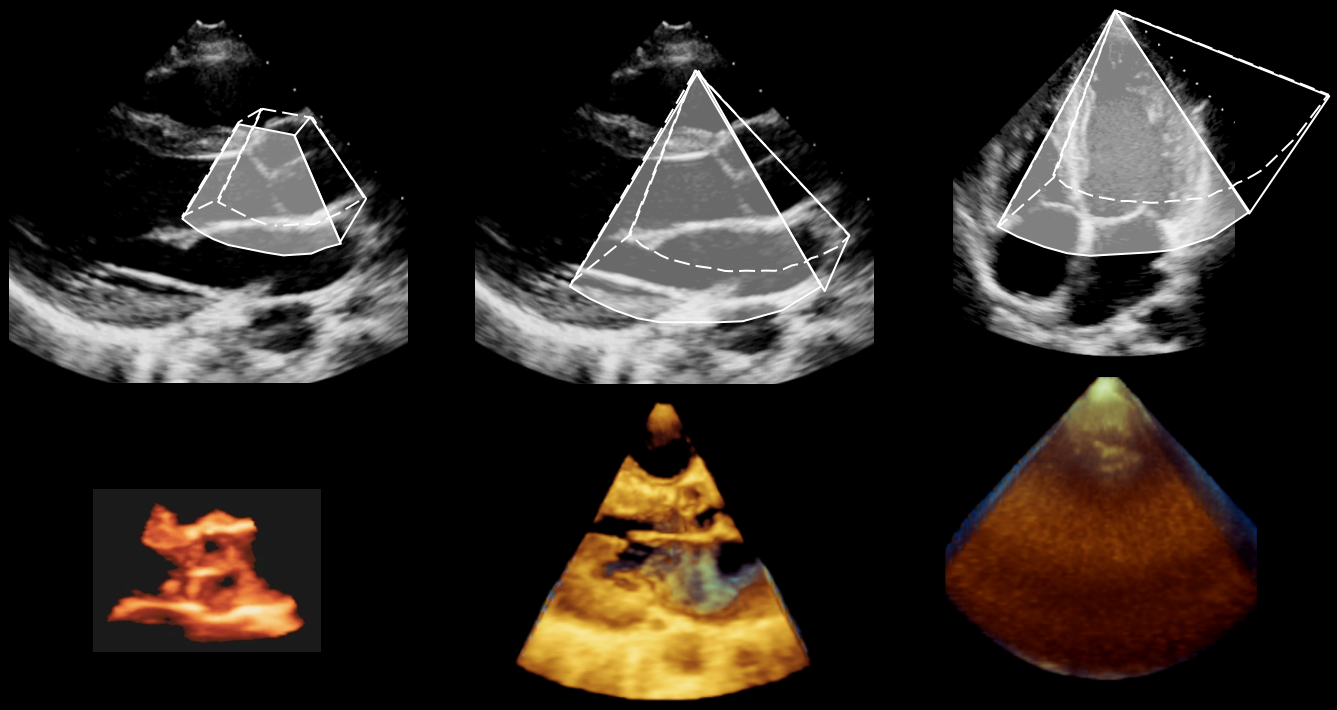


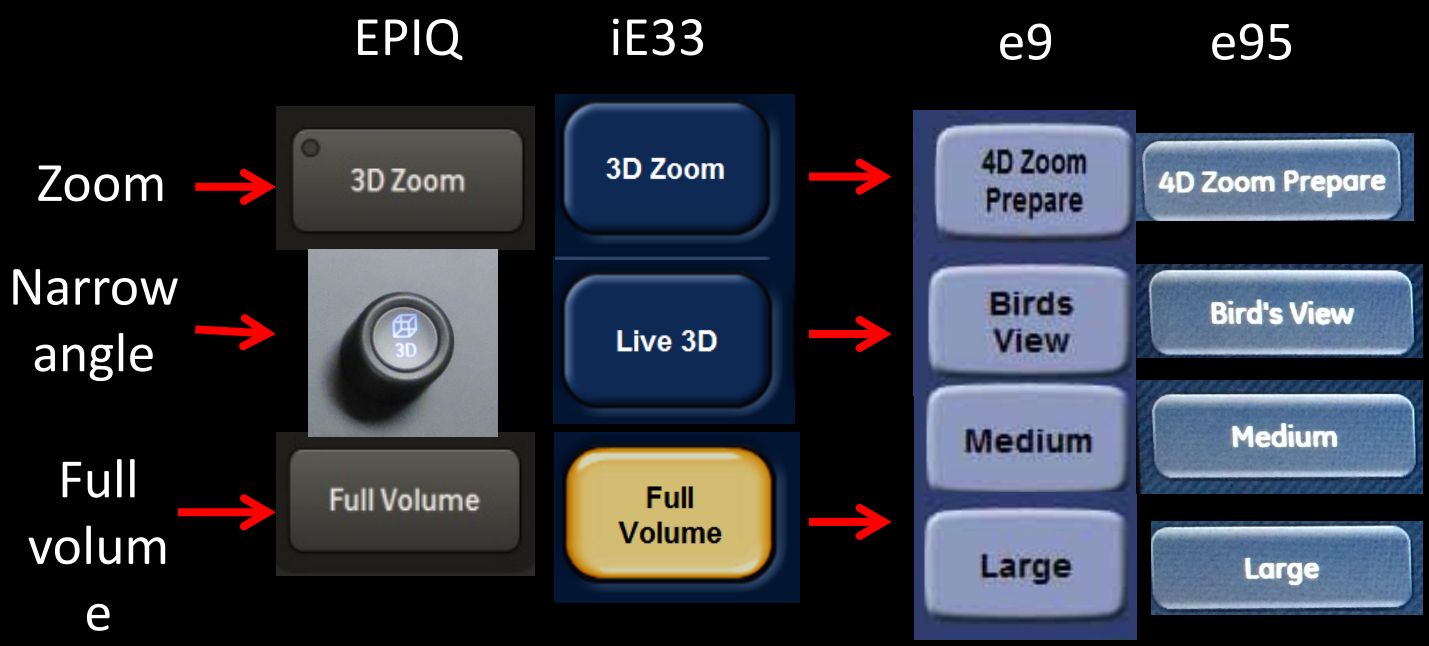
Modes of Acquisition



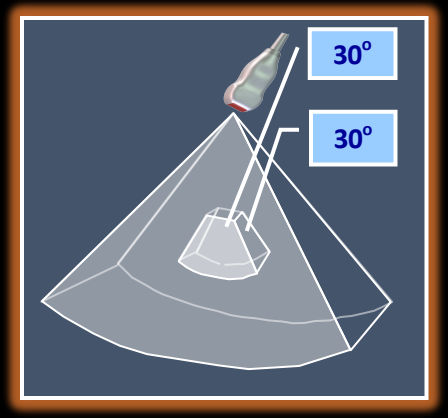
Select Acquisition Mode

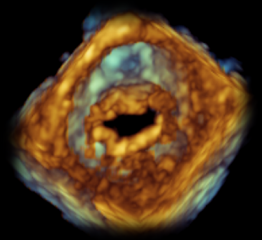
Zoom ⟷ Narrow Sector (Live) ⟷ Wide Sector (Full Volume)

