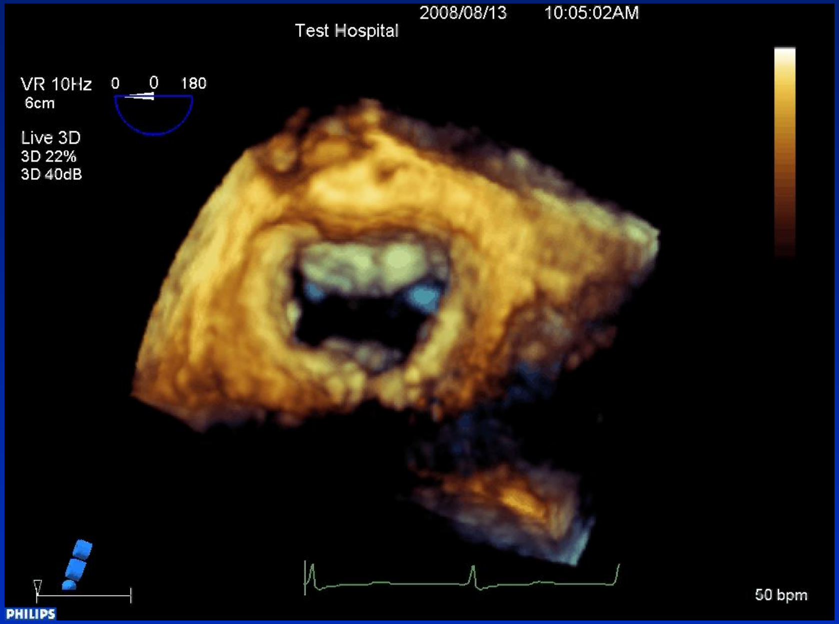
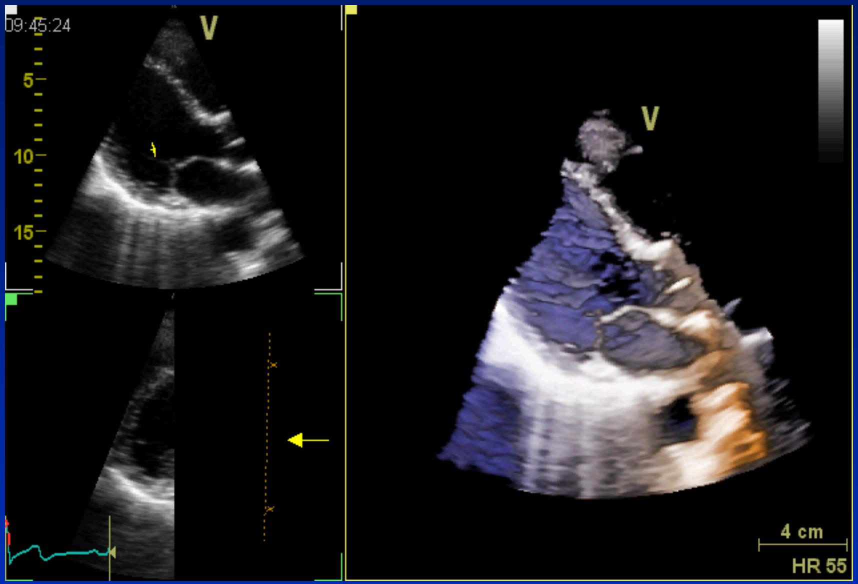
3D Echocardiography:
2011 update

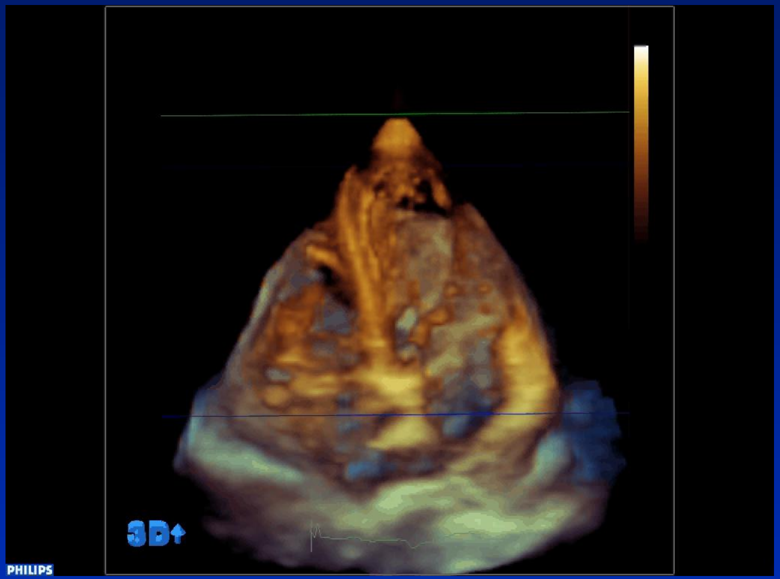


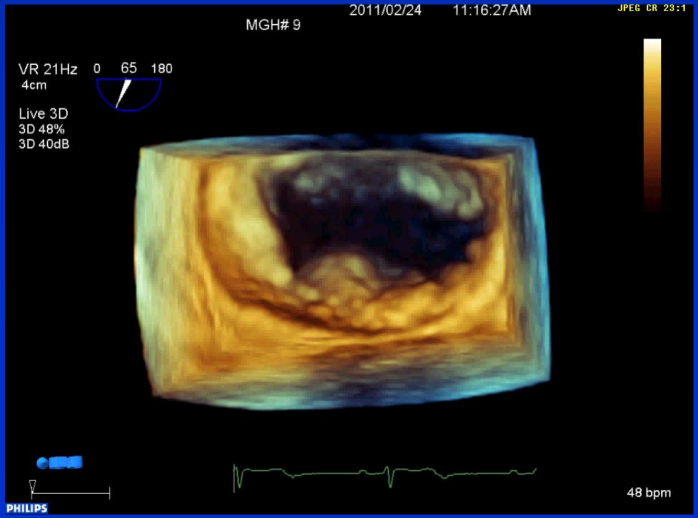
Michael H. Picard, M.D.
Massachusetts General Hospital
Harvard Medical School

No disclosures

3D cardiac ultrasound imaging in 2011: Just pretty pictures or added value ?





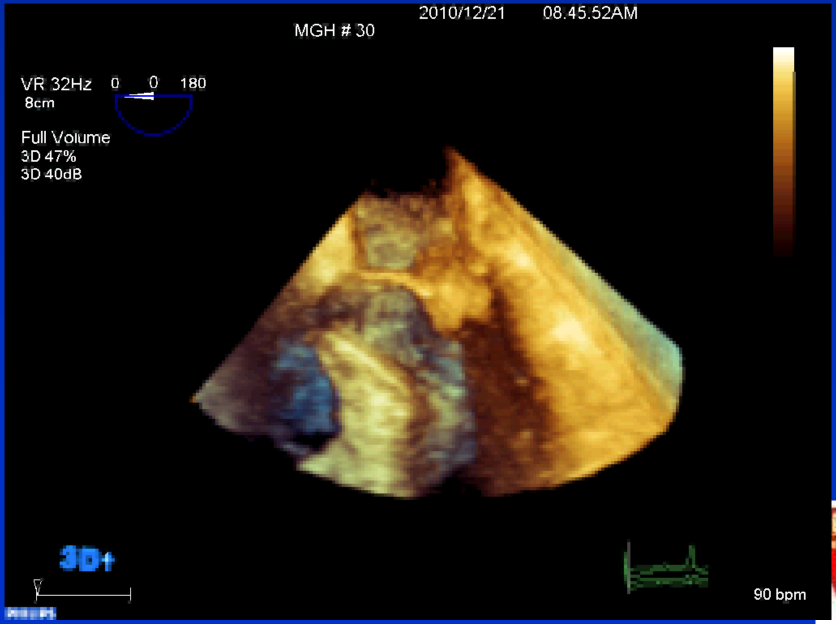


3D cardiac ultrasound imaging in 2011: Just pretty pictures or added value ?

- A bit of both

Why 3D echo ?

- Easier to understand 3D structure of the heart + relation of various structures to one another
  - No need to mentally reconstruct the 2D images
- Easier to demonstrate to those who are echo-challenged
- No need to rely on geometric assumptions when quantifying volumes, mass, function
- Potentially faster image acquisition



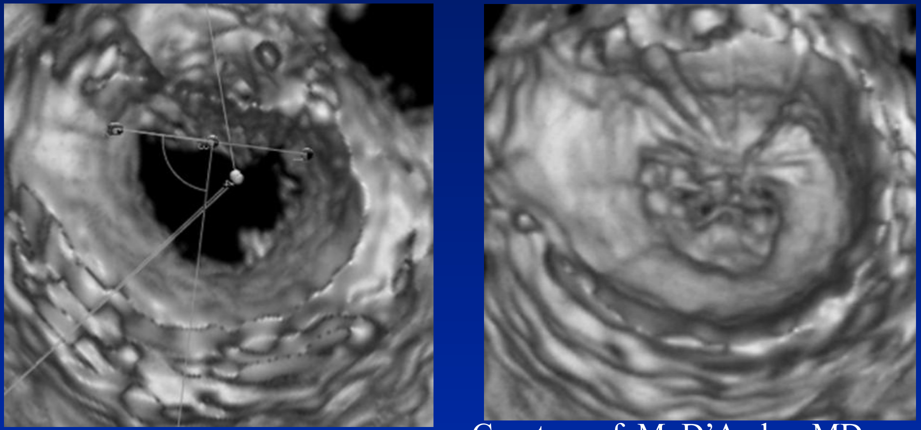
3D echo unique indications: *valve disease*

- 3D echo uniquely suited for imaging valves
  - Valves have
    - Non planar surfaces
      - Diagnosis of MVP
    - Complex spatial relationships of all components of the valve and surrounding structures
    - Complex Doppler color flow jets

3D echo reconstruction method

- Earliest approach in the 1970’s
- Requires precise location and timing of each image
- Time consuming
- Very accurate for quantitation

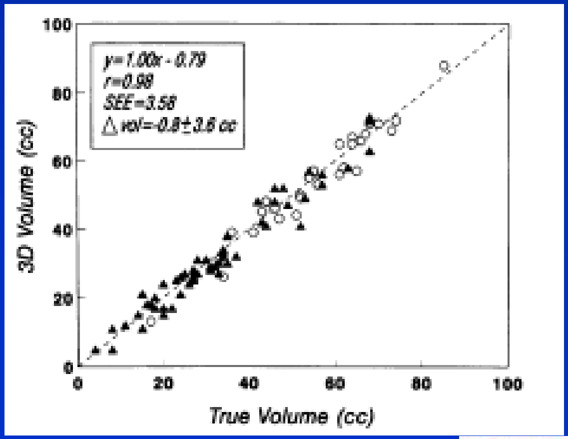
TEE - MV



Courtesy of M. D’Ambra MD

LV volume

Handschumacher et al, JACC 1993;21:743-753

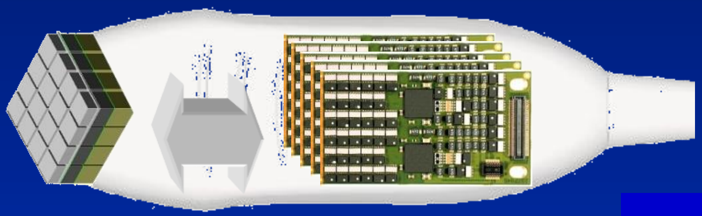


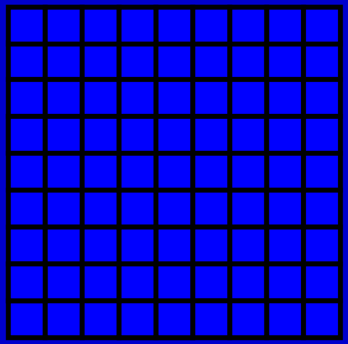
Siu et al, Circ 1993;88:1715-23

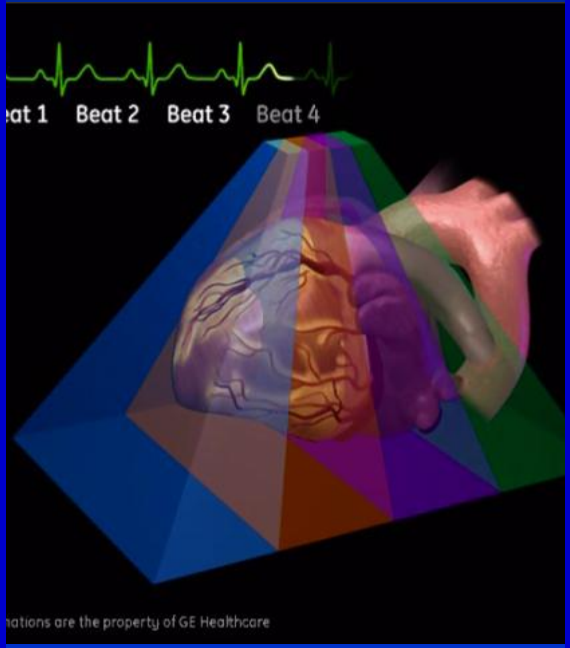
3D echo volumetric method

- Required development of matrix array transducer
  - 30^ox 50^o volume acquired / displayed in real time
  - 90^o x 90^o full volume created from 1 beat or fusion of subvolumes from more than 1 beat (esp for color Doppler)
- Cropping required
- Potentially fast
- Transducer also allows multiple-plane 2D imaging

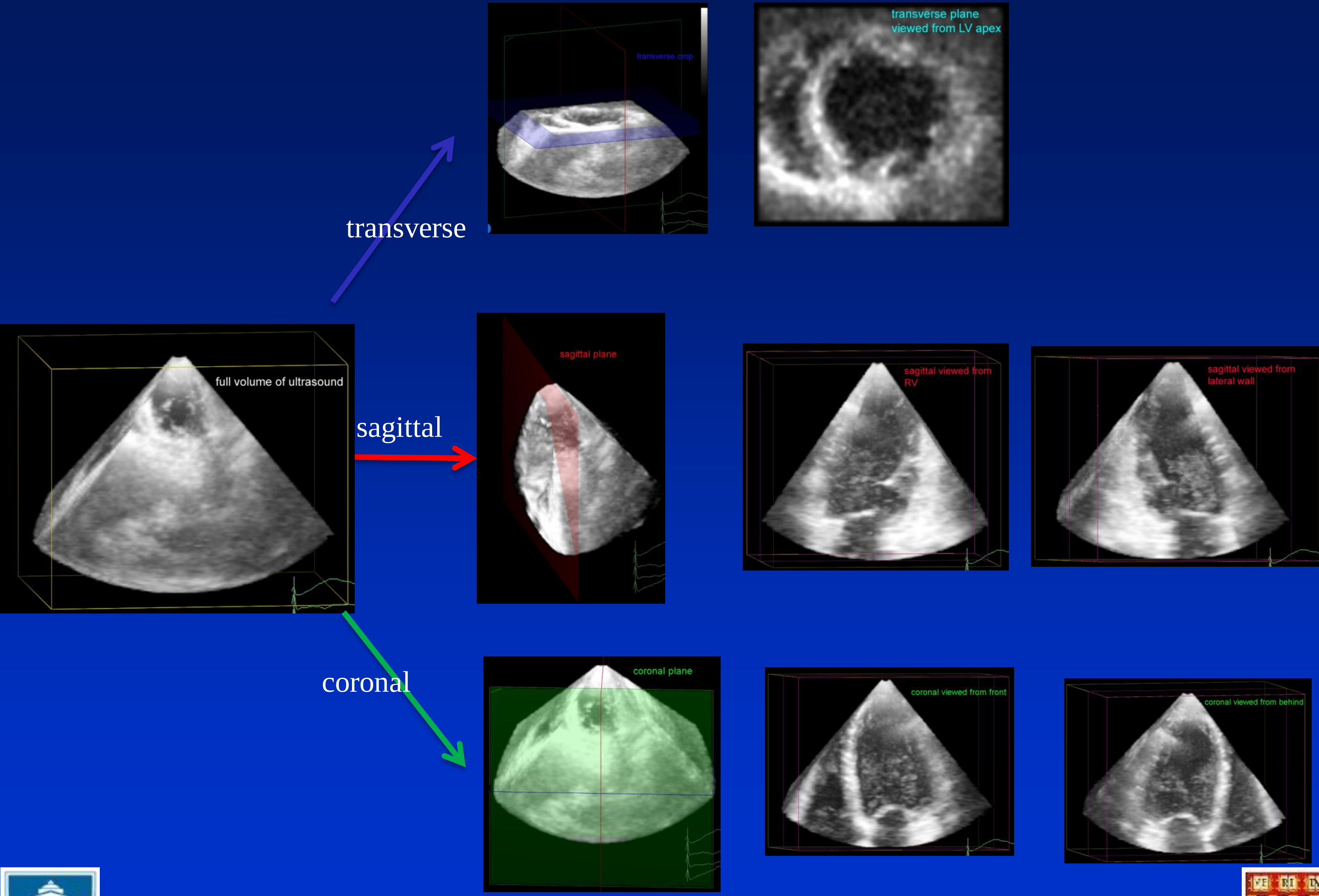
Real time 3 D matrix array ultrasound transducers:
acquire a volume of ultrasound rather than a single plane



