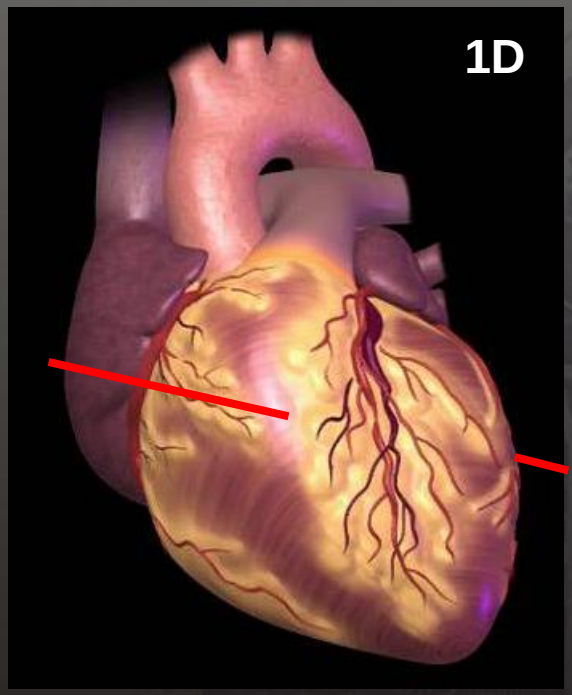
Clinica Cardiologica
Università degli Studi di Padova
Direttore: Prof. Sabino Iliceto

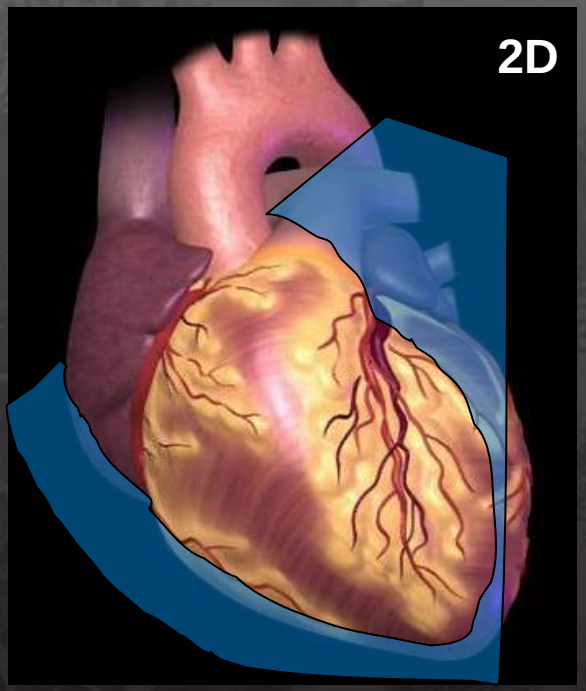
3D ECHO TO ASSESS LEFT VENTRICULAR GEOMETRY AND FUNCTION

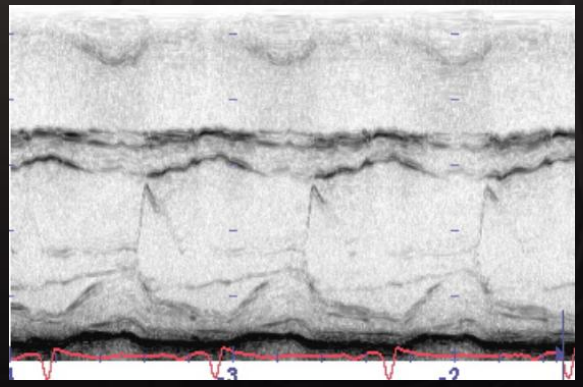
Luigi P. Badano**, MD, FESC

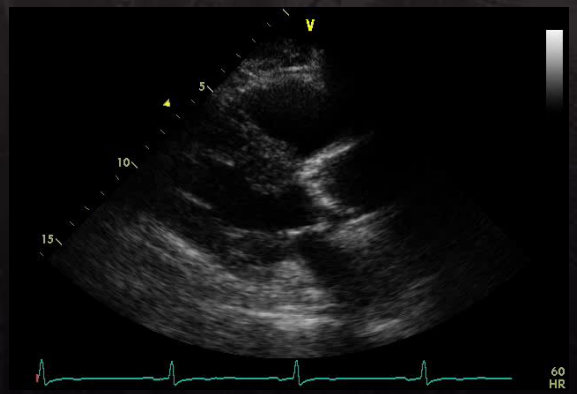
****Dr. Badano has received honoraries and research grants from GE Healthcare, Sorin cardio S.p.A., Actelion, Edwards Lifesciences**
***No off-label use of device**