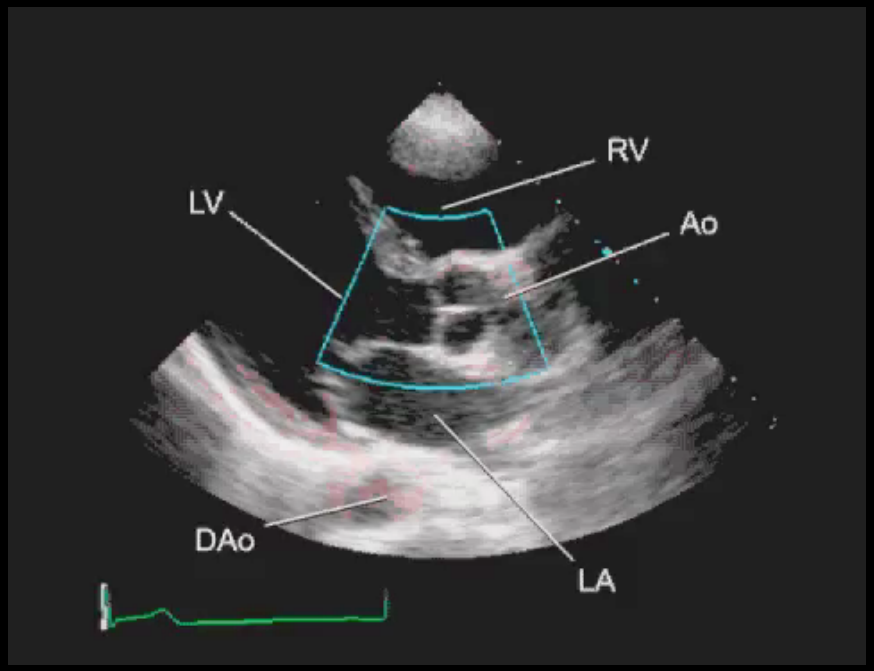



EPIQ
iE33
e9
e95
Zoom
Narrow angle
Full volume
3D Zoom
3D
Full Volume
3D Zoom
Live 3D
Full Volume
4D Zoom Prepare
Birds View
Medium
Large
4D Zoom Prepare
Bird's View
Medium
Large

Zoom Mode

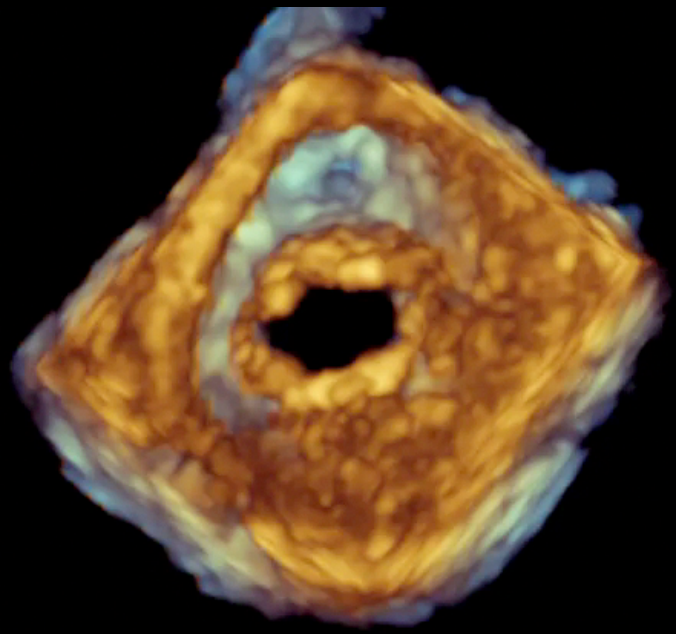




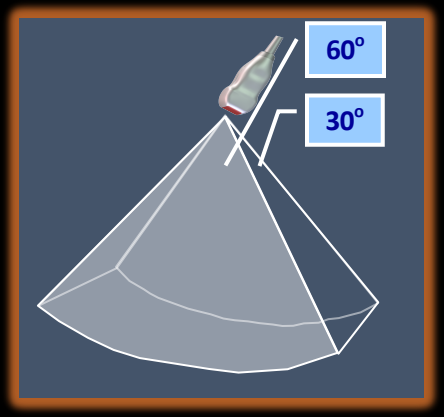


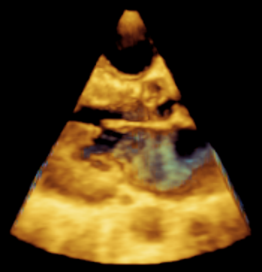
Zoom Mode

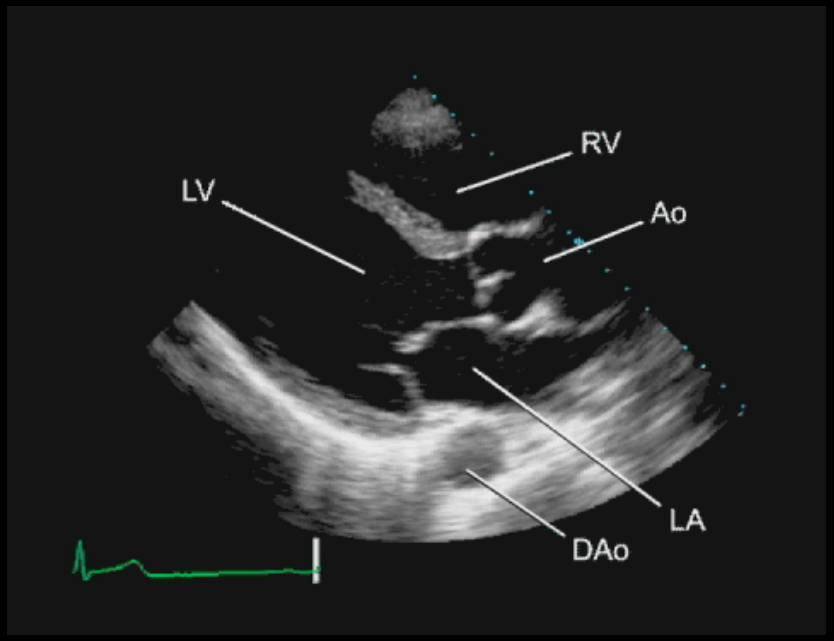
- Indications:
  - Valves
  - ASD
  - VSD
  - small, fast moving structures
- Beware of losing spatial orientation