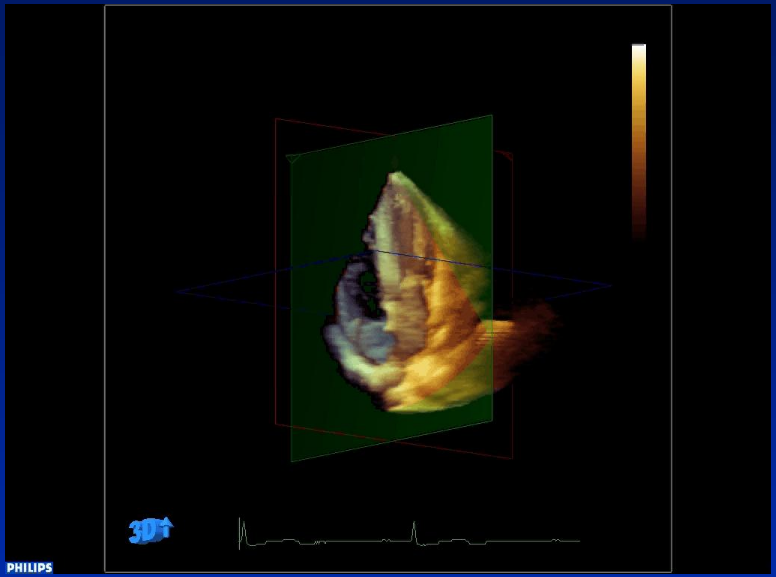


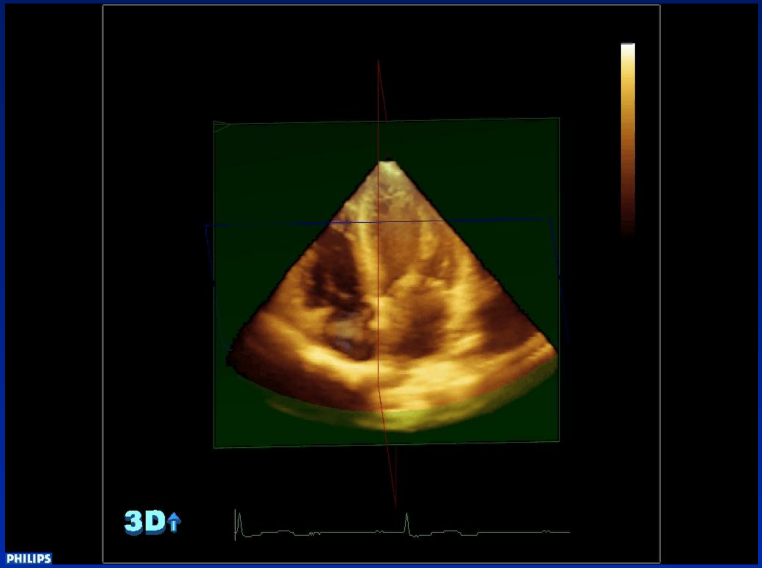


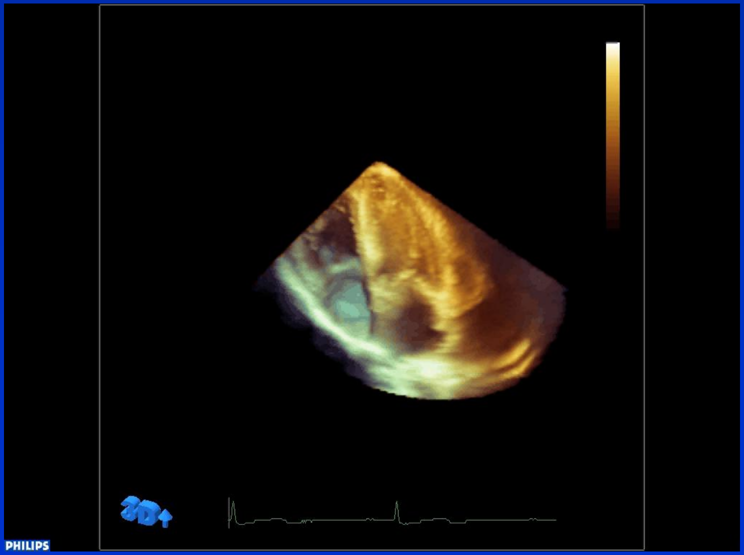
> 3000 elements

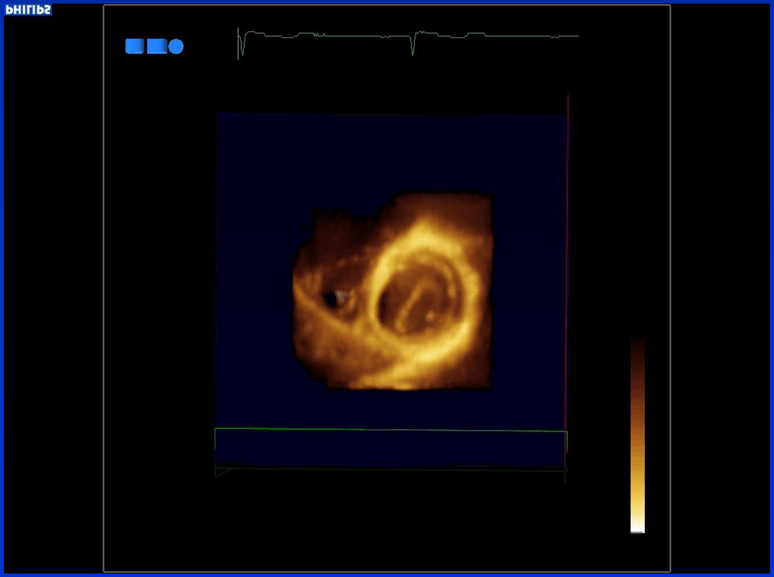

transverse
transverse crop
transverse plane
viewed from LV apex
full volume of ultrasound
sagittal
sagittal plane
sagittal viewed from
RV
sagittal viewed from
lateral wall
coronal
coronal plane
coronal viewed from front
coronal viewed from behind

Real time 3d TTE

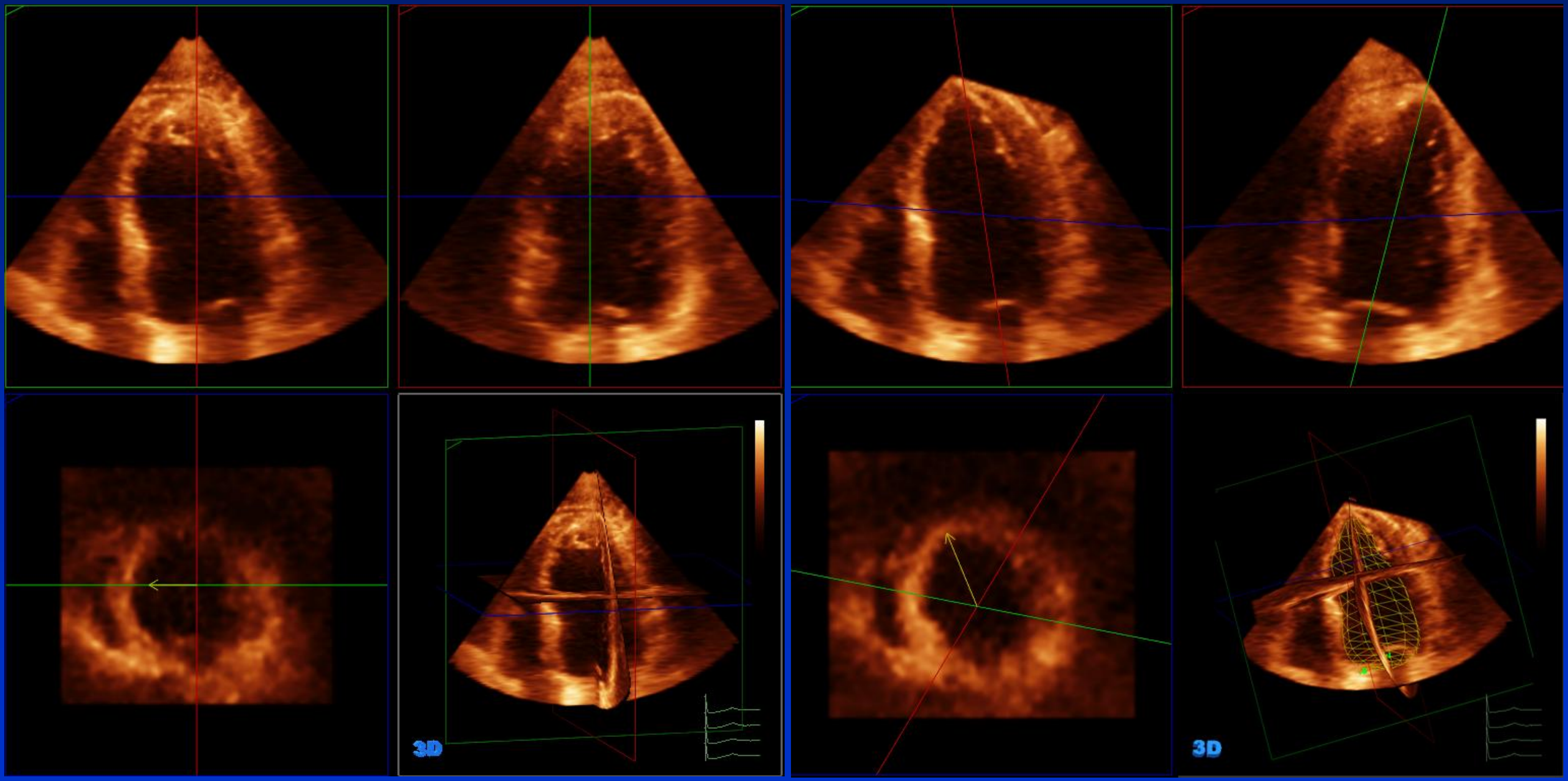




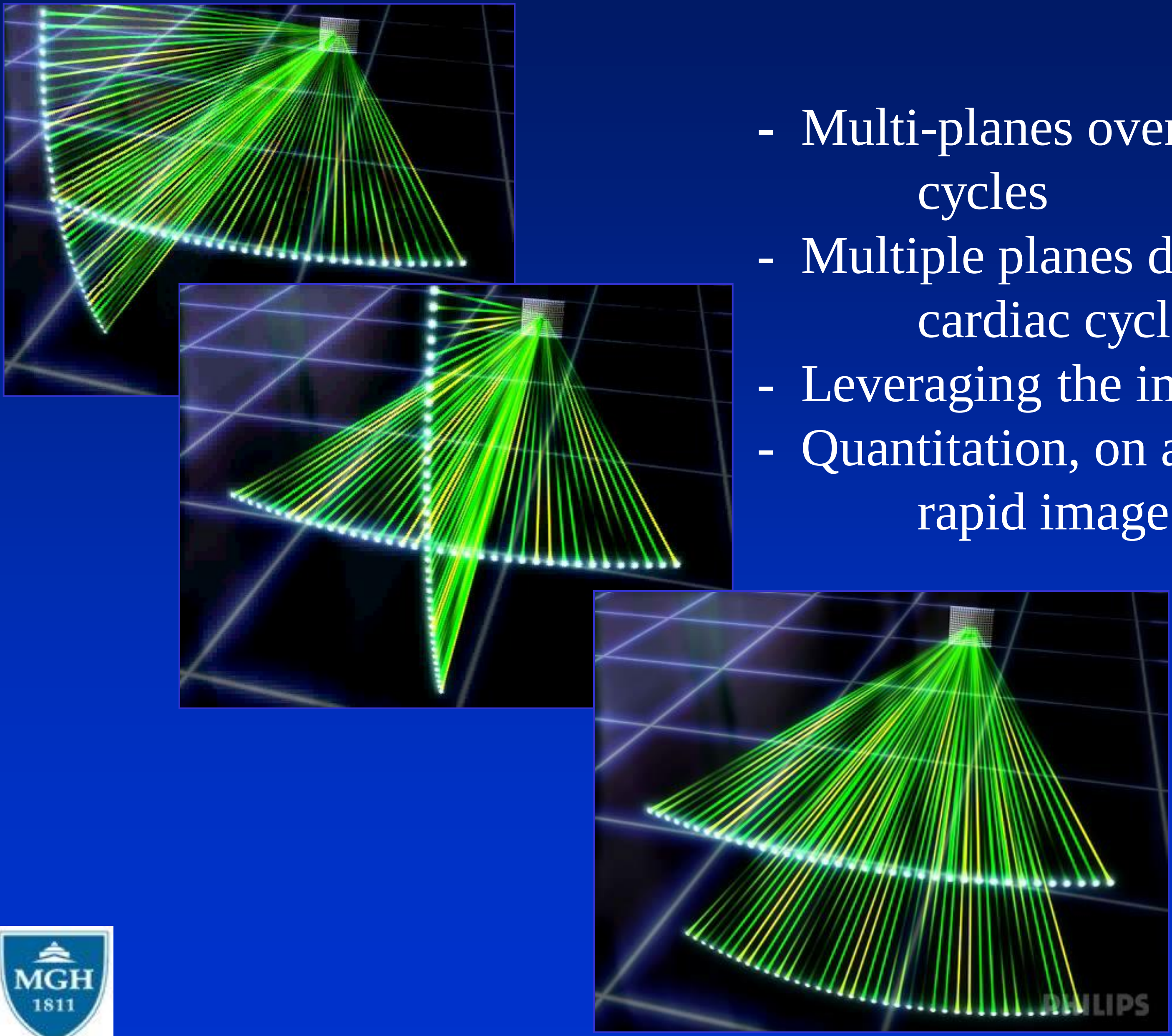




Cropping 3D image set avoids foreshortening of the LV

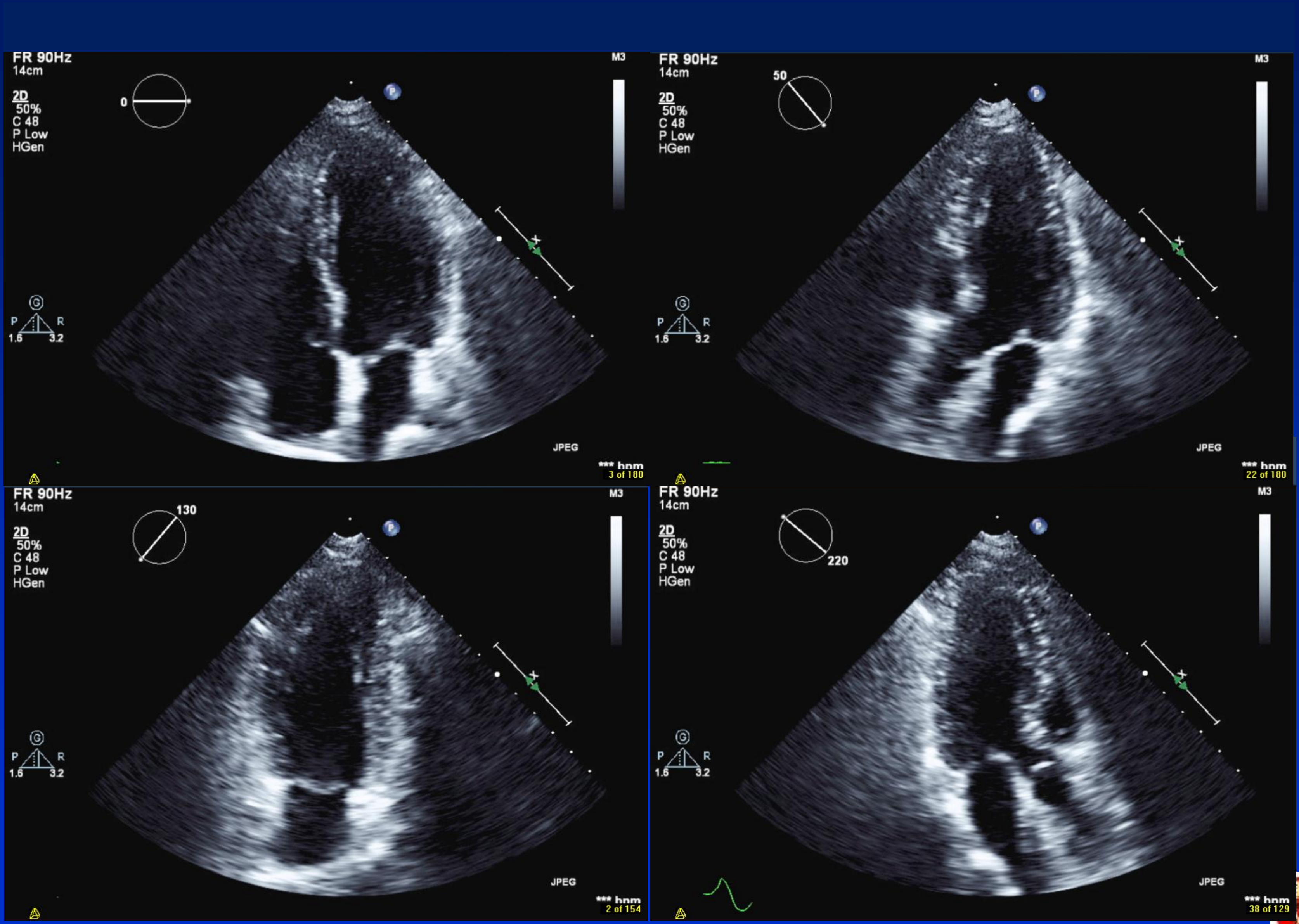


Real time 3 D matrix array ultrasound transducers allow imaging multiple 2D planes at same time



- Multi-planes over multiple cardiac cycles
- Multiple planes during the same cardiac cycle
- Leveraging the image quality of 2D
- Quantitation, on axis imaging, rapid image acquisition

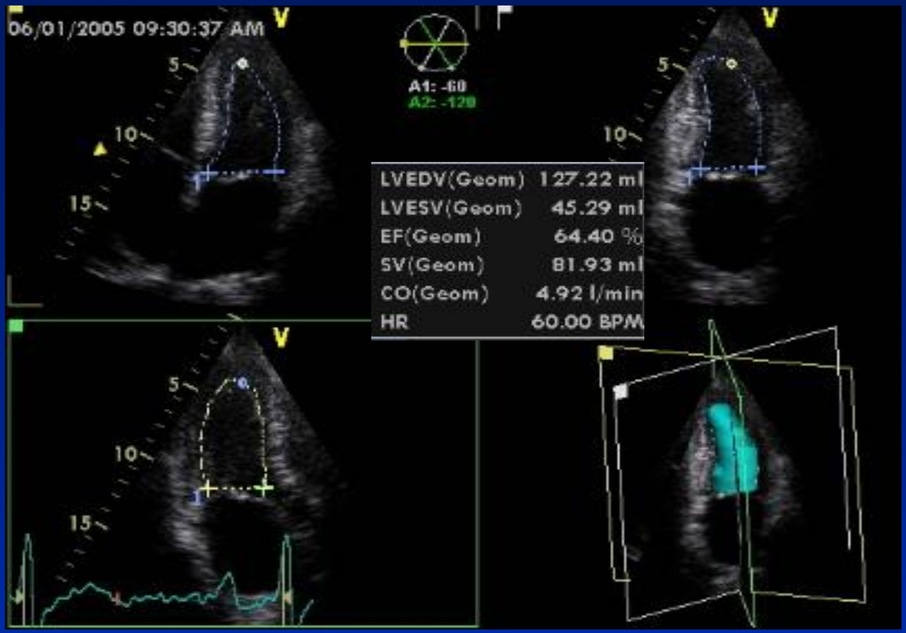
Multi-plane 2D imaging from 3D transducer

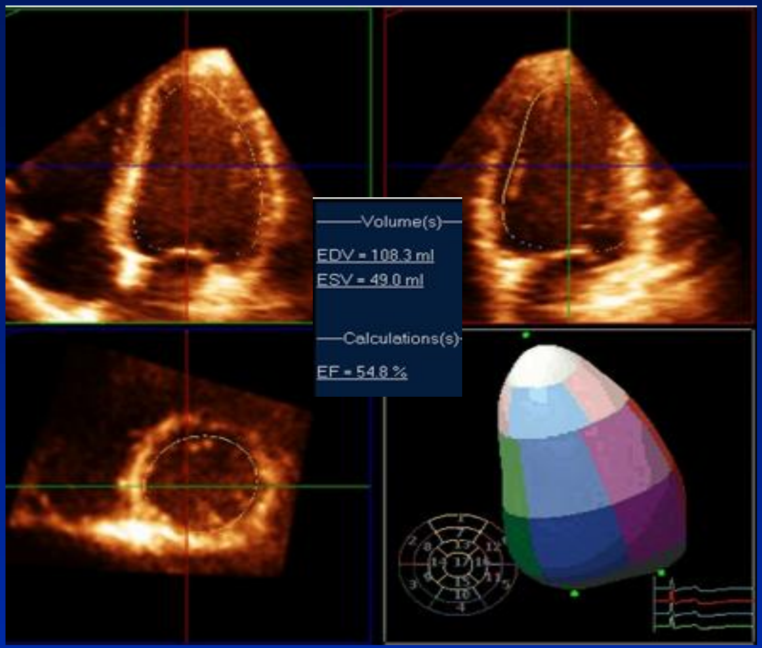


Evidence based value of 3D echo quantitation

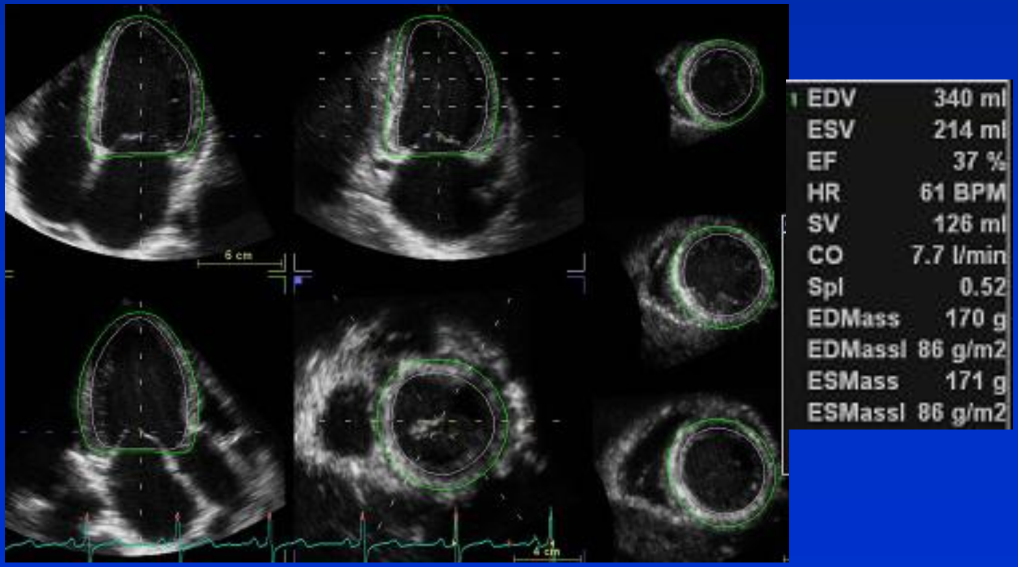
- LV volume, mass
- LA volume
- Valves
  - Stenosis
    - Planimetry of MVA, AVA
    - EROA of MR and AI