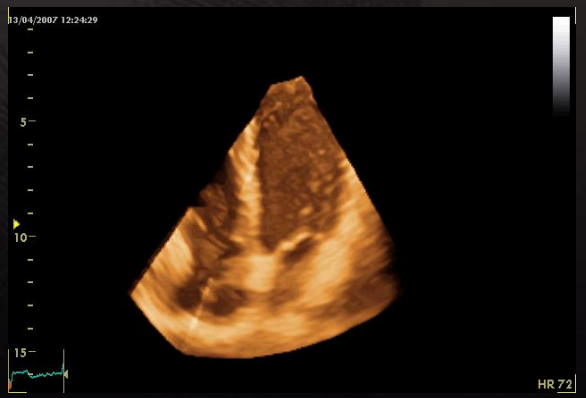
PROGRESS IN ULTRASOUND TECHNOLOGY







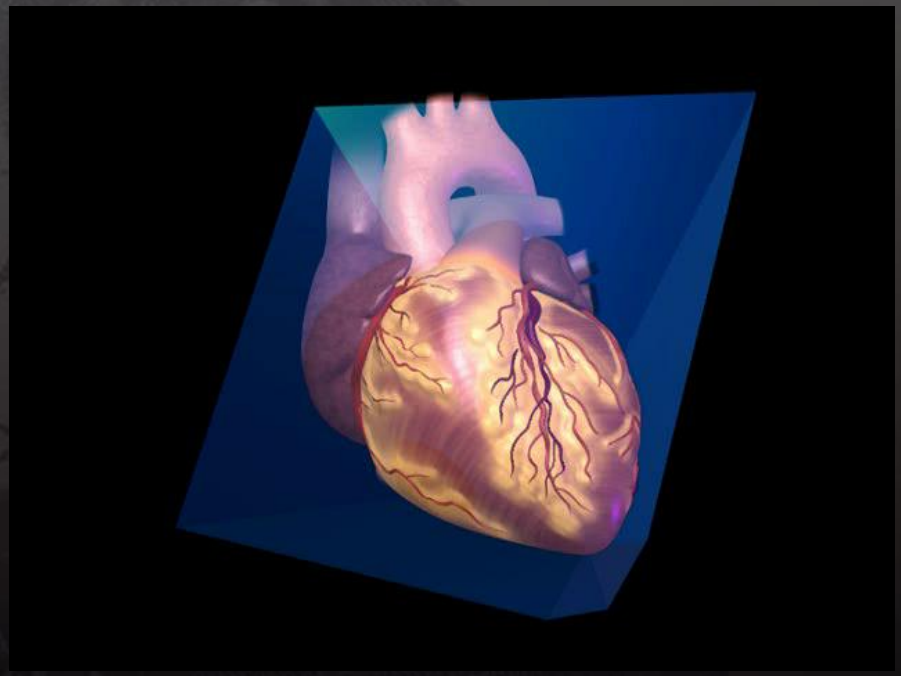




Edler 1959 ⟶ 2002

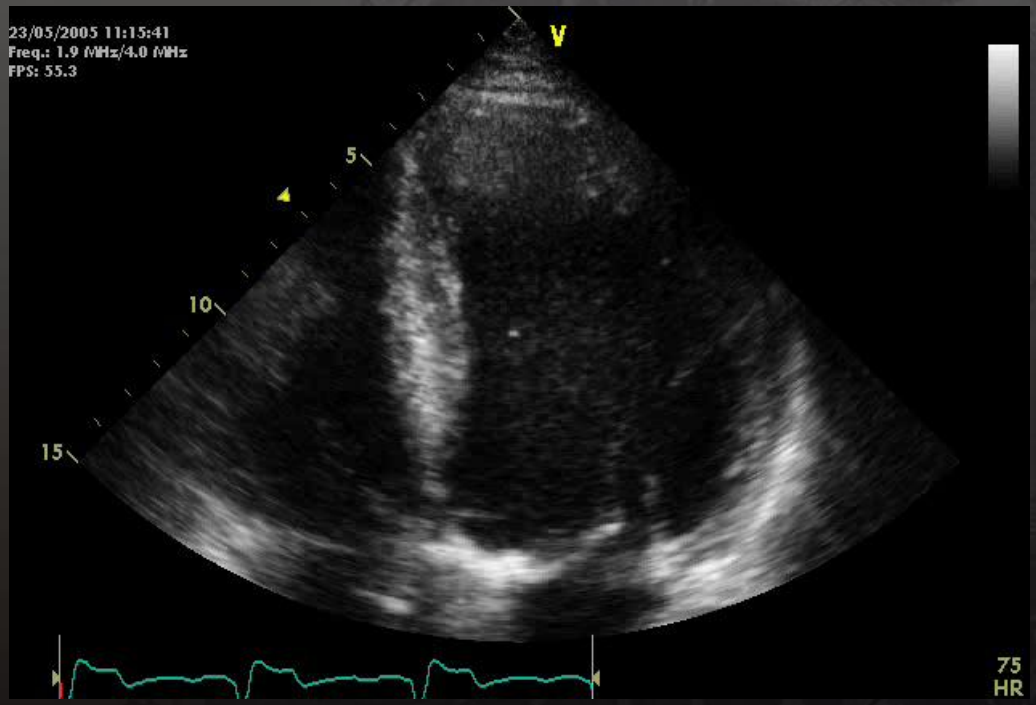
REAL-TIME 3D ECHOCARDIOGRAPHY

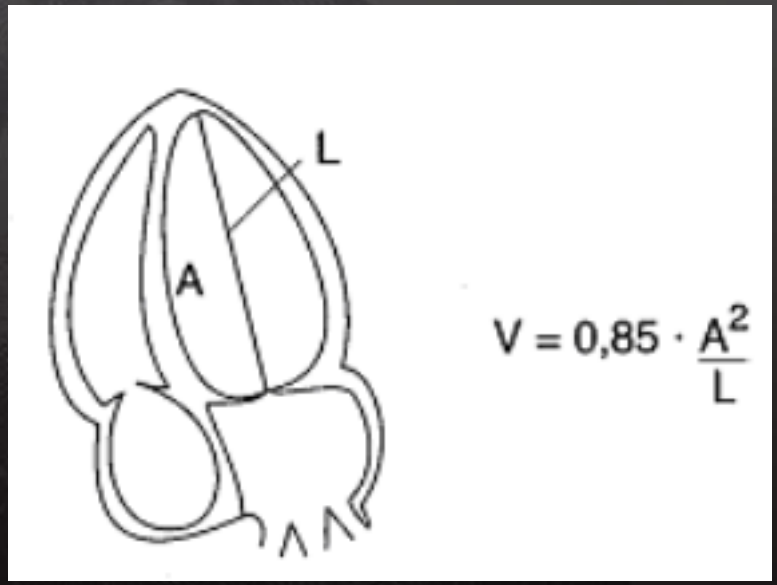
Measurement (NOT ANYMORE Calculations) of heart chamber size and function



3D QUANTITATION OF LV FUNCTION

Why do we need it?