Narrow Volume

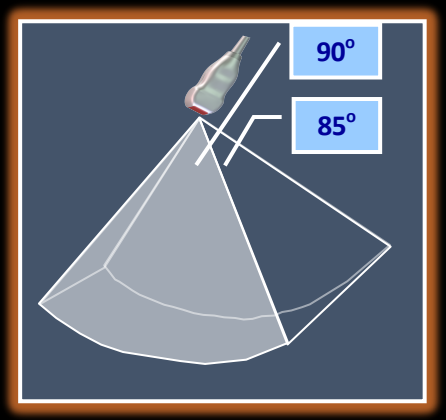


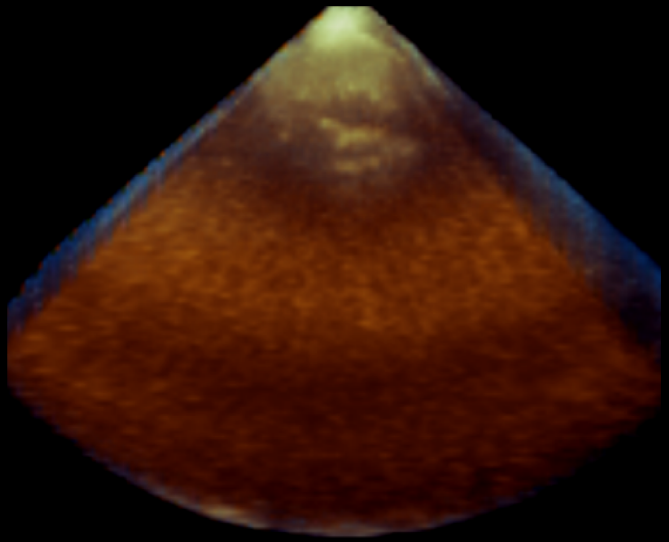




- Useful for procedures

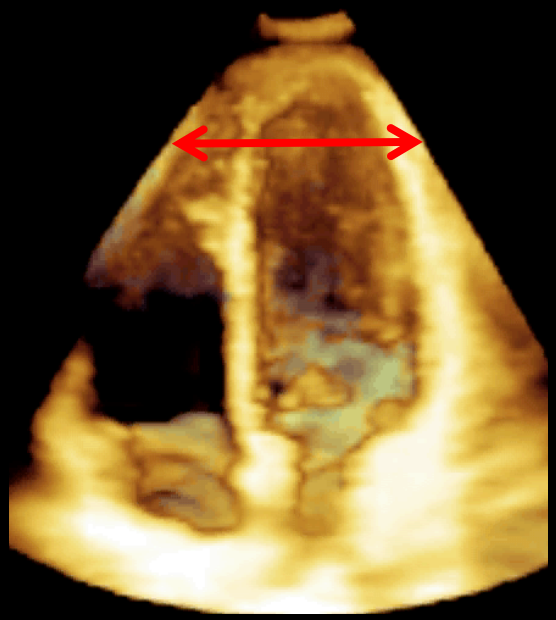
Wide Angle



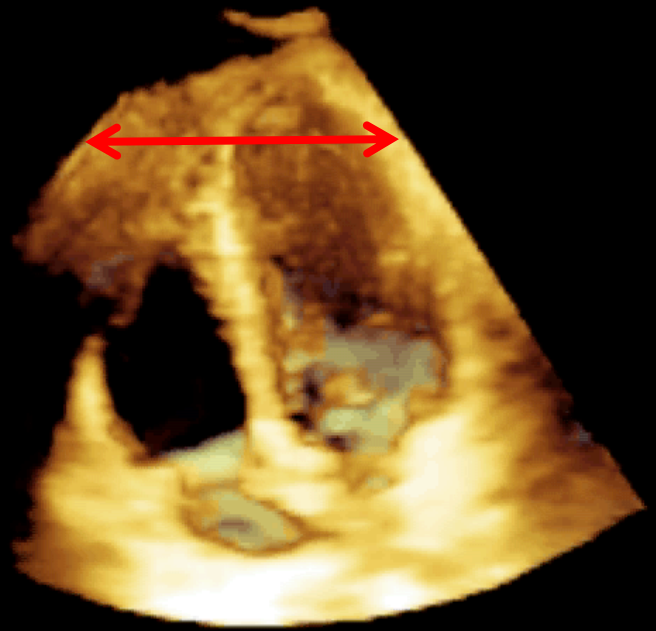


Pyramidal size

4- Beat, 30 Hz



4- Beat, 20 Hz



What size to choose?

Narrow angle/Zoomed

- Valves
- Inter-atrial septum
- Inter-ventricular septum

Wide angle

- LV
- RV
- Whole heart

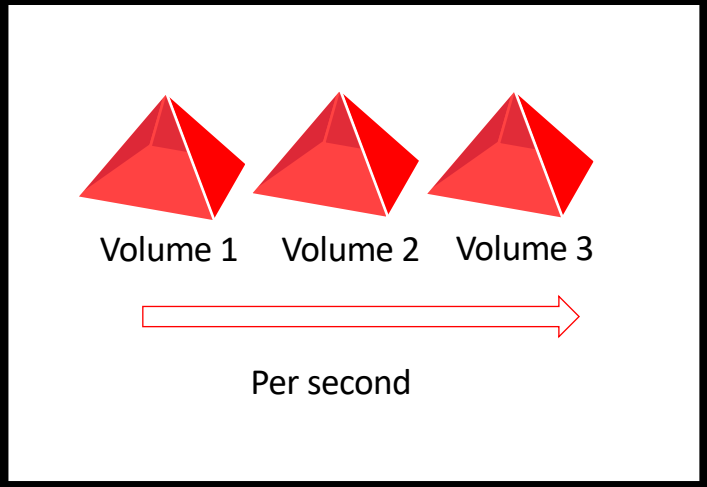
Trade Offs

Volume Rate
Pyramidal Size
Resolution
Volume Rate
Pyramidal Size
Resolution
Volume Rate
Pyramidal Size
Resolution