3D TTE for volume and EF



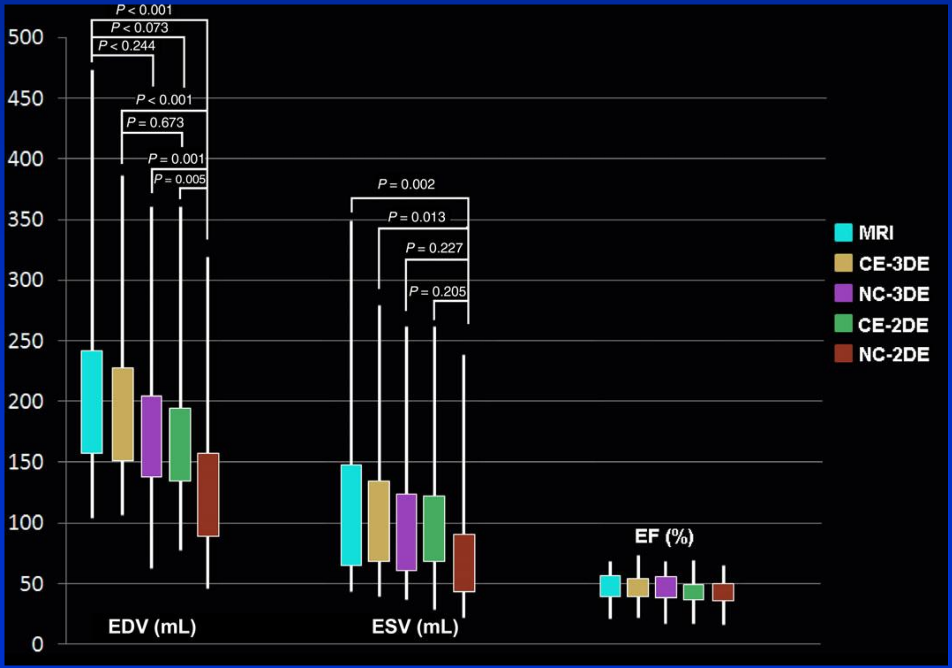


LV mass



Ref	Parameter	Reference standard	r	Mean diff ± 1SD	Inter-obs variability (%)
Circ 2006;114:654-61	LV EDV	cMR	0.97	-5 ± 24 ml	11.2
Circ 2006;114:654-61	LV ESV	cMR	0.96	-6 ± 28 ml	14.2
JASE 2005;18:991-7	LV mass	cMR	0.95	-1.8 ± 19.9 g	12
JASE 2010;23:116-26	RV EDV	cMR	0.84	10.2 ± 20.8 ml	
CV US 2009;7:16	LA volume	cMR	0.76	23.3 ± 9.6 ml/m^2	5.1

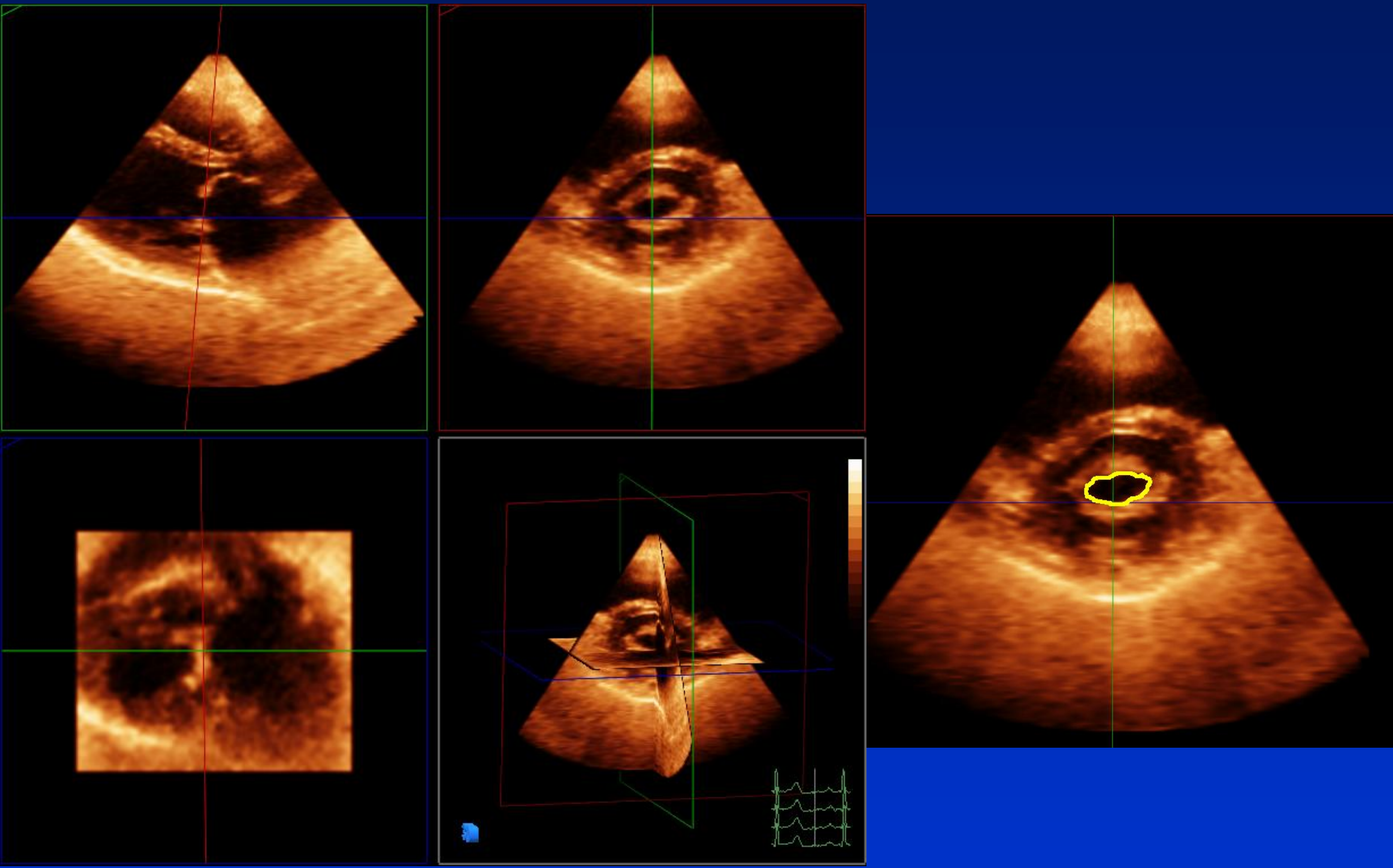
3D TTE superior to 2D TTE for LV volume in patients with prior MI



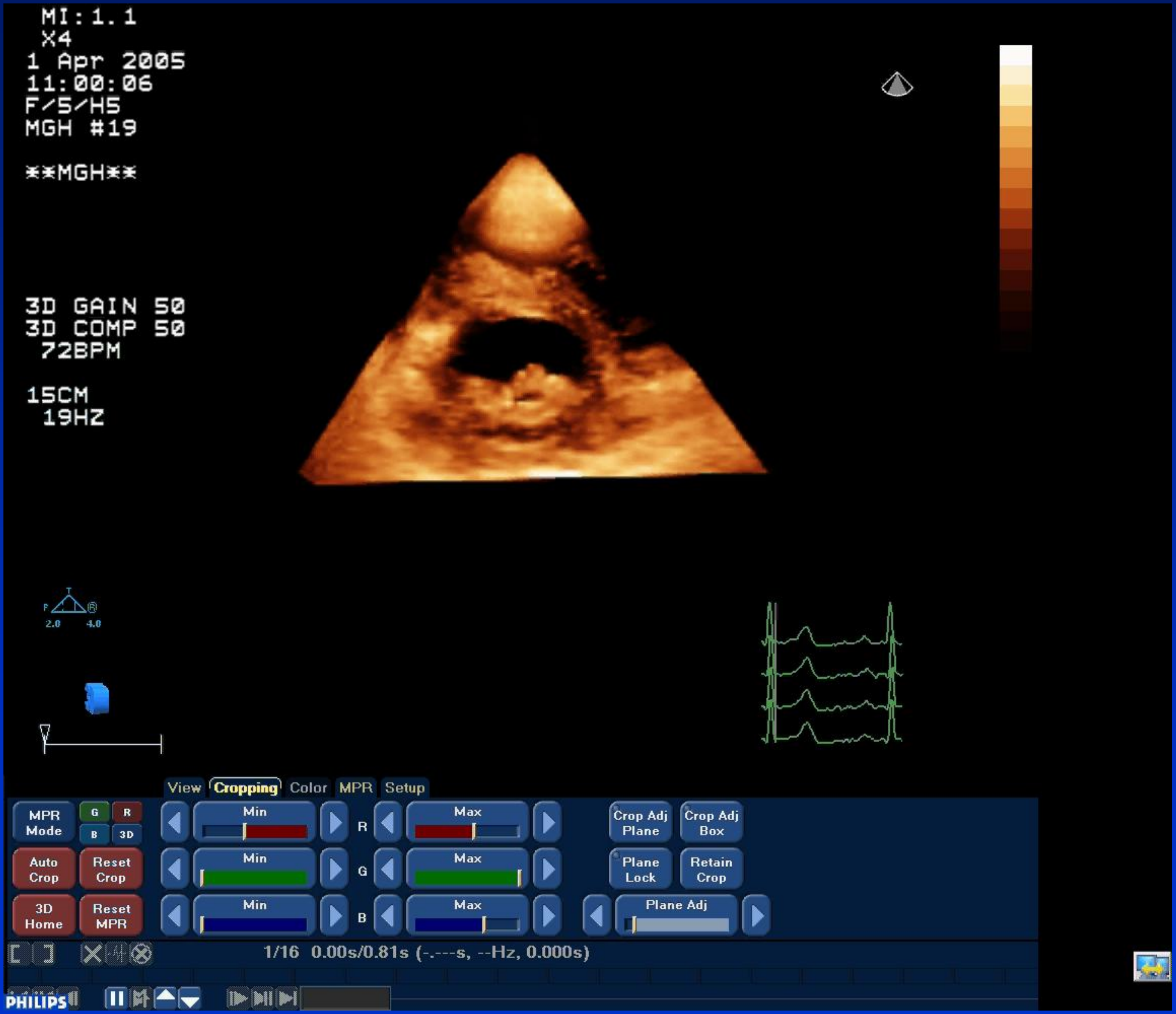
Jenkins et al, Eur Heart J 2009;30:898-106

3D echo for valve disease: mitral stenosis

- Quantitation - Sometimes planimetry is better than Doppler PHT for MVA
  - Yet planimetry requires a precise image plane that is perpendicular to the long axis of the smallest MV orifice
    - MV orifice may be asymmetrically narrowed
    - Improper plane position results in overestimation of MV Area

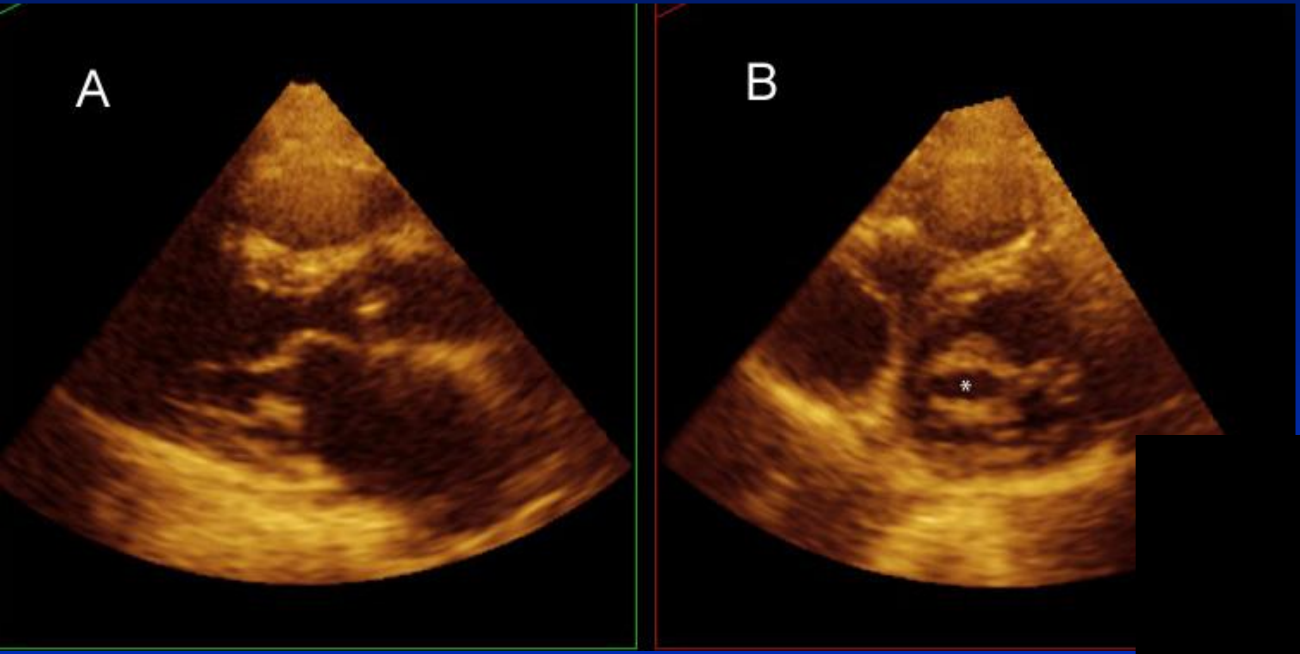


3D view of MS


MI:1.1
X4
1 Apr 2005
11:00:06
F/5/H5
MGH #19
MGH
3D GAIN 50
3D COMP 50
72BPM
15CM
19HZ
View
Cropping
Color
MPR
Setup
MPR Mode
Auto Crop
Reset Crop
3D Home
Reset MPR
Min
Max
Crop Adj Plane
Crop Adj Box
Plane Lock
Retain Crop
Plane Adj
1/16 0.00s/0.81s (-.---s, --Hz, 0.000s)
PHILIPS