Single or Multi-beat

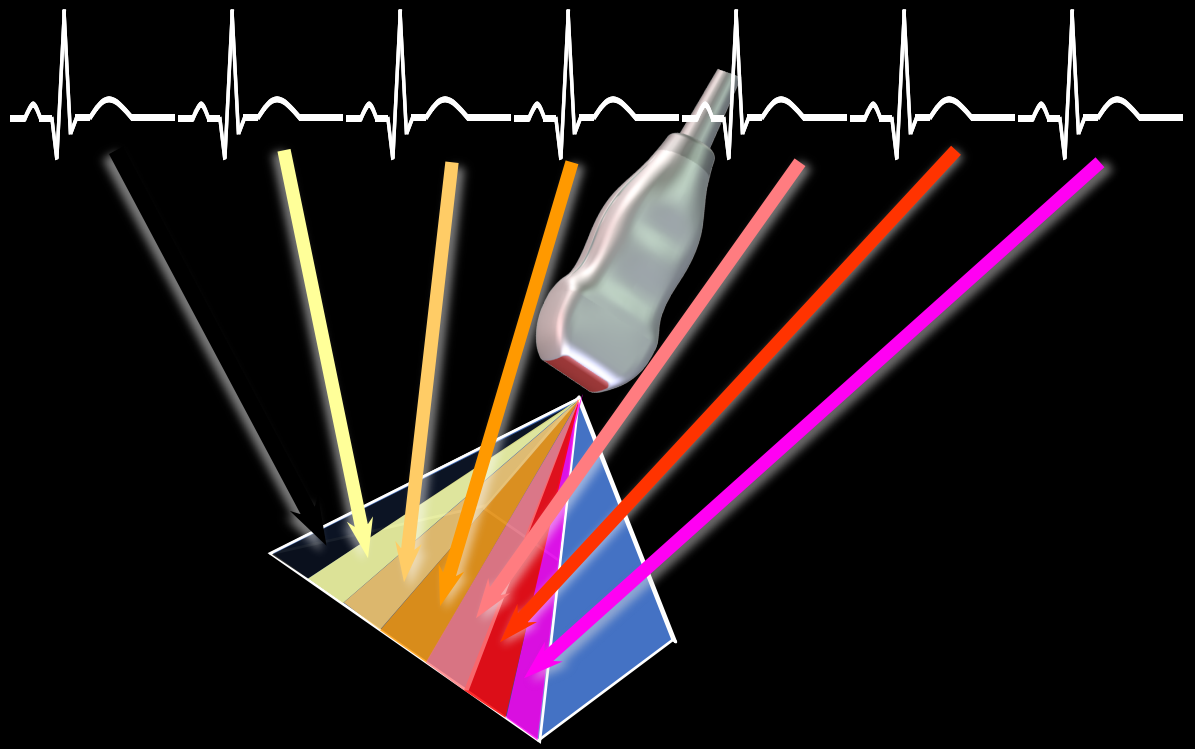
Single-beat acquisition

- acquisition of multiple pyramidal data sets per second in a single heartbeat



Single or Multi-beat

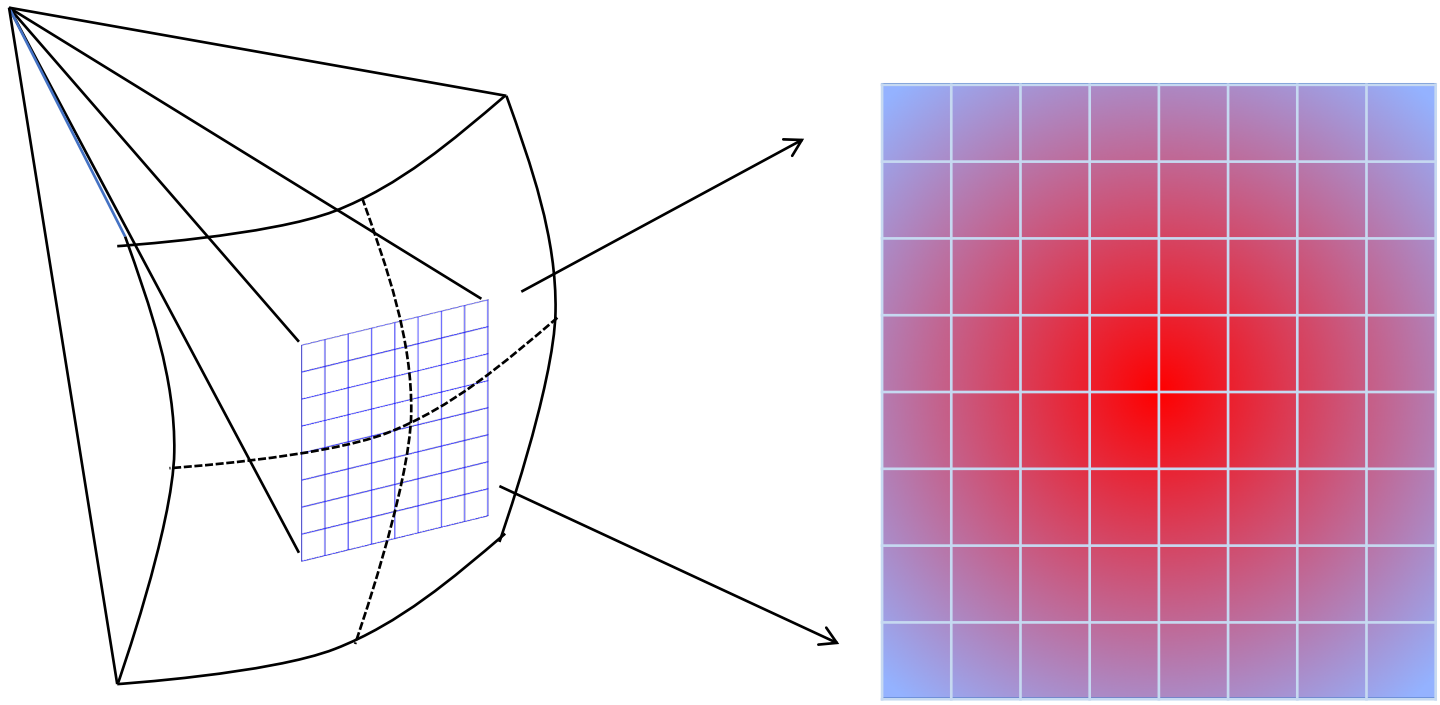
ECG-triggered multiple-beat acquisition



Methods to Increase Volumes Rates

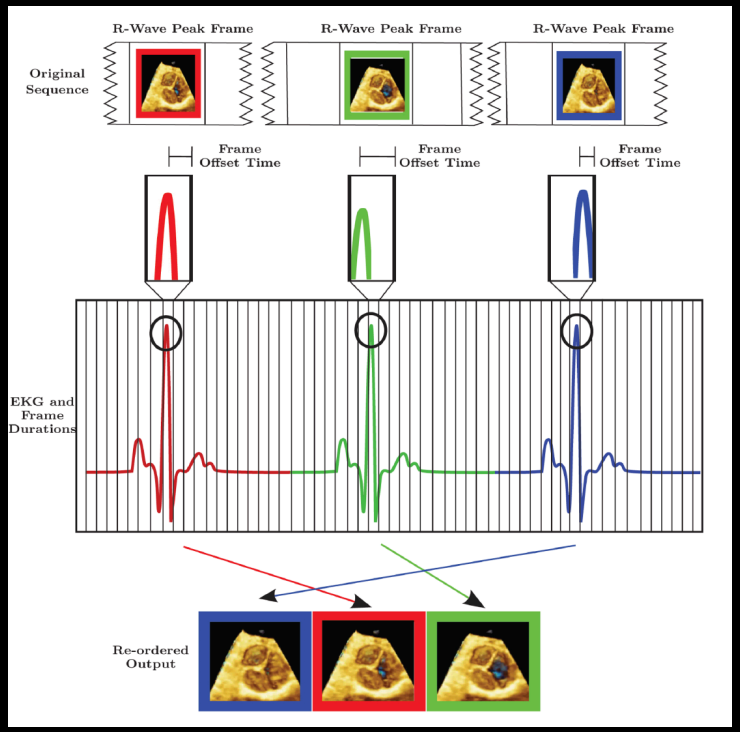
- Built in
  - Parallel beamforming
  - Frame reordering
  - Multiline transmission
  - High pulse repetition
- Controllable
  - Interpolation
  - Virtual array

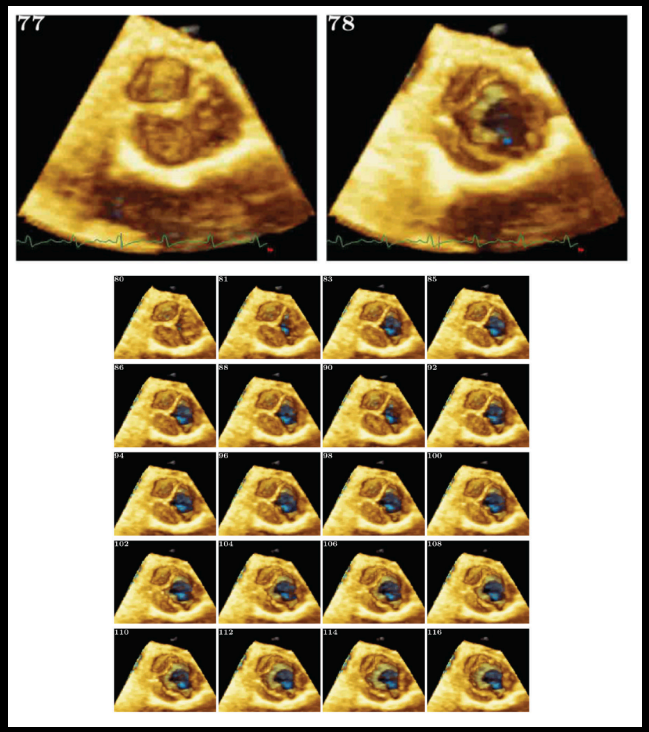
PARALLEL BEAMFORMING



One transmit beam
Multiple receiving beams
Increases volume rate by number of receiving beams.

FRAME REORDERING

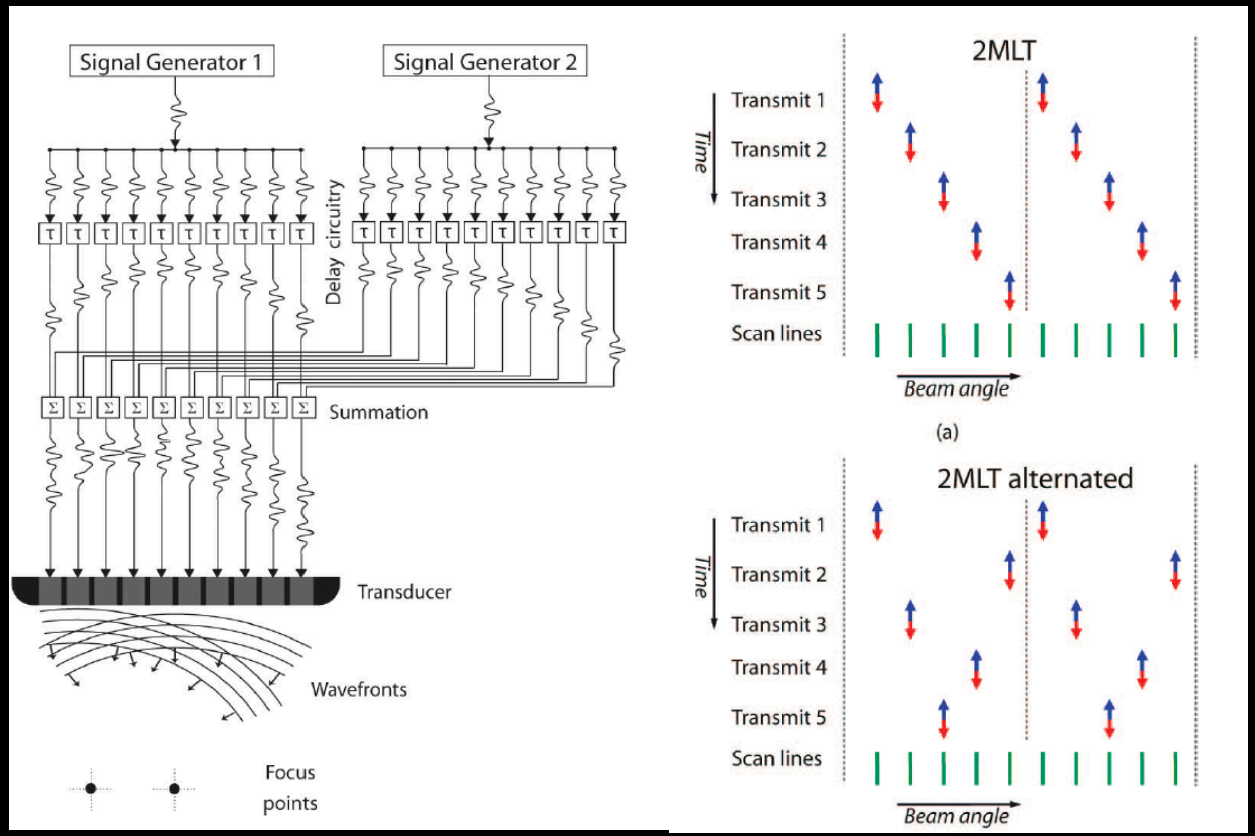




- high frame (volume) rate algorithm is used that reorders 3DE volumes of a periodically moving cardiac structure taken at a number of instances over several cardiac cycles.