Selection for PMV

3D echo provides better assessment of degree and location of commissural fusion

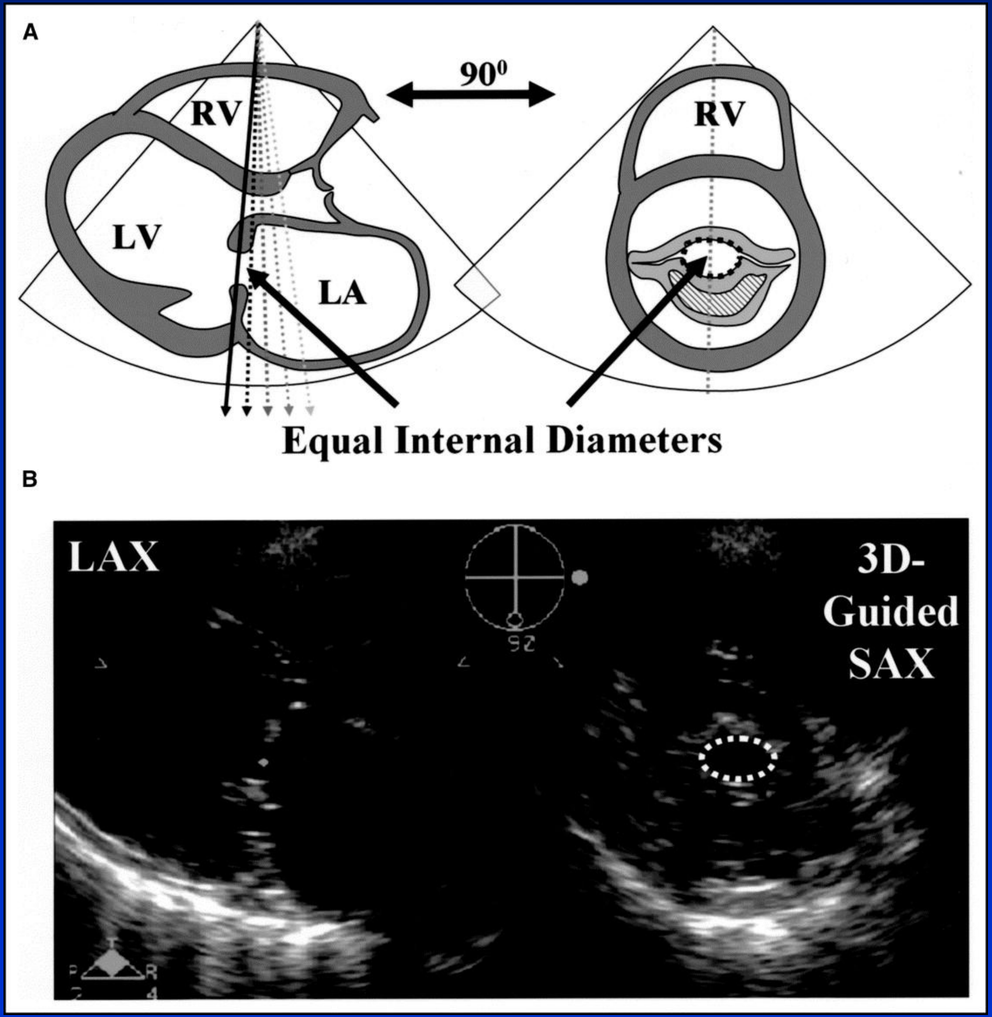


View from LV

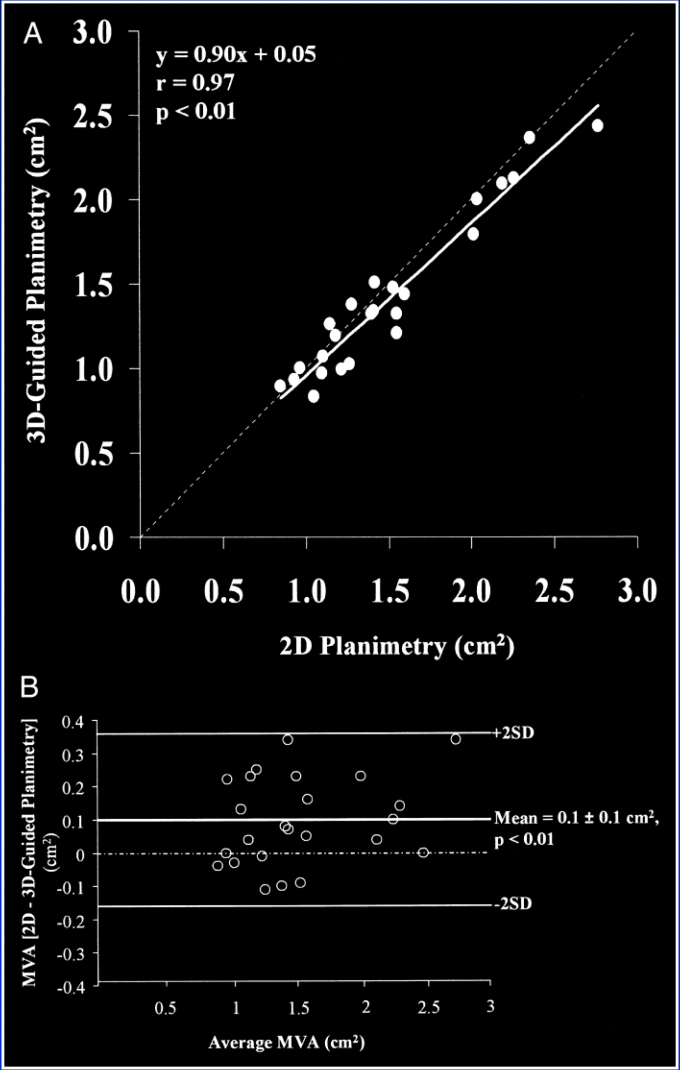
View from LA

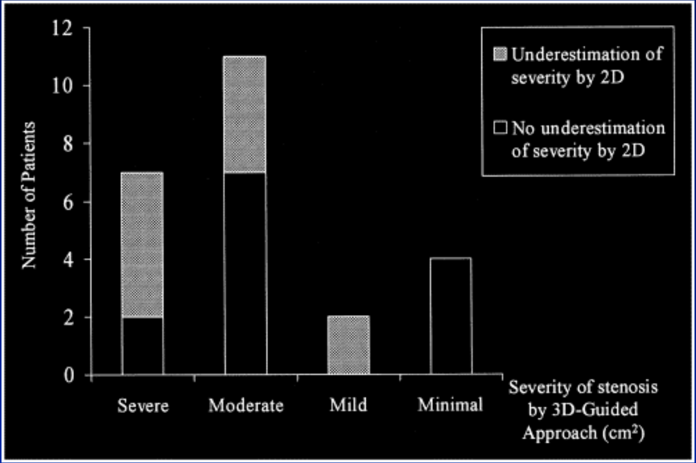
Alternative use of matrix transducer for MS:

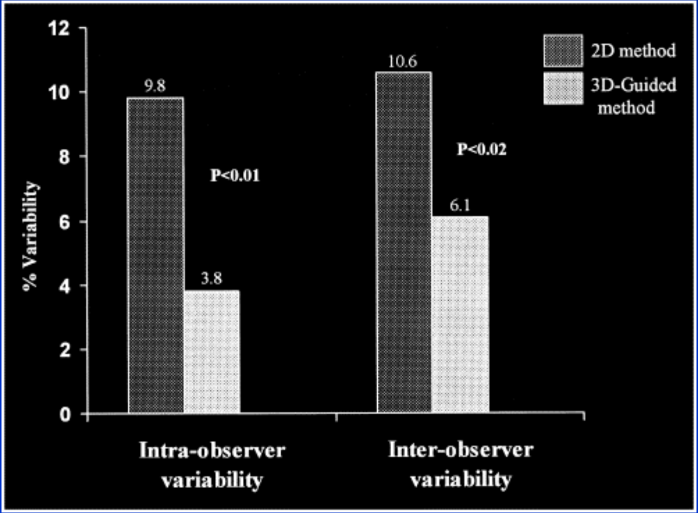
simultaneous multiplane imaging



3D TTE guided MV planimetry: excellent correlations with 2D but improved classification of disease severity and reduced measurement variability







Sebag et al, Am J Cardiol 2005;96;1151-6

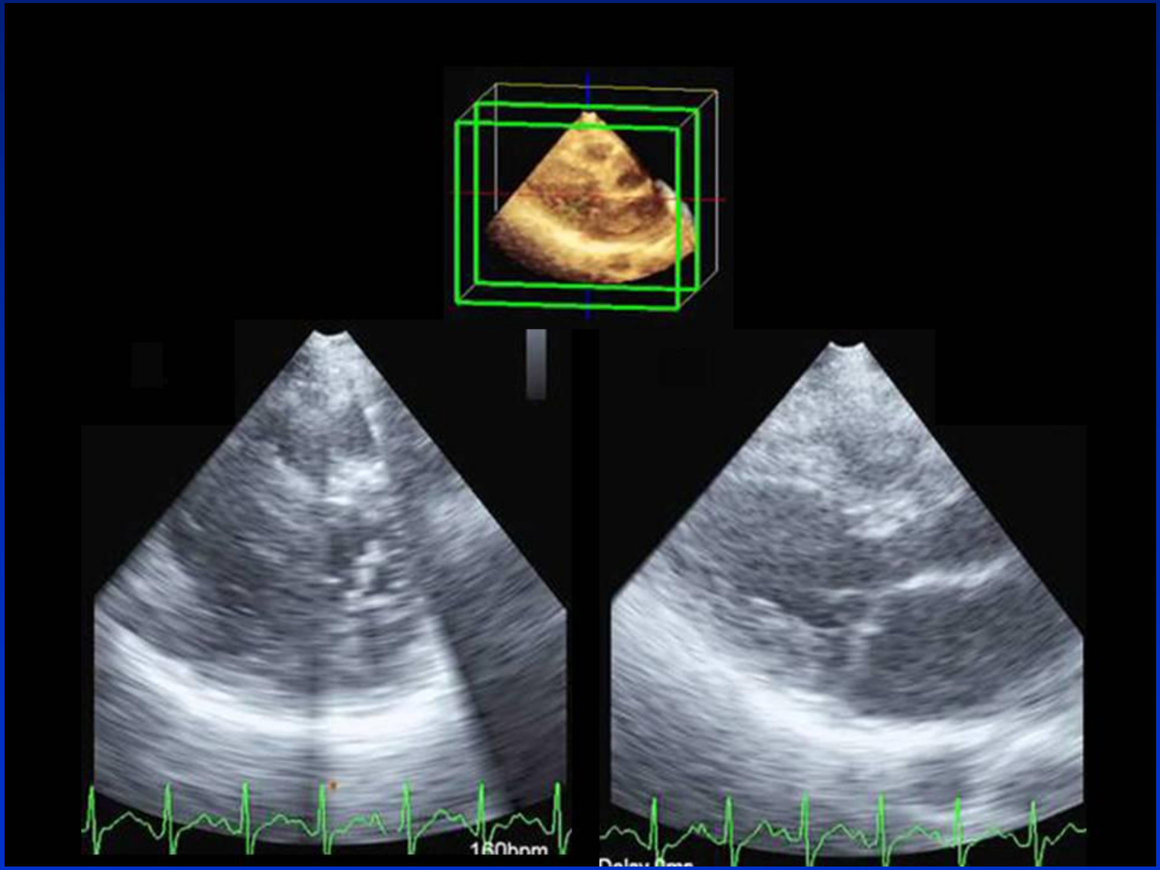
Value of 3D TTE quantitation of MS

Zamorano et al, JACC 2004:43:2091-96
Sebag et al, Am J Cardiol 2005;96;1151-6

- More precise than 2D planimetry
  - Reduced measurement variability
- Better classification of disease severity
- Particular benefit for less-experienced personnel
  - Even experts will notice time savings

- Current Challenges:
  - AF with variable response
    - If integrating multiple cardiac cycles into 3D volume

Stitch artifact due to respiration

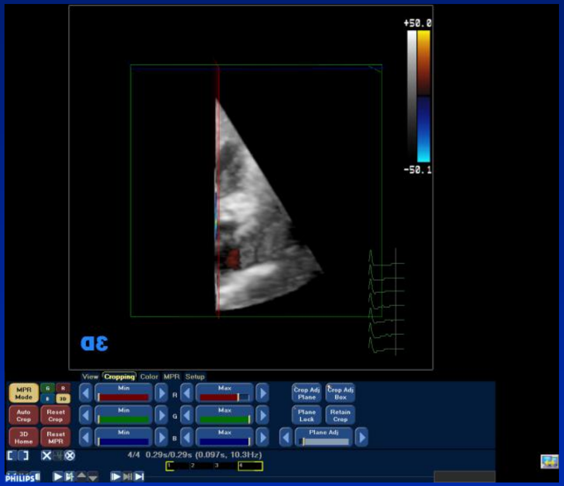


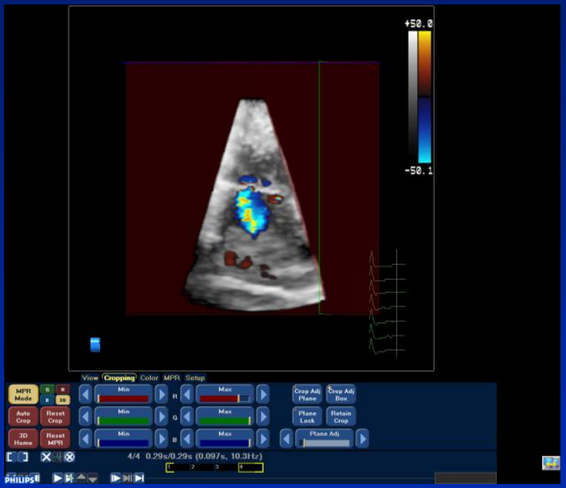
3D echo for valve disease: Mitral regurgitation

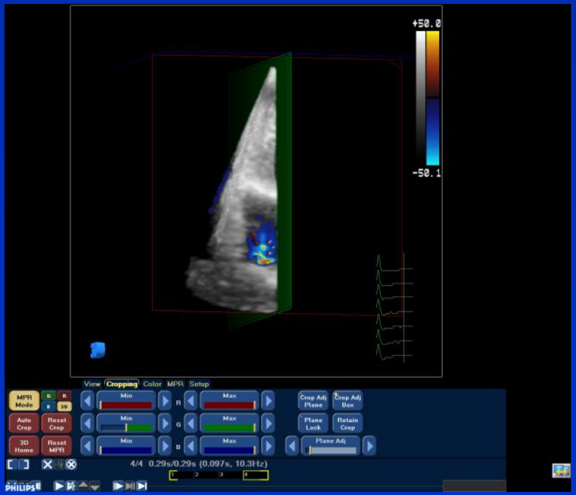
- Quantify severity of MR (Vena contracta, PISA)
- Delineate specific lesions responsible for MR
  - Degenerative, myxomatous, congenital, endocarditis
- Provide insights into mechanism of functional and ischemic MR
- By better understanding shape and anatomic relationships of surrounding structures, can assist in design of valve repair techniques and prosthetic supports (rings, etc)

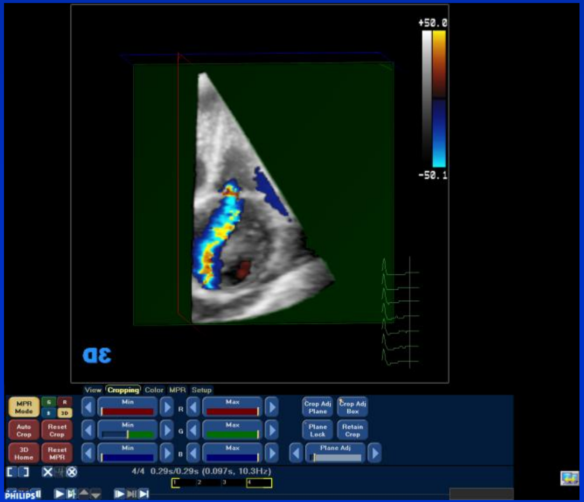
Quantifying MR by vena contracta area

1. acquire full volume
2. crop to get best display of jet

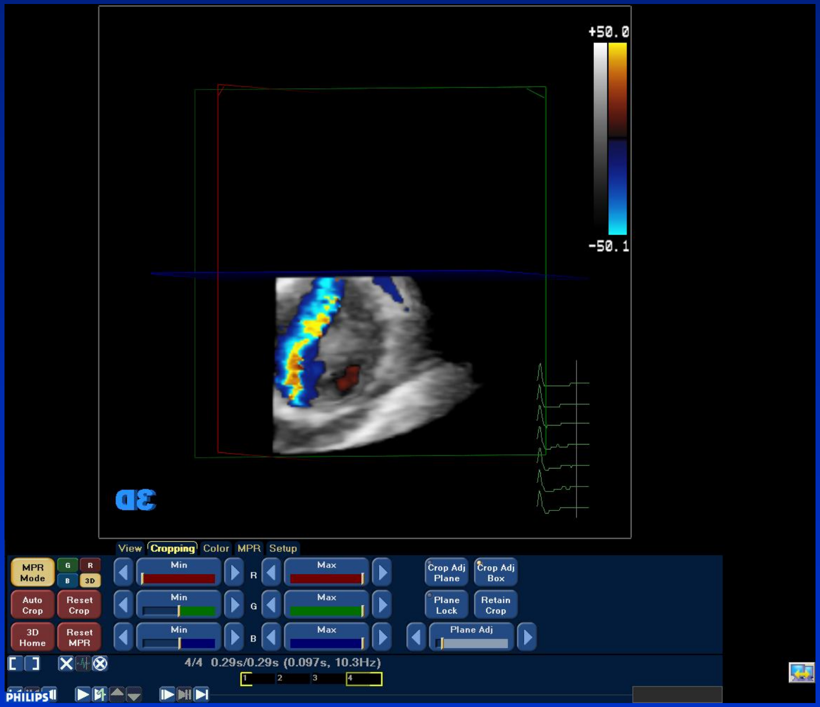


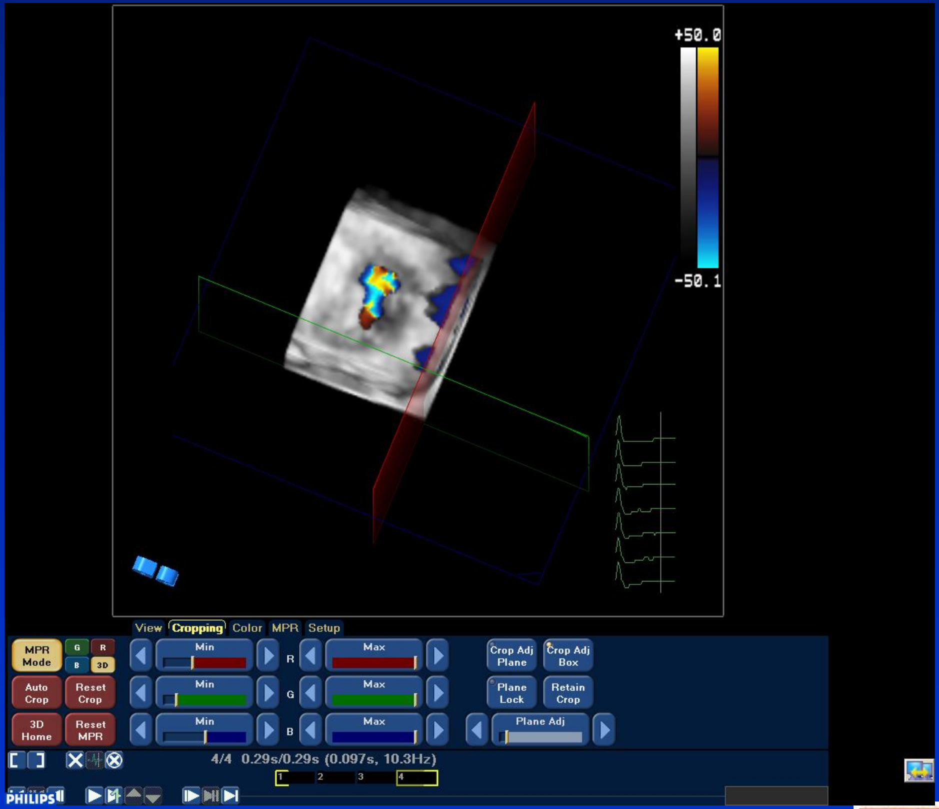




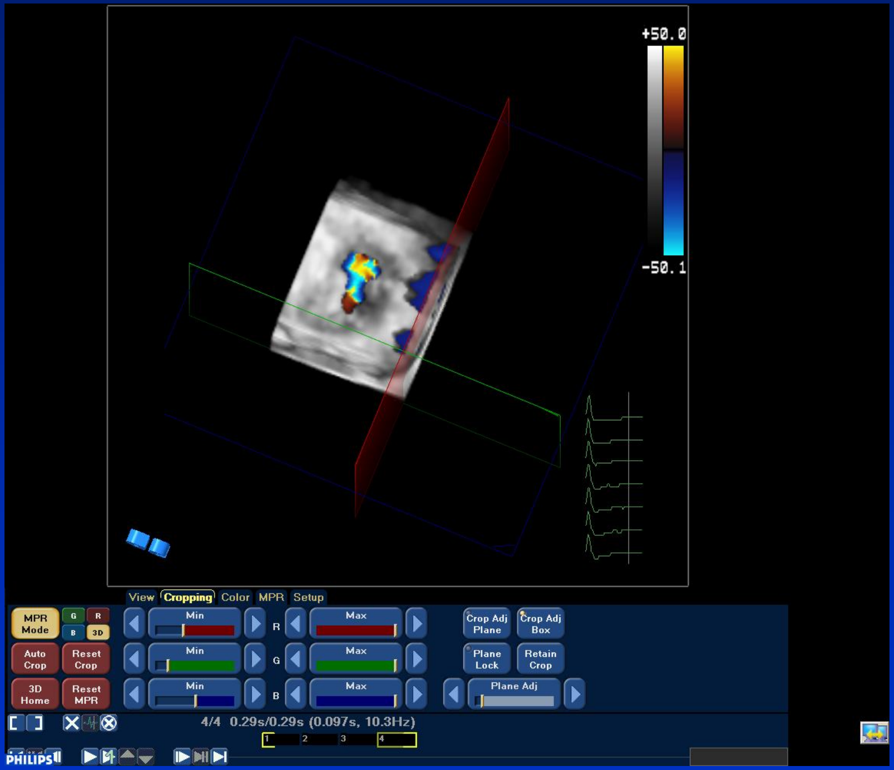


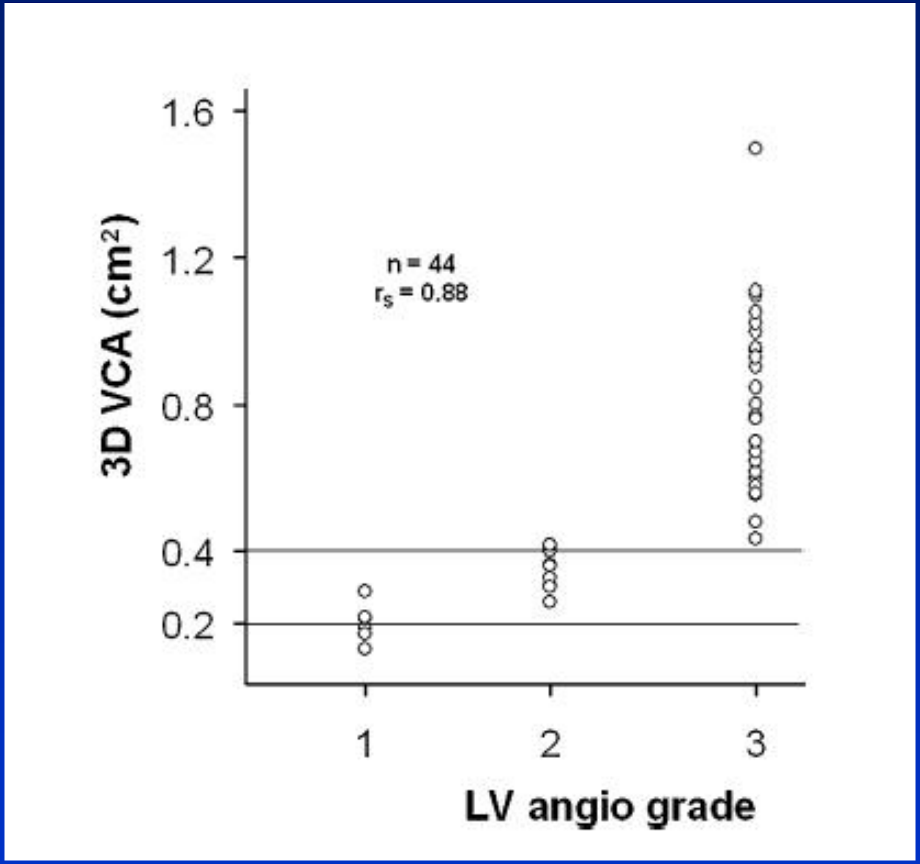
3. Crop in plane orthogonal to orifice (parallel to leaflets)
4.Rotate and display en face the smallest color jet area in LA immediately behind orifice
5. Planimeter vena contracta





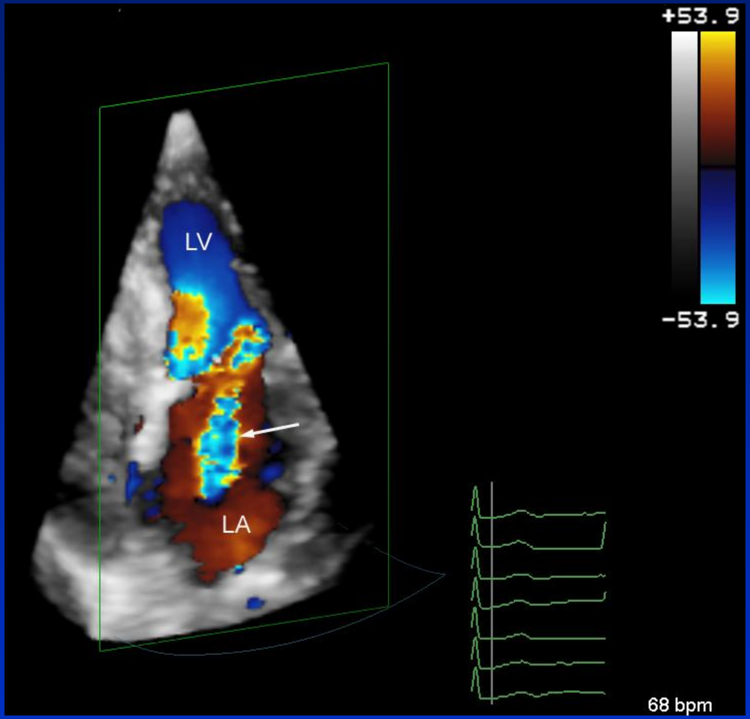
MR quantitation by RT3D
vena contracta area

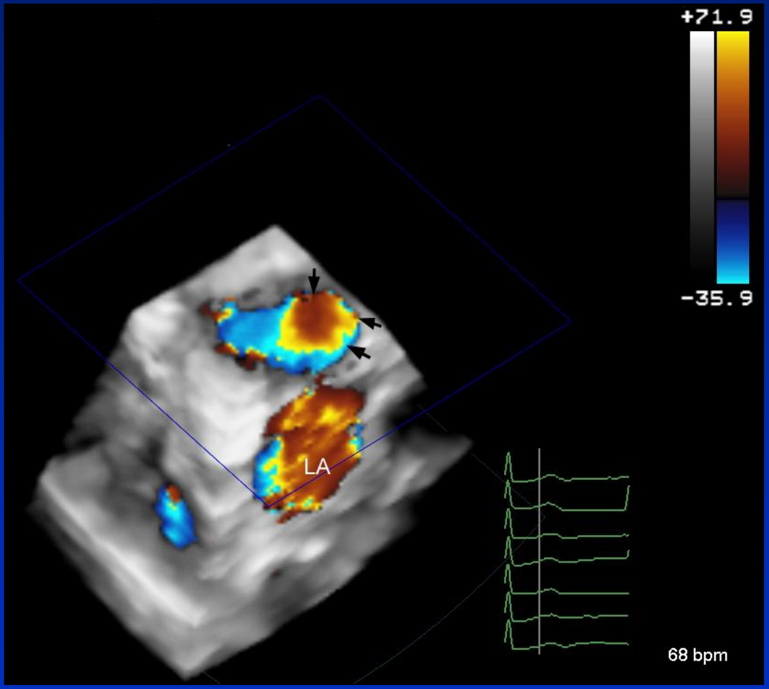




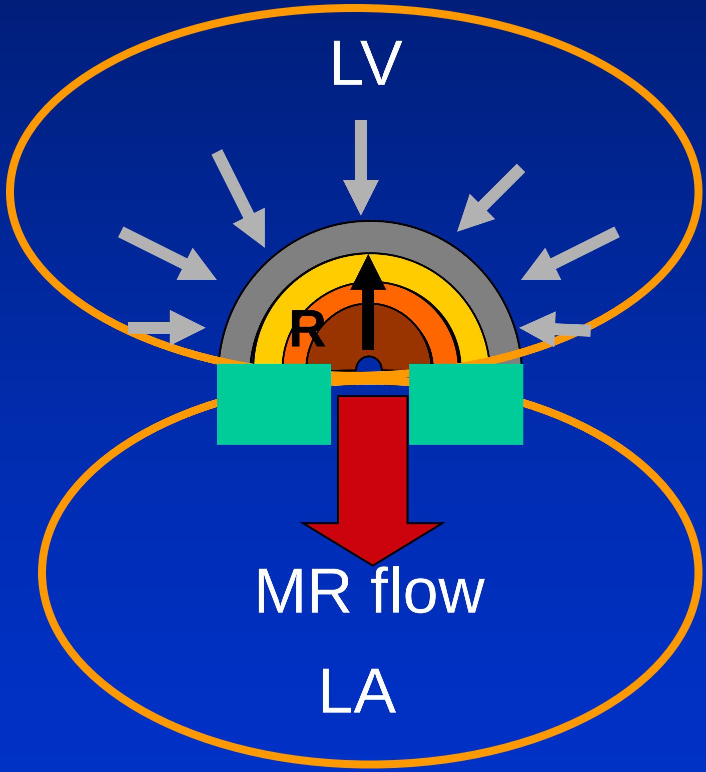
Khanna et al, Echocardiogr 2005

RT3D of PISA for MR

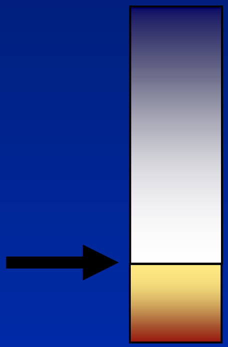




- Fluid dynamic theory predicts that as flow approaches a circular, finite orifice, it forms a series of concentric hemispheric shells with gradually decreasing area and increasing velocity.
- By conservation of mass, the flow rate of each one of the isovelocity hemispheres should equal the flow rate at the regurgitant orifice



Aliasing Velocity



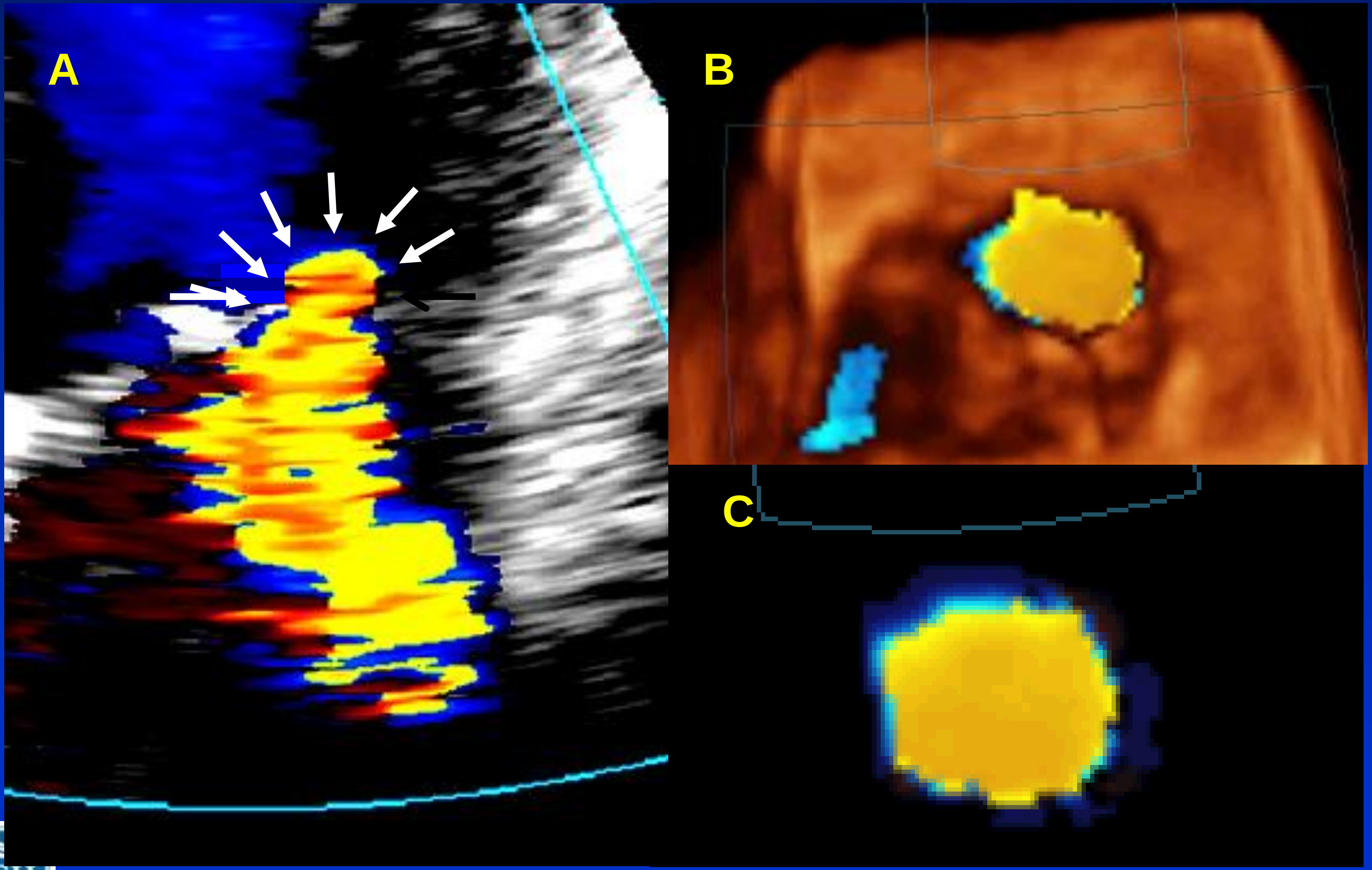
PFCR Area= $2\pi R^2$

Flow rate =

Surface Area x Velocity

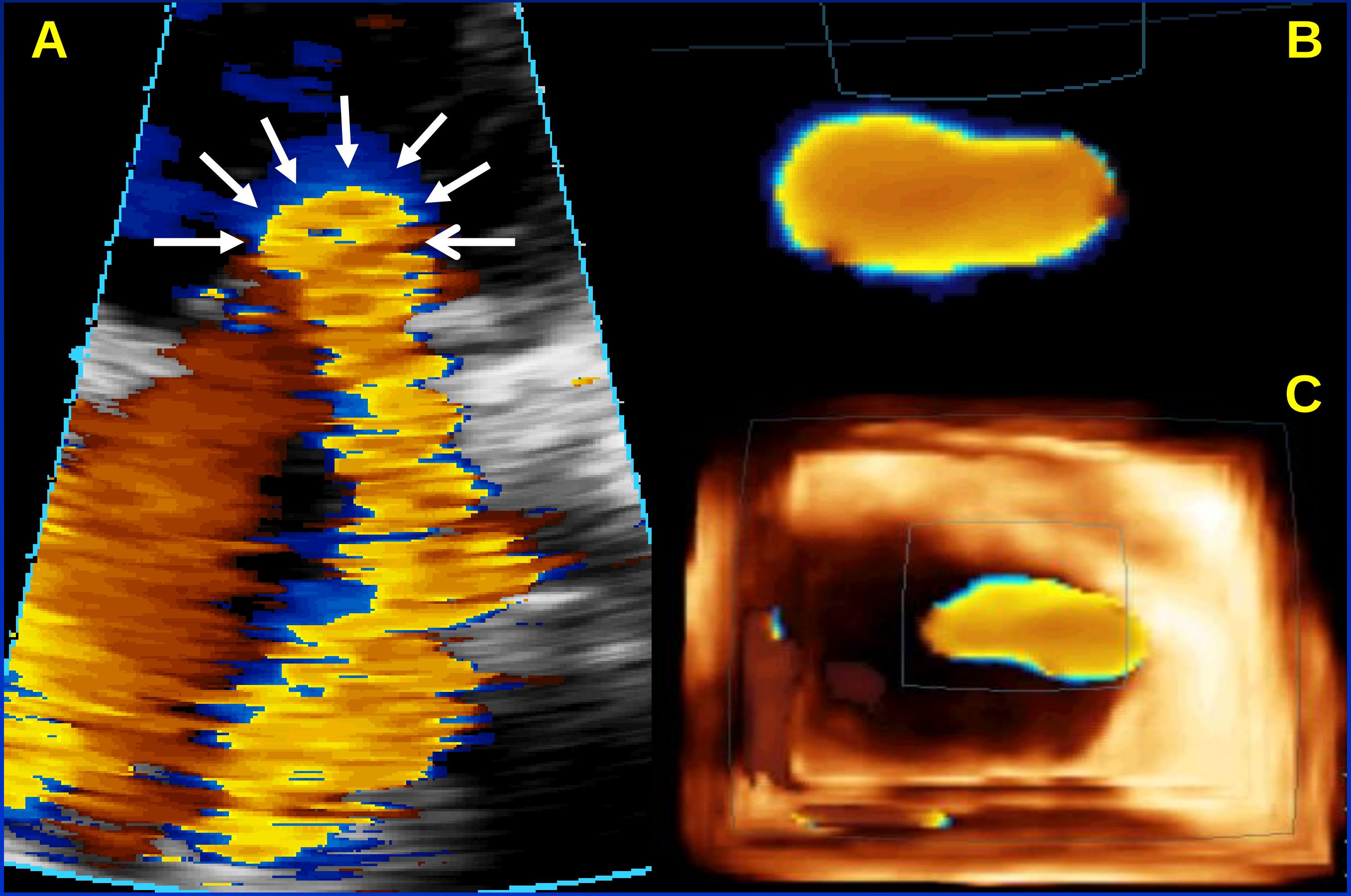
Is the hemispherical assumption for PFCR valid for the mitral valve ?

A hemispherical PFCR by 2D (A, arrows) and by 3D (B, C) seen in this patient with functional MR.



Yosefy et al JASE 2007:20:389-96

A patient with dilated cardiomyopathy with a typical hemispherical PFCR by 2D (A, arrows); yet the PFCR contour is actually hemielliptical as shown by 3D (B, C).



Yosefy et al JASE 2007:20:389-96

2D proximal flow convergence region (PFCR) underestimated effective regurgitant orifice area (EROA) compared to the quantitative Doppler (Doppler Q) method .

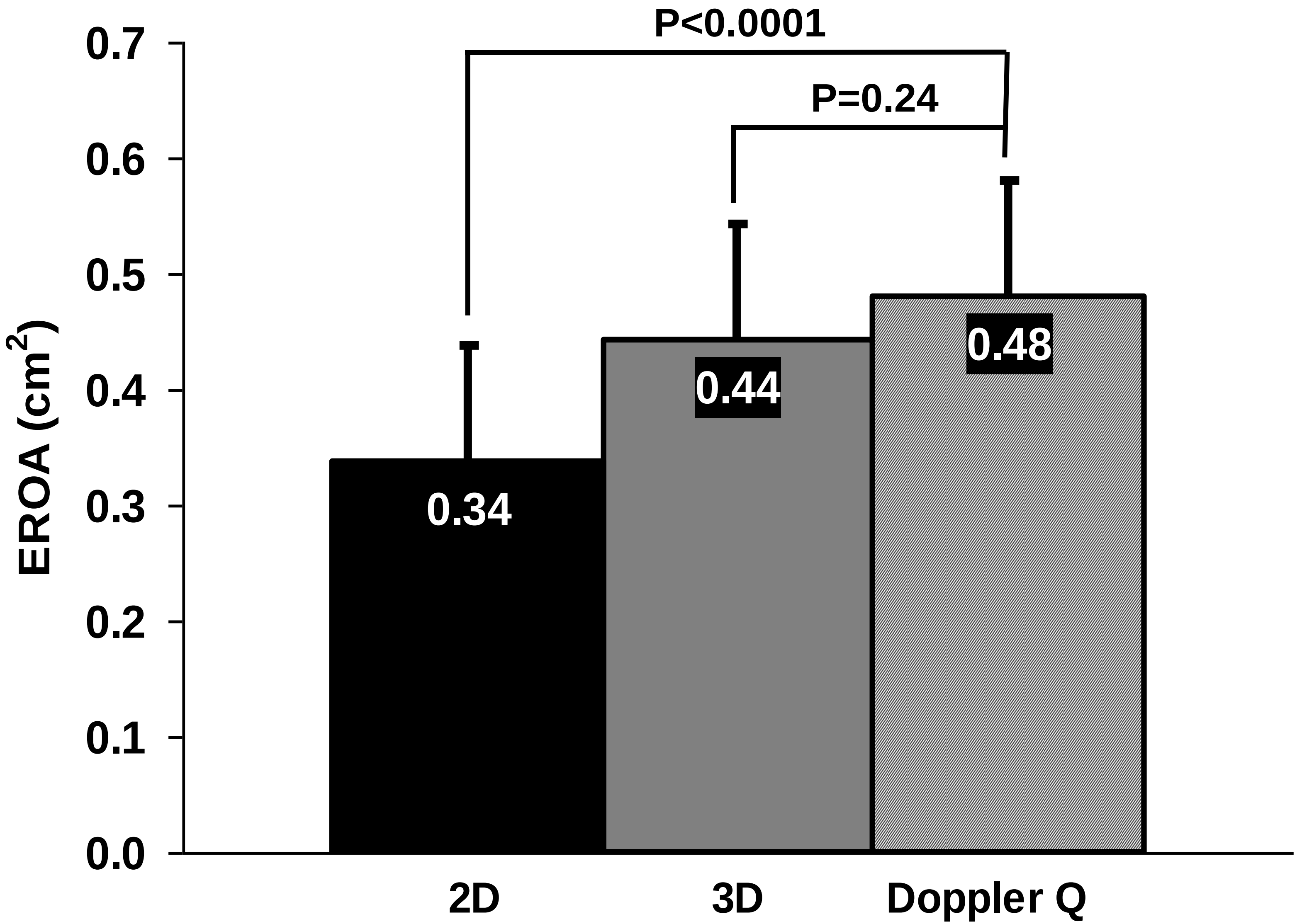
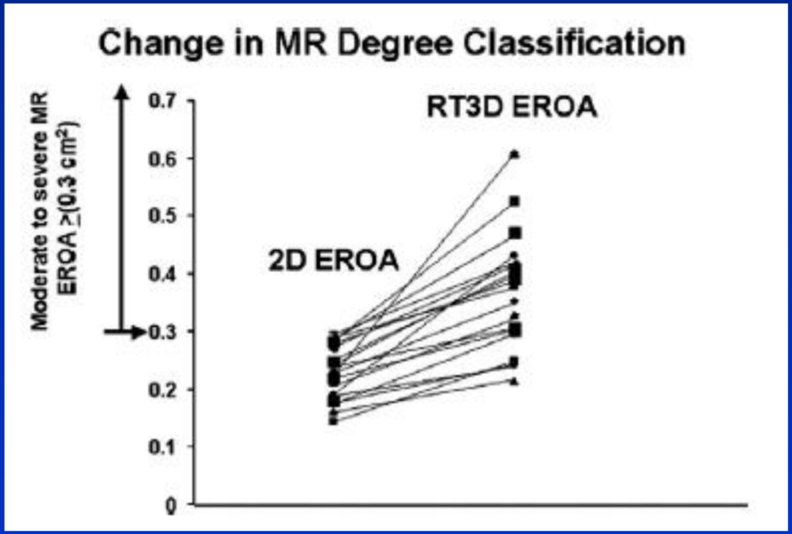