Perrin DP et al. JACC Cardiovasc Imaging. 2012 March ; 5(3): 300–304

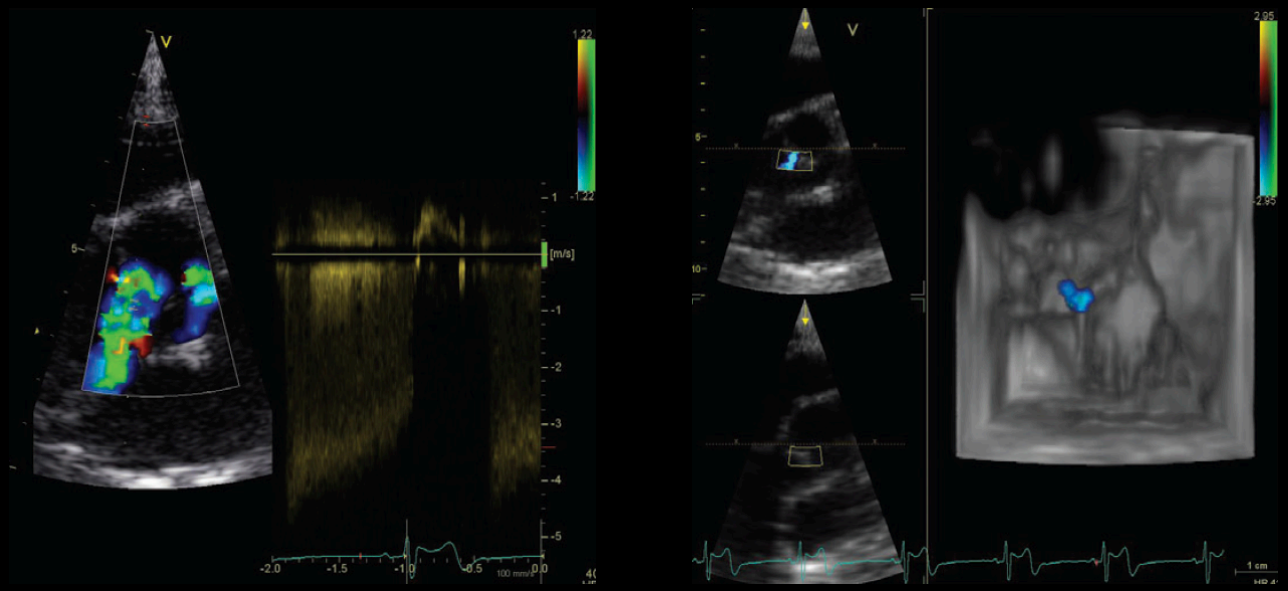
MULTILINE TRANSMISSION



- multiple ultrasound pulses focused along different steering directions are transmitted simultaneously

Denarie B et al. IEEE 2013:60(8);1708

HIGH PULSE REPETITION FREQUENCY



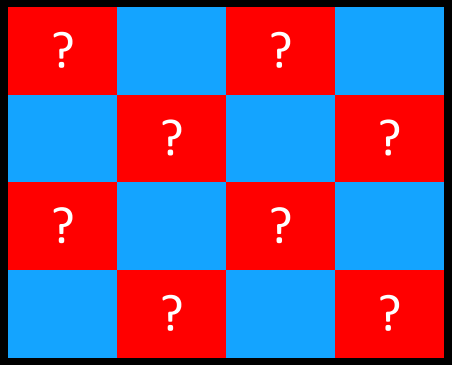
- Pulses are transmitted with three times the frequency that is needed to allow the echo from the farthest depth to return
  - I.E. IF two pulses are emitted, the echo from the first pulse will return from the farthest depth at the same time the echo from the second pulse returns from an intermediate depth. When this occurs, there is no way to determine whether the signal originates from the deepest or the intermediate level. The high-pulse repetition frequency increases the Nyquist limit, thereby shortening the acquisition time.

Skaug TR et al. European Heart Journal – Cardiovascular Imaging (2014) 15, 615–622

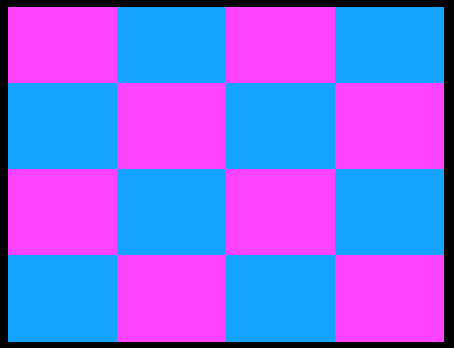
Interpolation

1st Cardiac Cycle

- **BLUE** squares are scanned
- Missing **RED** squares are estimated using the surrounding **BLUE** squares



- Estimated squares are shown as the **PINK** squares



Interpolation

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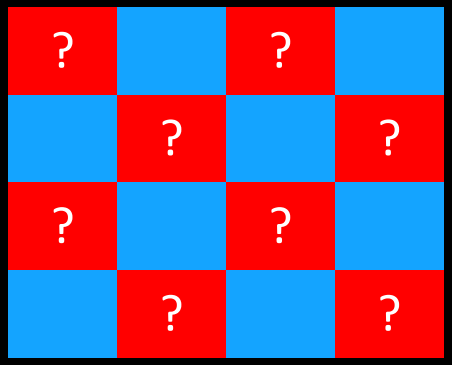

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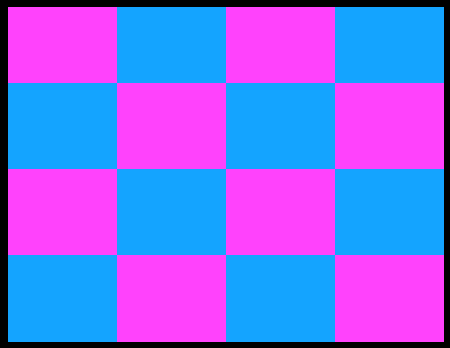
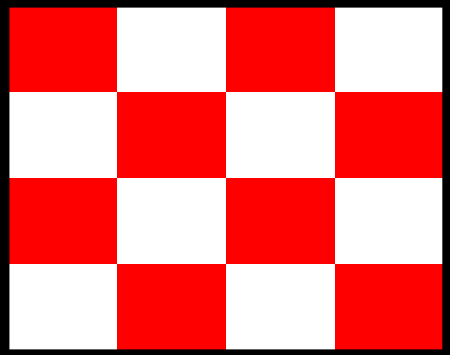
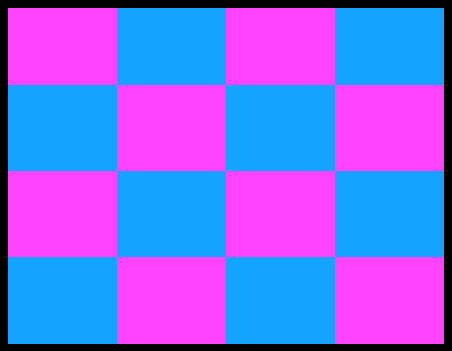


2nd Cardiac Cycle

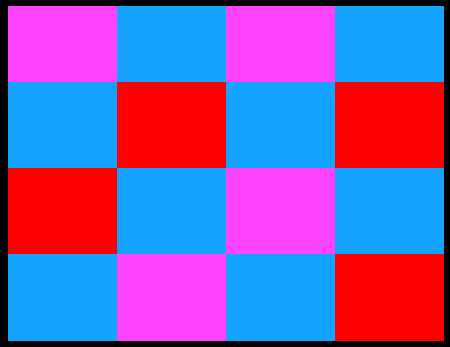
- **RED** squares are scanned



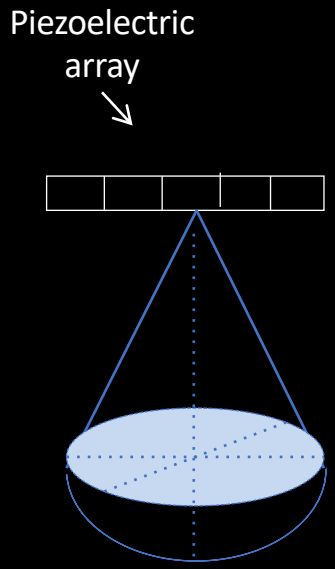
- Each **PINK** square is 'contrasted and compared' to the matching **RED** square in the previous cardiac cycle