Figure 4

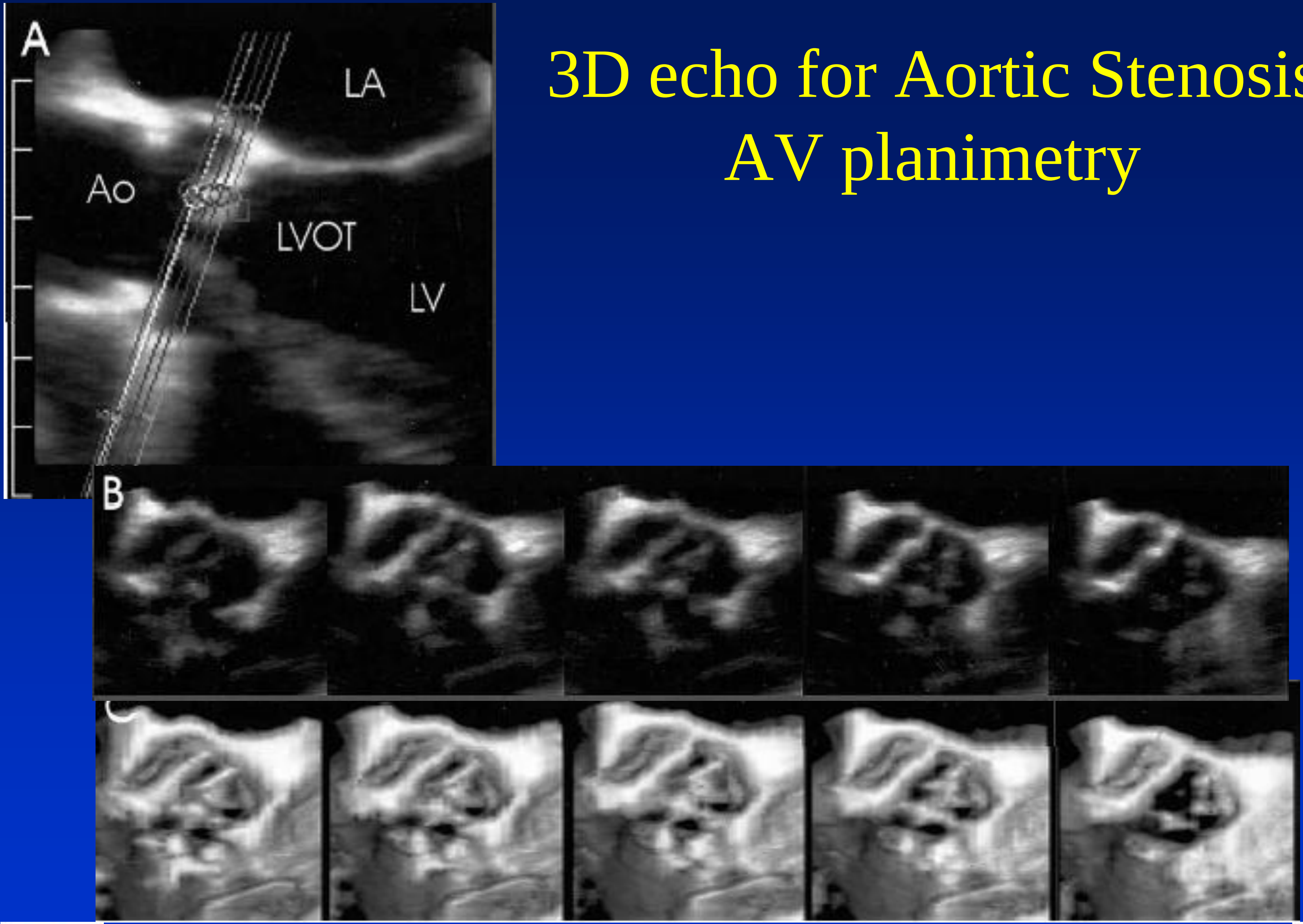
Yosefy et al JASE 2007:20:389-96

2D misclassified 56% (14/25) as mild-to-moderate with nearly half of those (25% of the total) misclassified as mild– versus (1/25) 4% misclassified as mild-to-moderate by the simplified RT3D method.



Yosefy et al JASE 2007;20:389-96

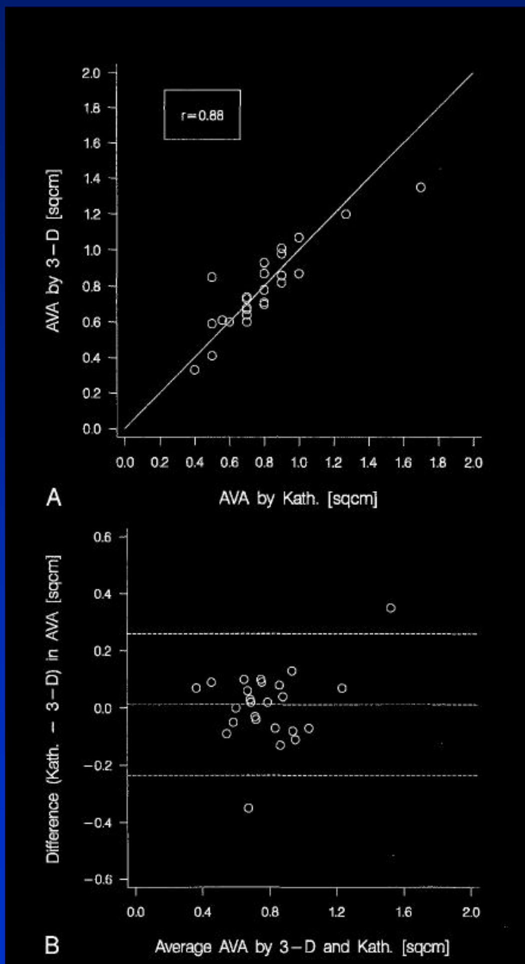
3D echo for Aortic Stenosis
AV planimetry



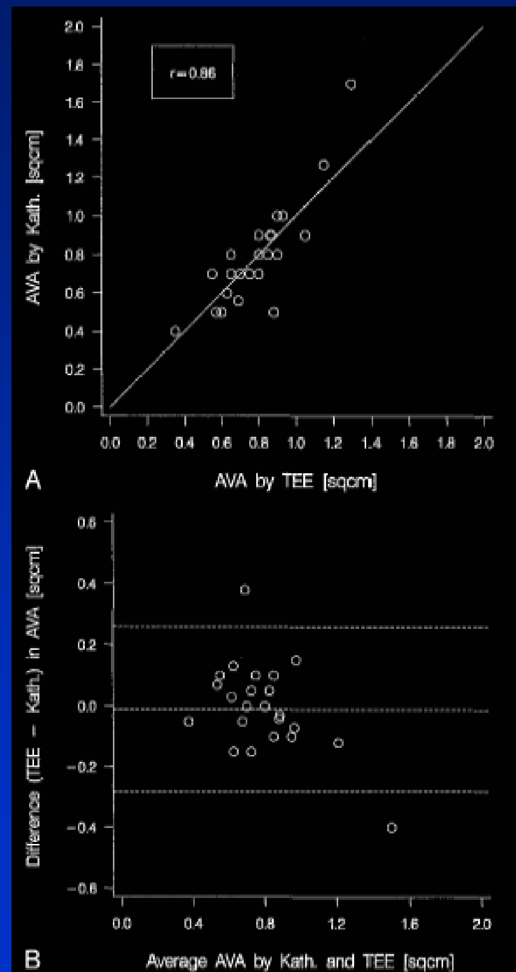
Handke et al, Echocardiography 2002;19:45-53

AS quantitation: 3D TEE comparable to 2D

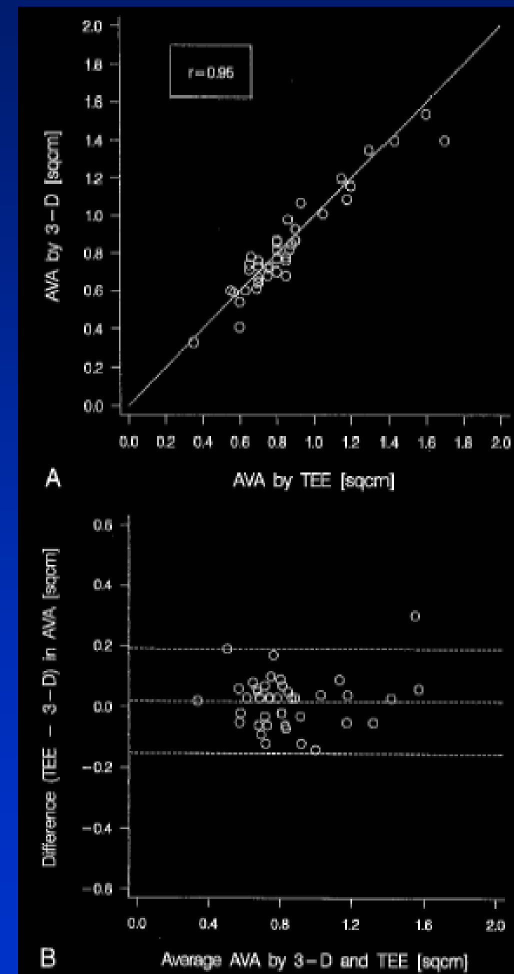
3D vs gorlin



2D vs gorlin



3D TEE vs 2D TEE



Menzel et al JASE 1997;10:215-23

Rapid recognition of AS etiology

Viewed from aorta

Viewed from LV

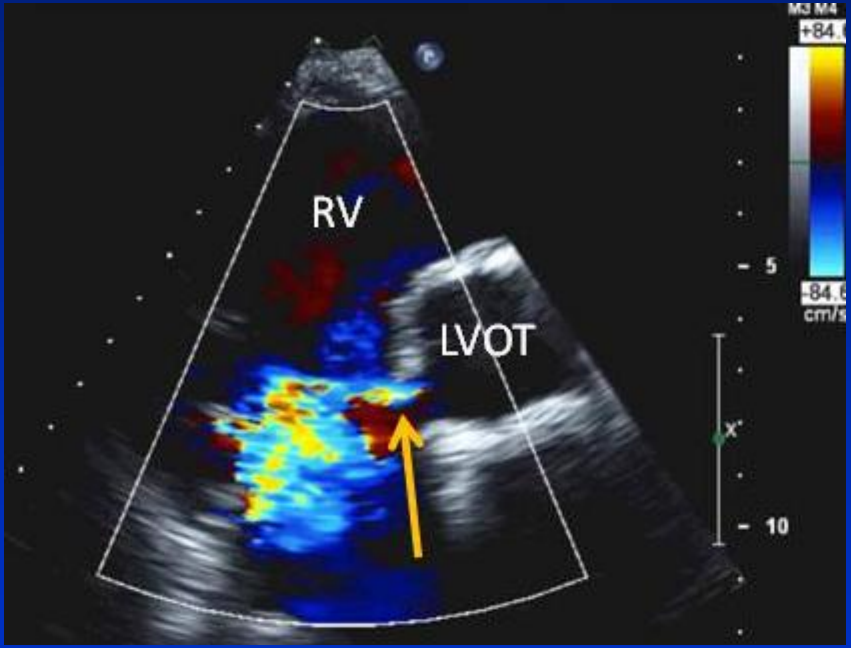
3D echo for valve disease: aortic insufficiency

- Improved quantitation
  - PISA, Vena contracta as for MR
- Mechanism of AR
- Quantitation of structural relationships
  - Important for valve repair of AI
    - Sinotubular junction to coaptation, STJ to annulus, annulus to coaptation, annulus, STJ

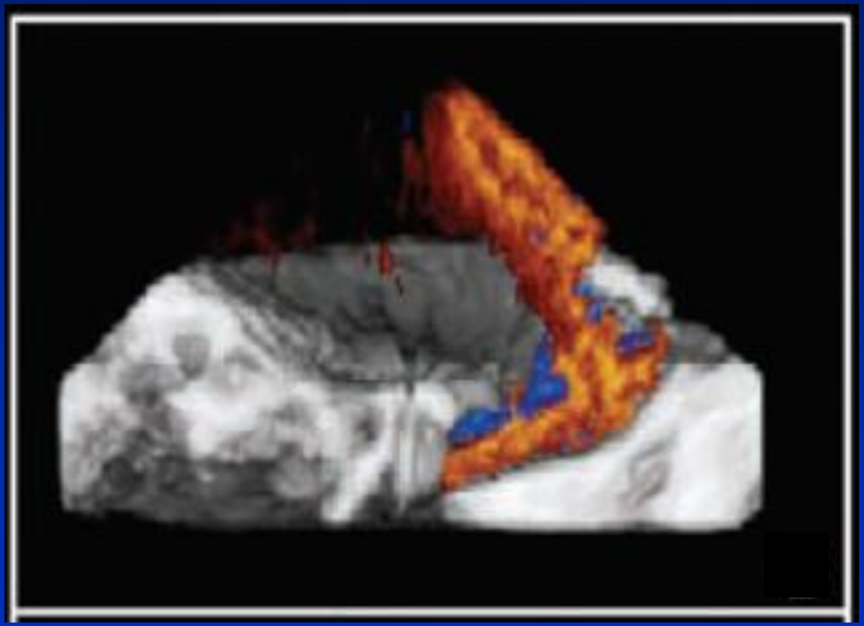
Value of 3D echo: visualizing spatial relationships

- Accurate localization of redundant portion of MVP leaflet
- Localizing cardiac masses
- Complex regurgitant color jets
- Congenital heart disease

Identifying small membranous VSD



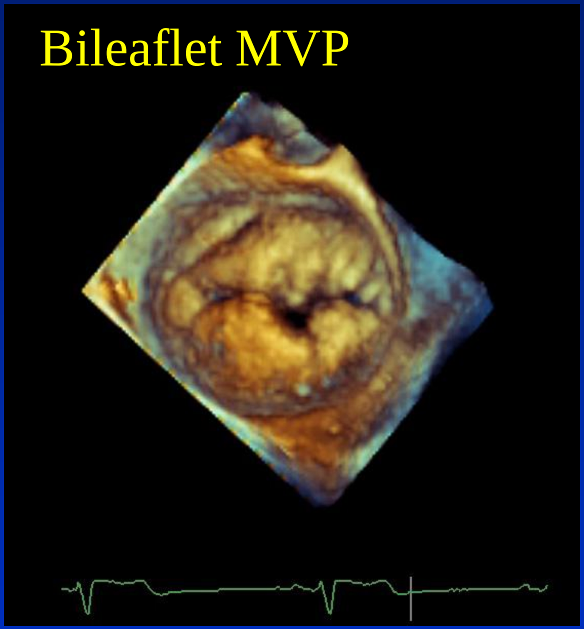
Rapid recognition of MR mechanisms



Prosthetic MV dehiscence

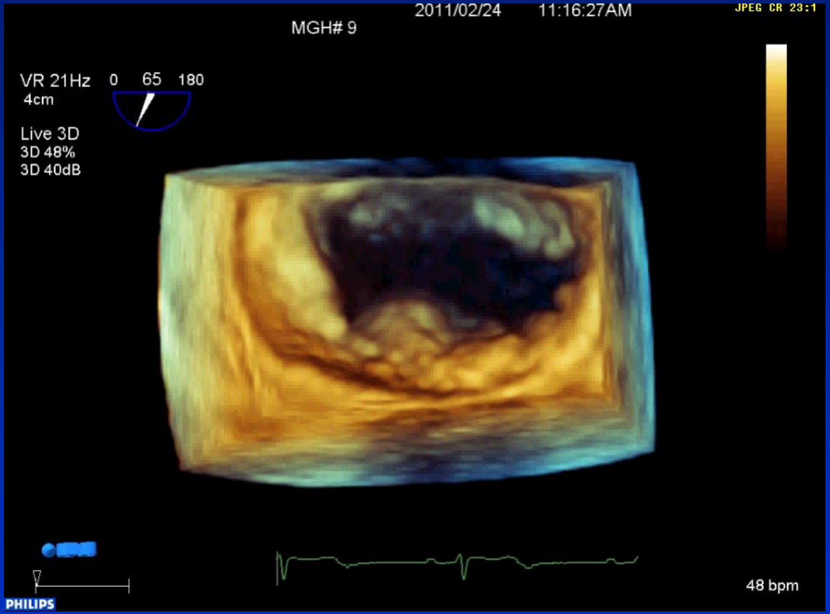
Sugeng et al, Echocardiography 2003;20:265-273

3D TEE of MVs viewed from LA



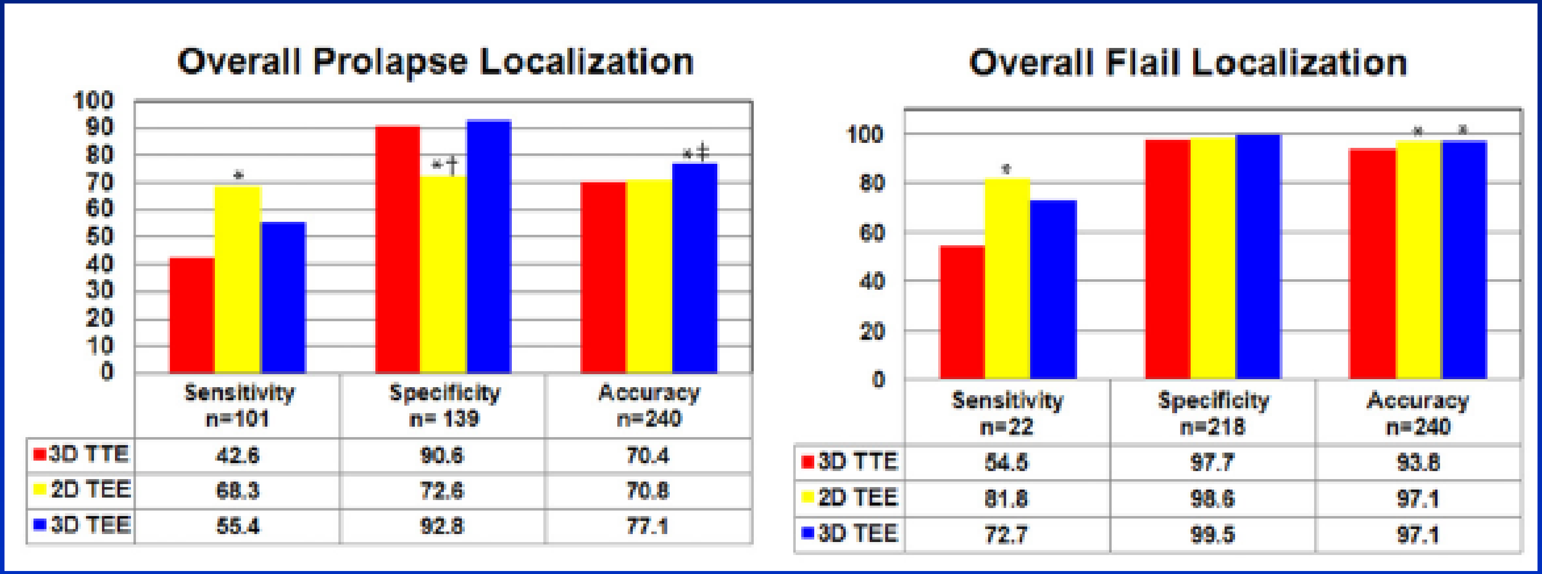
Johri et al, Br Hrt J. 2010;96;390-397

Posterior leaflet MVP



Comparative accuracy of 2D and 3D TTE and TEE in identifying MV pathology in patients undergoing MV repair

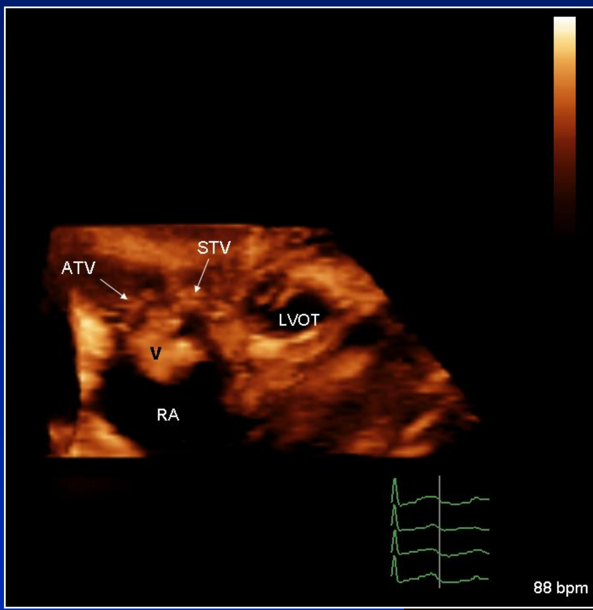
Zekry et al, JASE 2011;24;1079-85

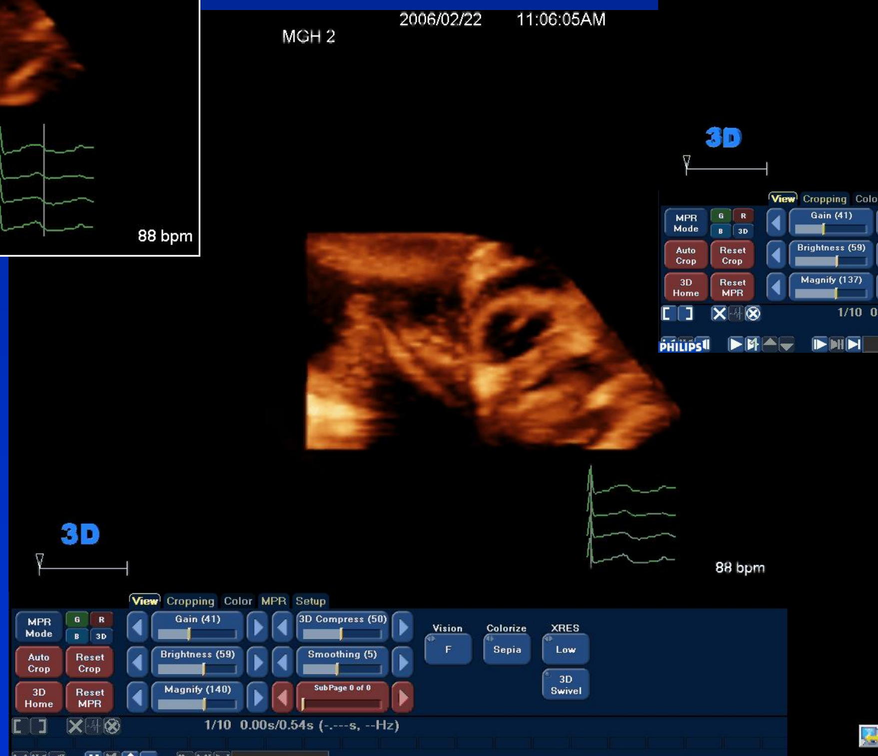


All modalities equally reliable for functional MR.
2D TEE and 3D TEE comparable for diagnosis of MR mechanism but 3D TEE had advantage of better localizing lesions

3D echo for valve disease: unique views of valves

- Localizing vegetations and other lesions





Value of 3D echo

real time guidance of catheter-based interventional procedures

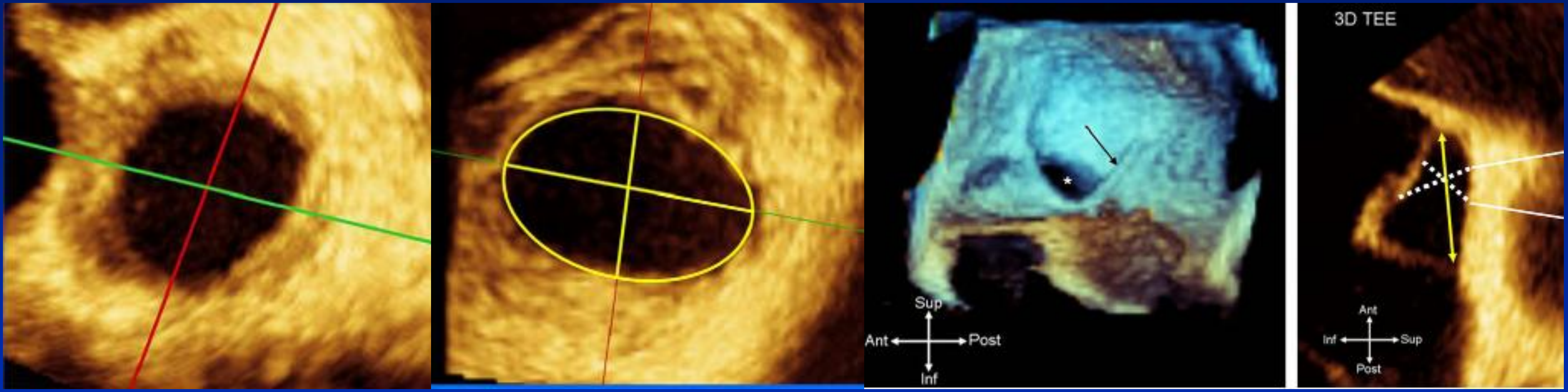
- PFO / ASD closure
- Closure of Paravalvular leaks
- Deployment of left atrial appendage closure devices
- Percutaneous AV replacement and MV repairs

MGH 1811

VE RI TAS

3D TEE provides more accurate depiction of ASD shape than 2D TEE and improves device selection and reduces residual leaks

circular oval complex

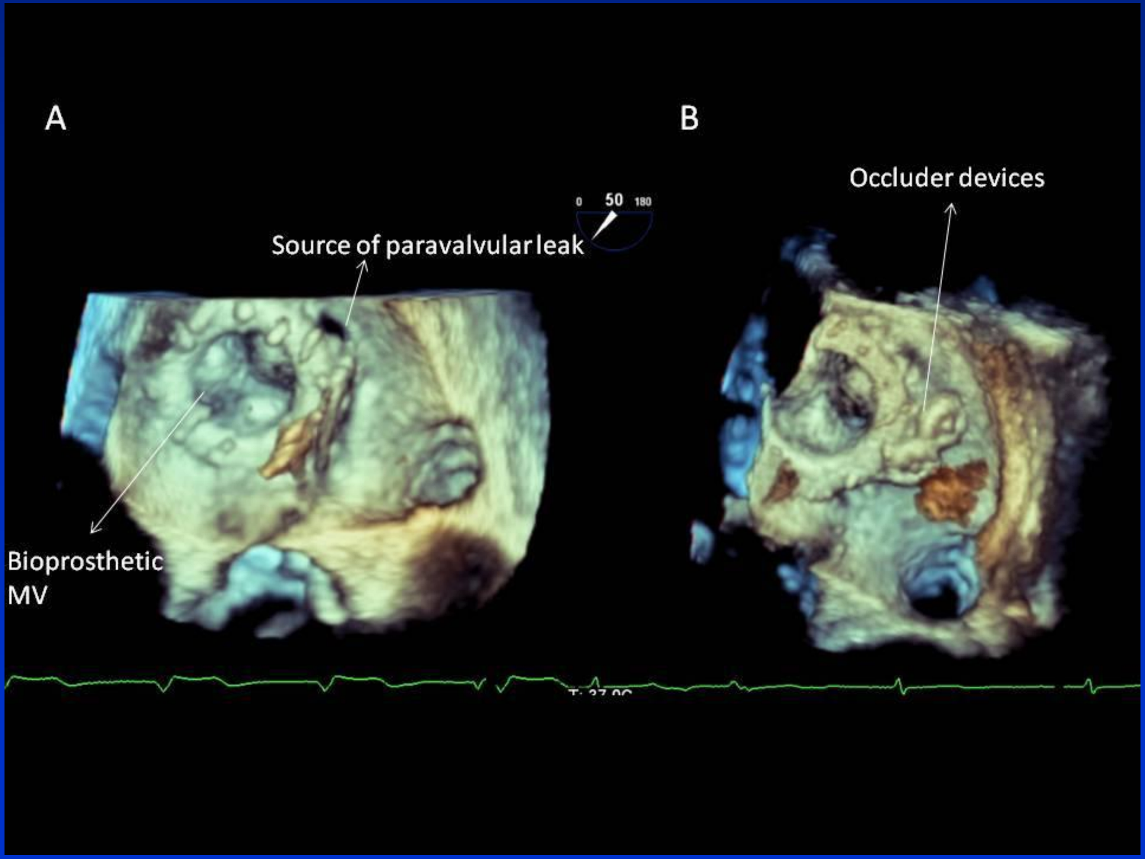


Defect area and maximal dimensions underestimated by 2D TEE in the complex ASDs

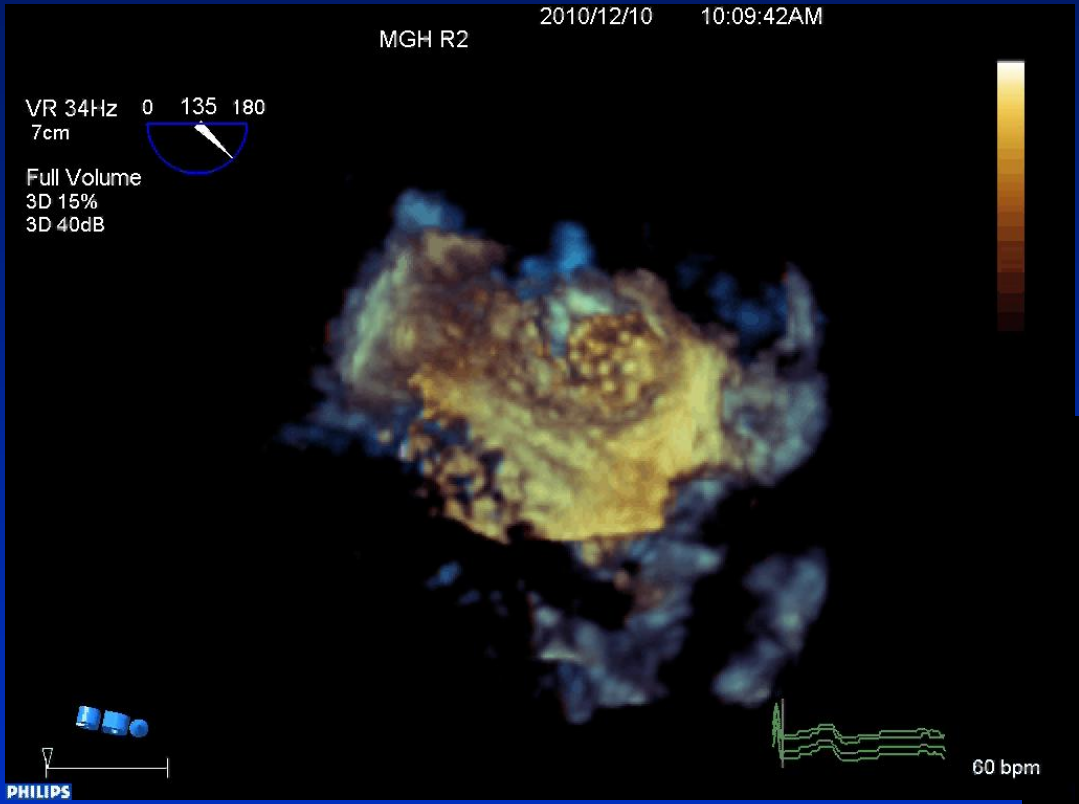
Johri et al, JASE 2011;24:431-7

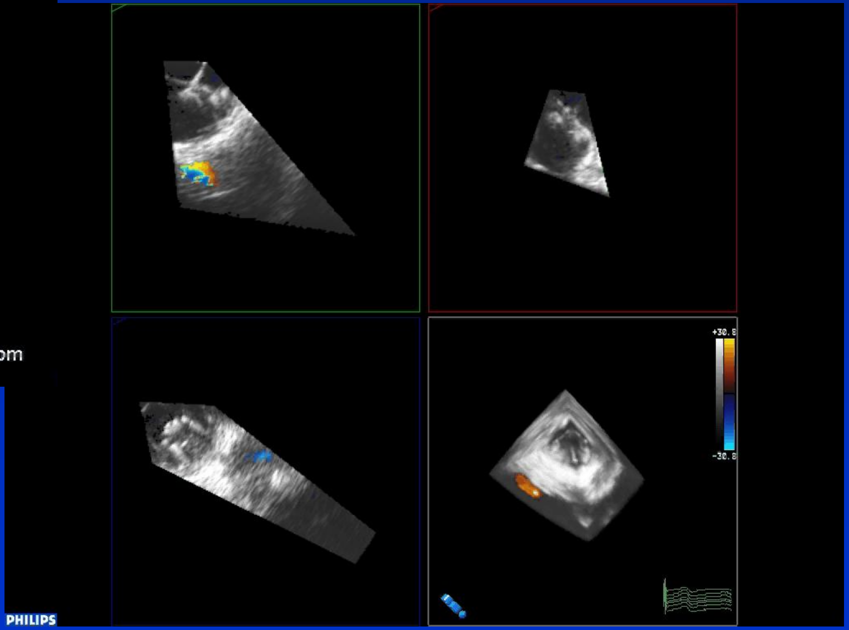
Real-time 3D TEE-guided catheter based repair of severe paravalvular regurgitation in prosthetic valves

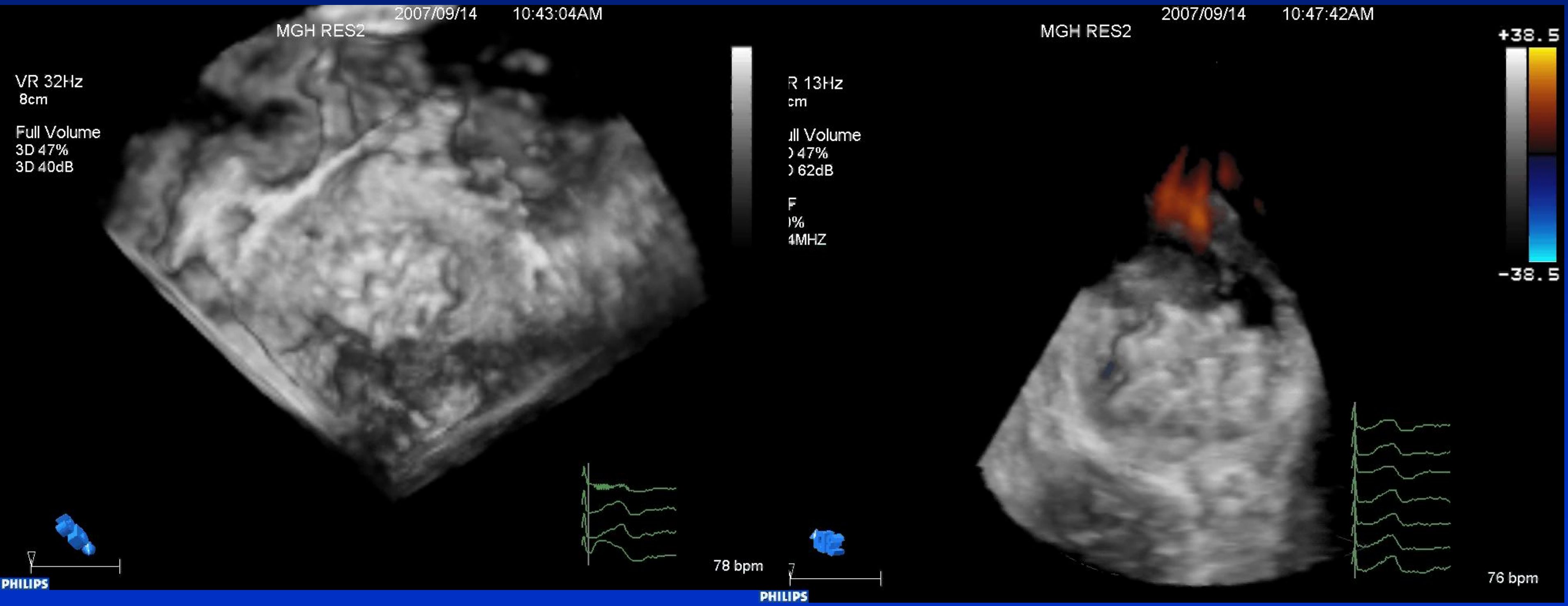
Johri et al, Eur J Echocardiogr 2009;10:572-5