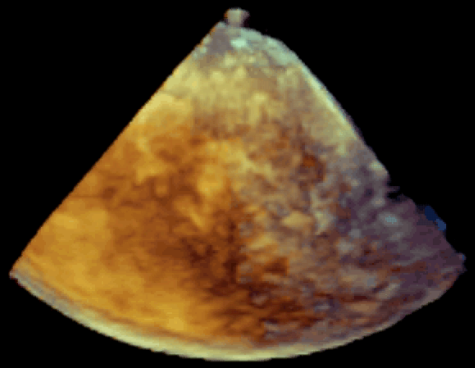


- If the **RED** square is similar to the **PINK** square value, then the **PINK** square is replaced by the **RED** square



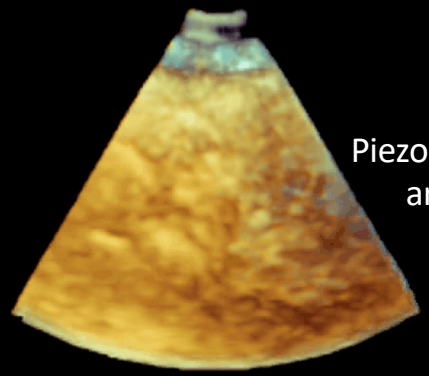
Virtual array





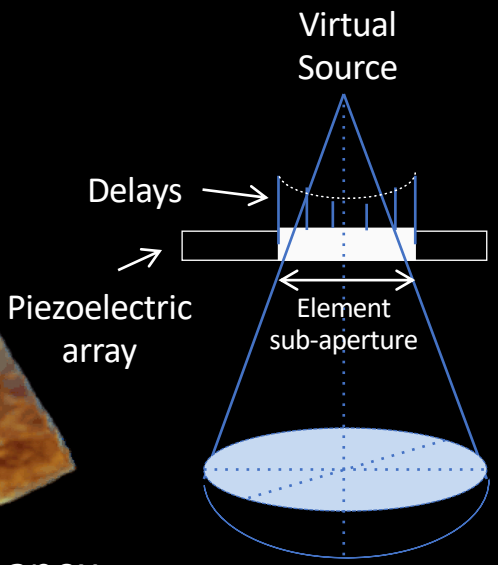
Wider base, pointed apex

VR 17 Hz



Narrow base, flat apex

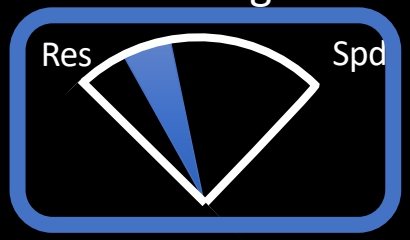
VR 31 Hz



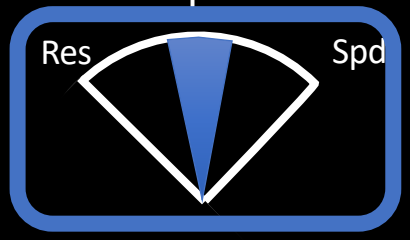
Increasing Volume Rate – Virtual Apex

Philips iE33 'Res-Spd"