Left atrial appendage closure







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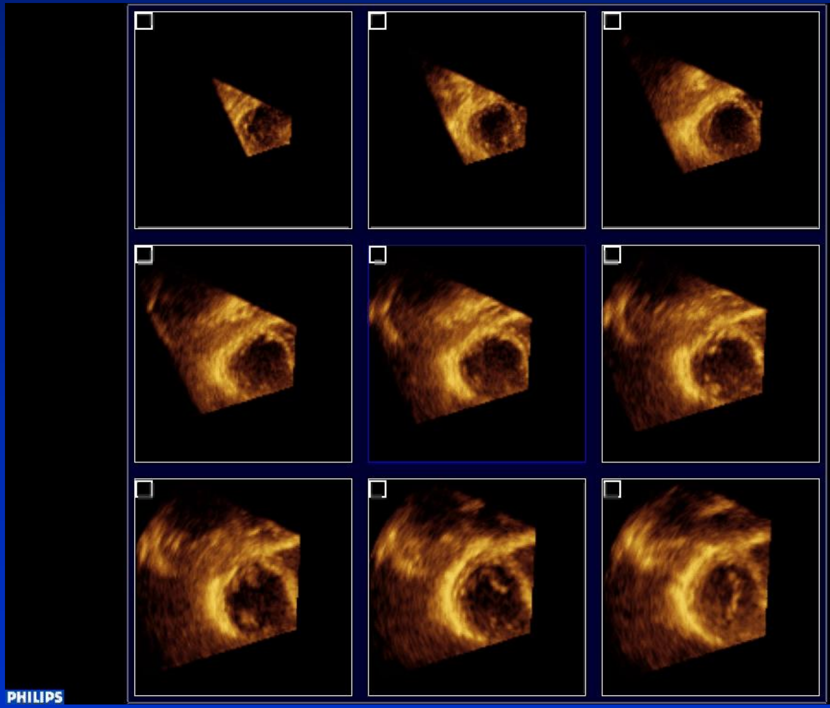
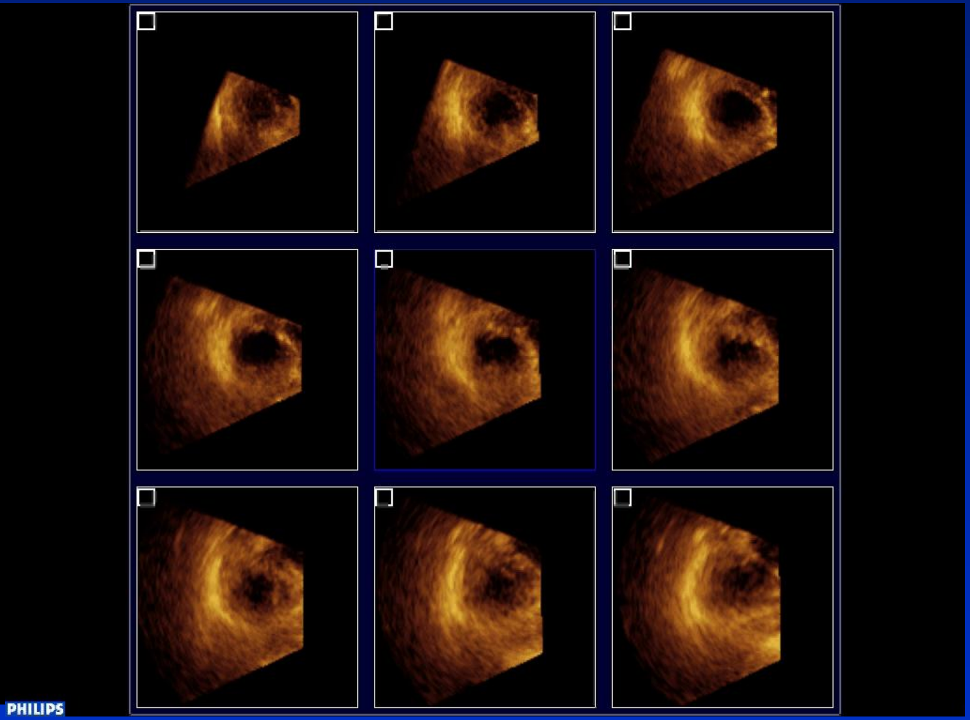
MGH RES2
VR 32Hz
8cm
Full Volume
3D 47%
3D 40dB
78 bpm
PHILIPS
2007/09/14 10:47:42AM
MGH RES2
+38.5
-38.5
R 13Hz
cm
ıll Volume
) 47%
) 62dB
F
)%
4MHZ
76 bpm
PHILIPS

Future uses of 3D echo

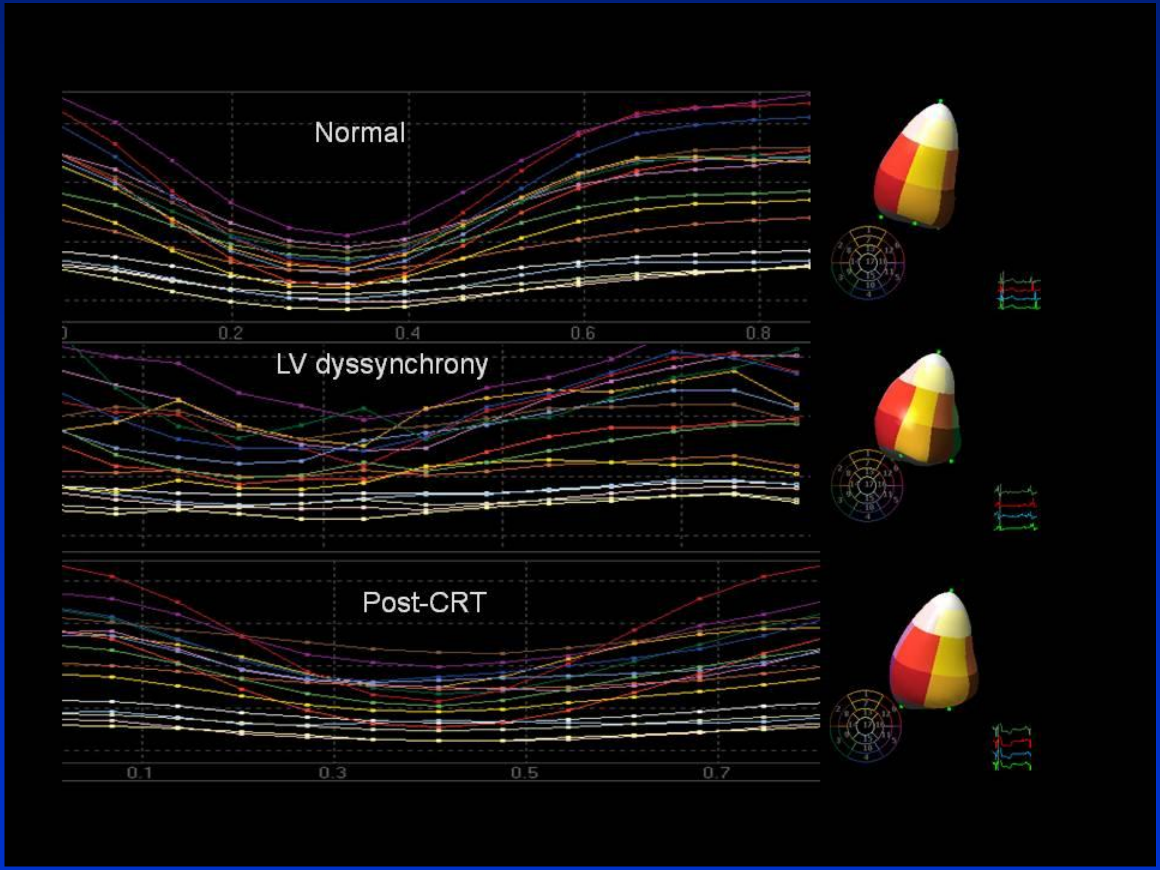
- RV volume
- Valvular heart disease
  - Quantitation of valve regurgitation
    - Vena contracta
    - PISA
    - Direct planimetry ROA
  - Quantitation of AVA
    - More accurate LVOT area
- Stress echo
- LV dyssynchrony
- Fusion imaging

3D stress echo

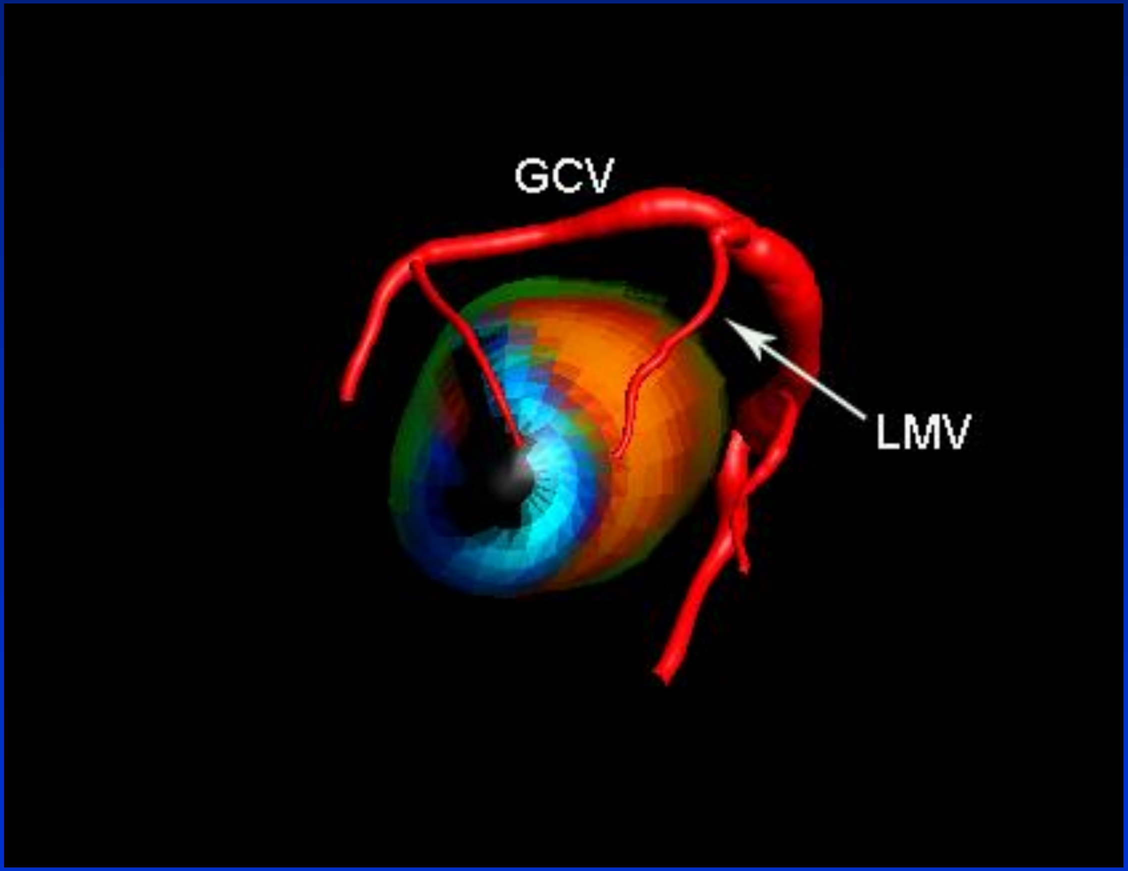




3D for CRT



Fusion imaging
3D LV volume and dysynchrony map integrated with 3D coronary venogram

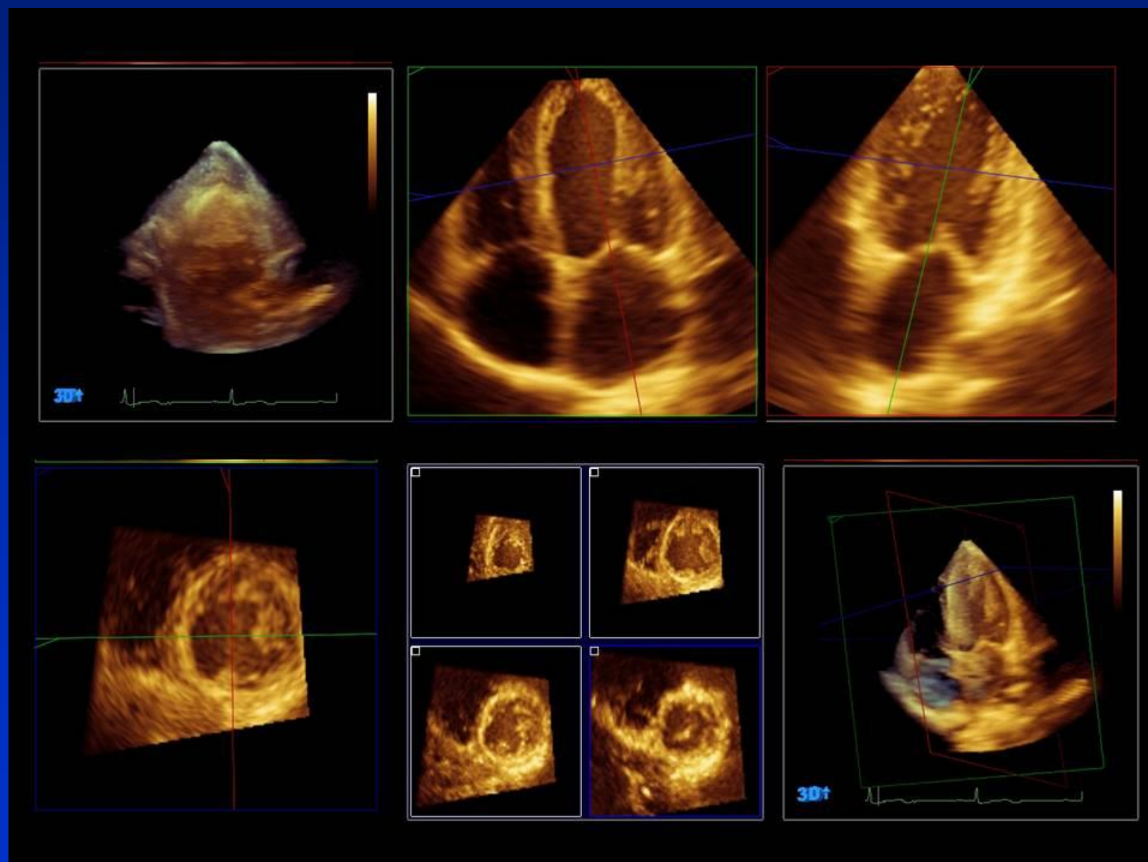


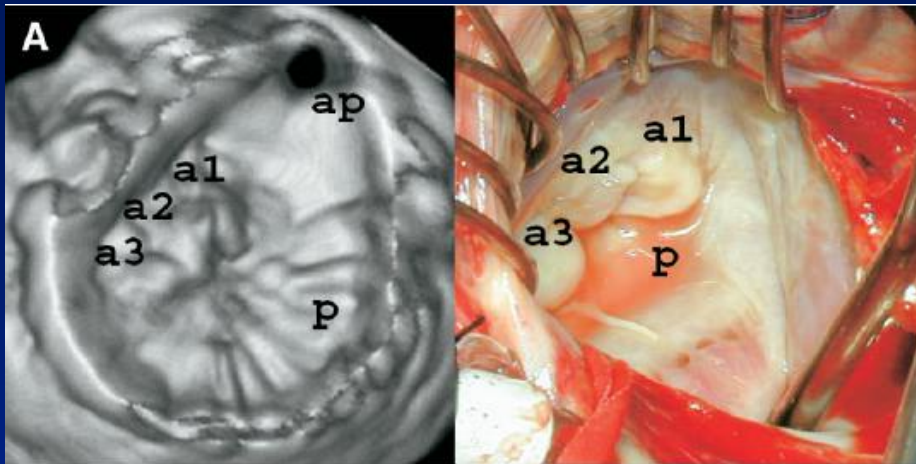
3D echocardiography 2011
Challenges remain

- Technology diffusion
  - Hands-on training
- Continued technologic enhancements
  - Higher frame (volume) rate acquisitions
    - Single beat full volumes
  - Image quality (TTE)
  - Processing time
    - Automated cropping

3D echocardiography 2011

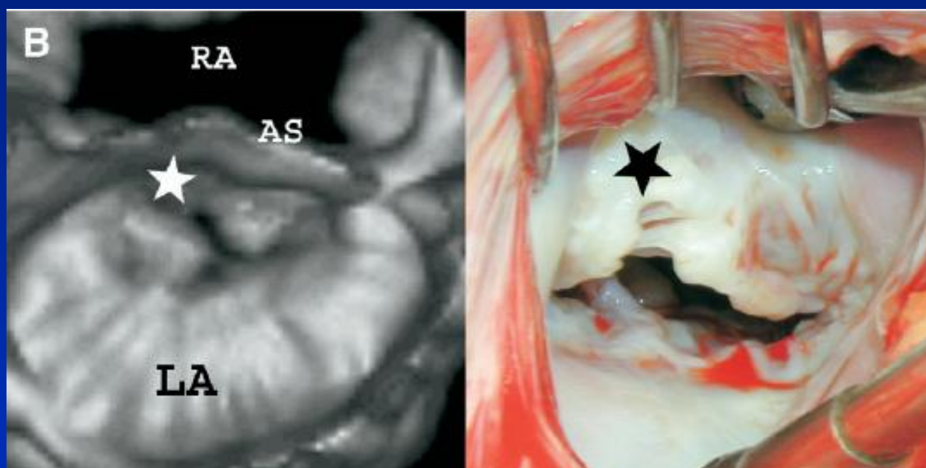
- Clear uses today with advantageous over 2D
  - Visualizing spatial relationships between structures
  - Assessment of valvular heart disease
  - TTE
    - Quantitation of LV volume, EF, mass, LA volume
    - Improved quantitation of valve area, severity of regurgitation
  - TEE
    - MV morphology, improved visualization of pathologies
      - Enhanced communication with surgeons
    - Guiding interventional procedures


3D
3D



TEE 3D reconstructions to guide MV repair

Garcia-Orta et al, JASE 2007;20:4-12

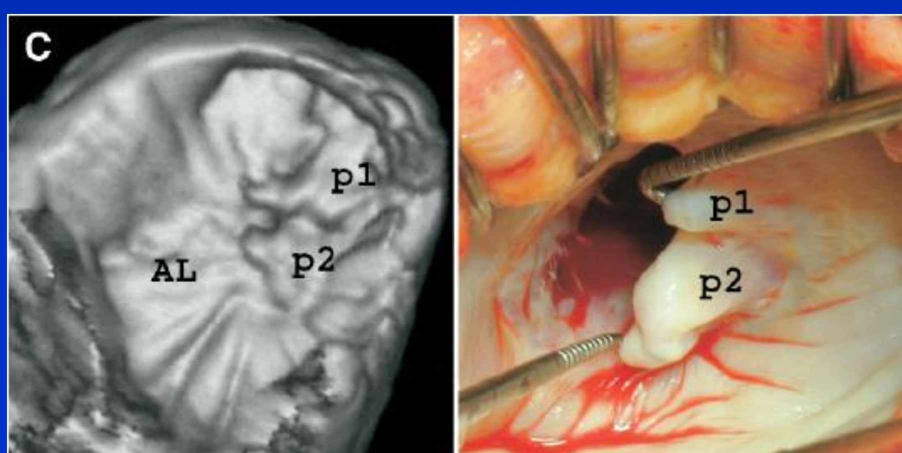


1) 3D better than 2D TEE for:

A1 segment involvement,
Commissural involvement

2) No difference for:

A2, A3, P1, P2, P3,
Leaflet perforation,
annular dilation,
ruptured chords



3) 2D less accurate than 3D:

# of segments involved, two leaflet prolapse, multi-segment prolapse, commissural ds