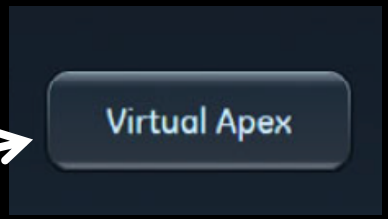
Default setting



Optimized – at 12 o'clock position



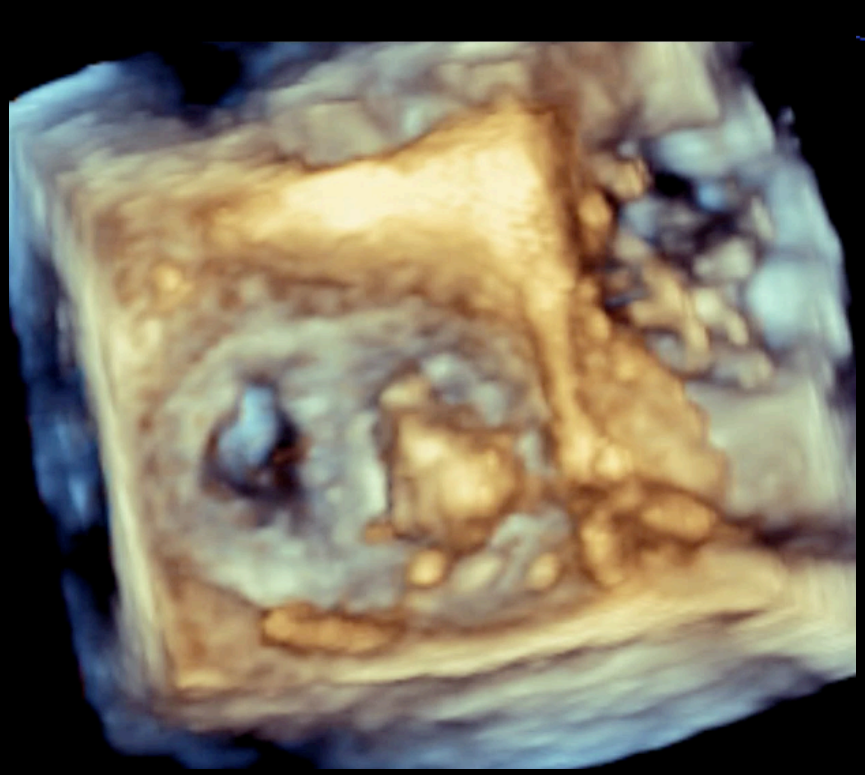
GE e95

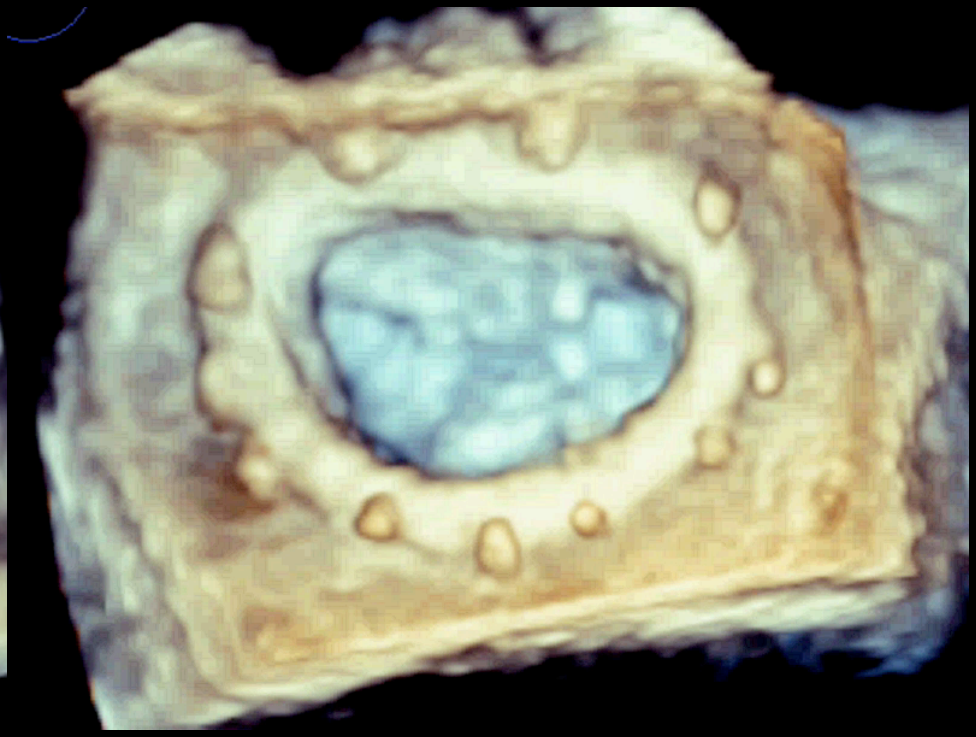


3DE ARTIFACTS

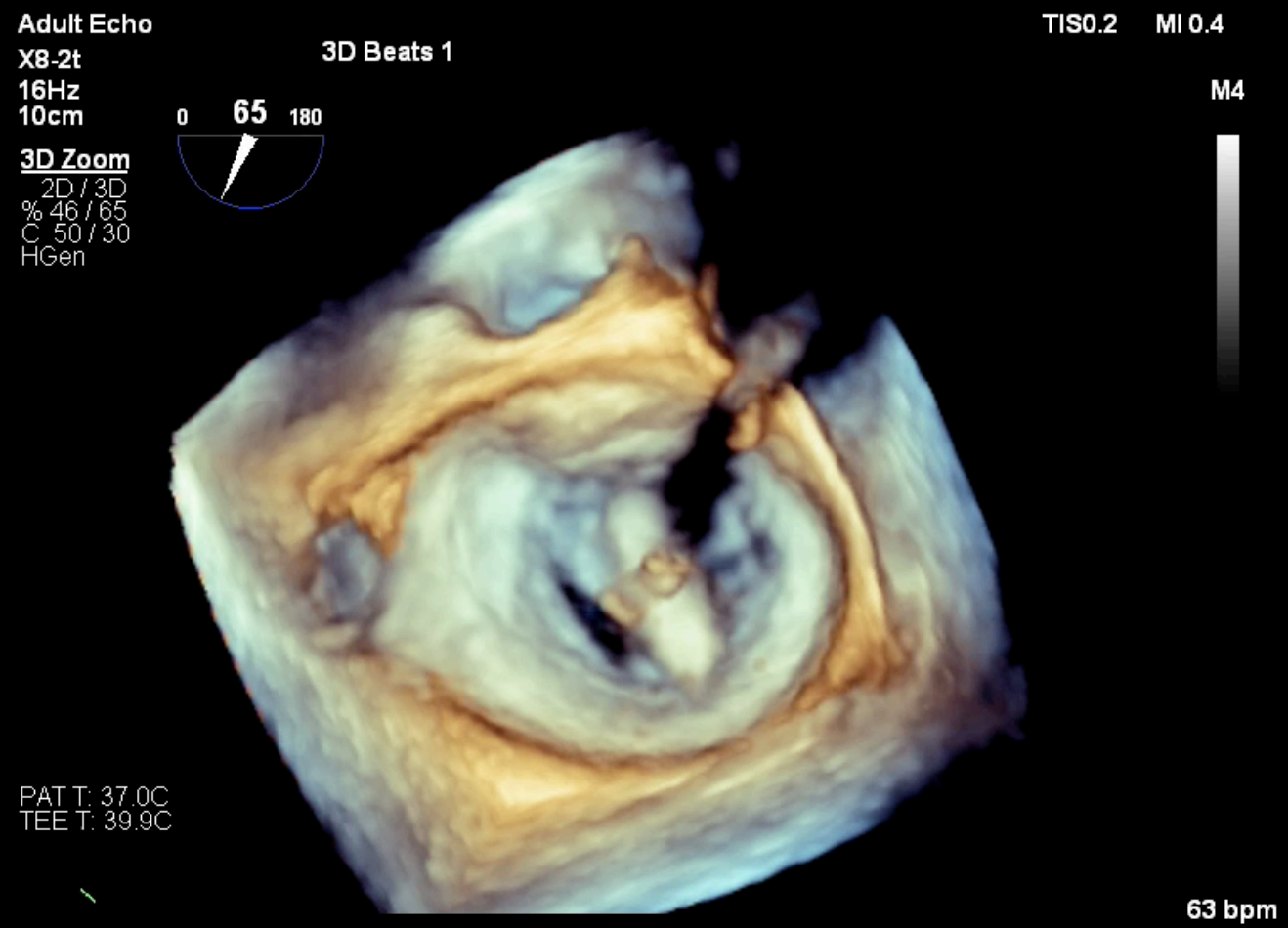
- Stitch
- Dropout
- Blooming
- Shadowing
- Gain
- Reverberations

Blooming





Shadowing


Adult Echo
X8-2t
16Hz
10cm
3D Beats 1
0
65
180
3D Zoom
2D / 3D
% 46 / 65
C 50 / 30
HGen
TIS0.2
MI 0.4
M4
PAT T: 37.0C
TEE T: 39.9C
63 bpm

1. Image Optimization

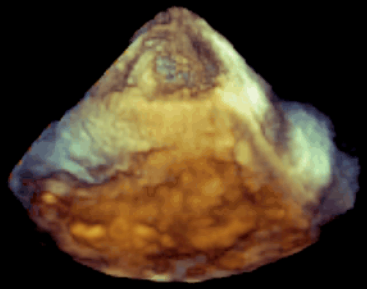
2. Acquisition Modes

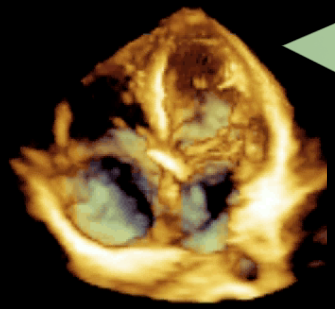
Spatial vs temporal resolution
Gating artifacts

- Zoom
- Narrow volume
- Wide volume
- Single beat
- Multi-beat
- Color Doppler

3. Rendering

- Cropping
- Thresholds





4. Final Image Display + Analysis

Thank you for listening!