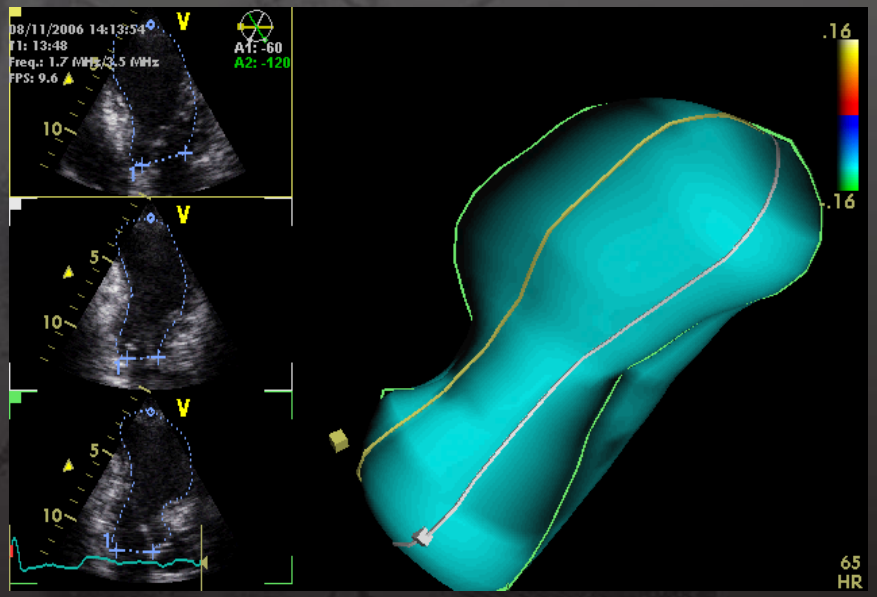


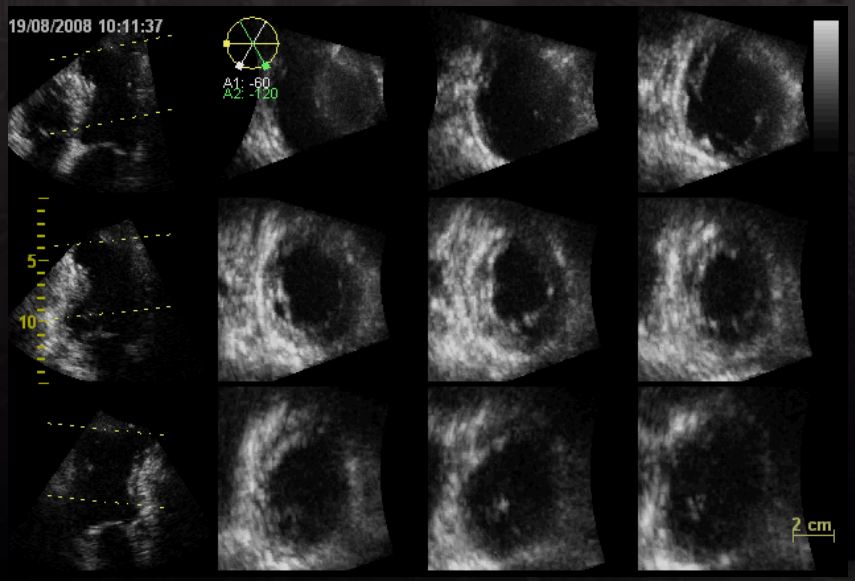


Apical 4CH-view

3D QUANTITATION OF LV FUNCTION

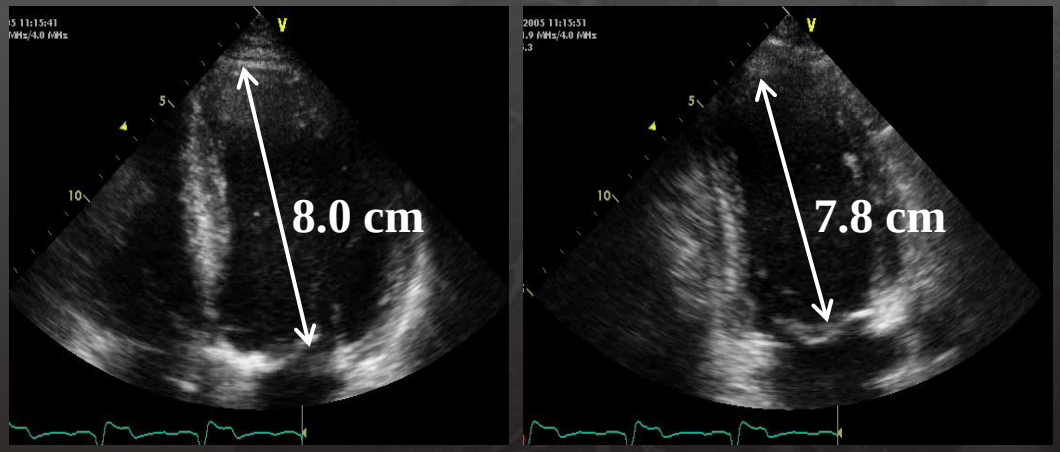
Clinical Case – Heart Failure in IHD

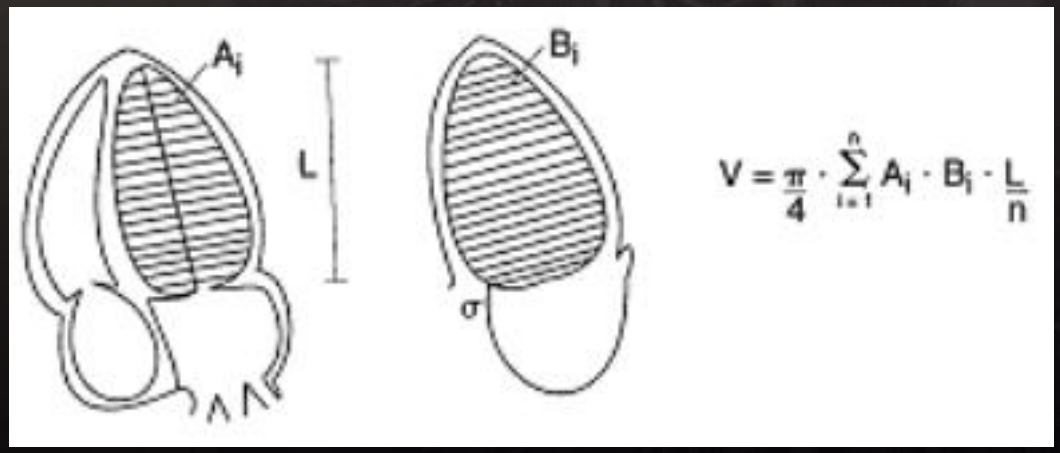




3D QUANTITATION OF LV FUNCTION

Errors associated with biplane LV volume assessment





1. Long-Axis foreshortening;
2. Image plane positioning errors as there is an assumption of orthogonality between 4CH and 2CH;
3. Geometric assumption errors as it assumes an ellipsoid LV shape as specified by the equation;
4. Boundary tracing errors.

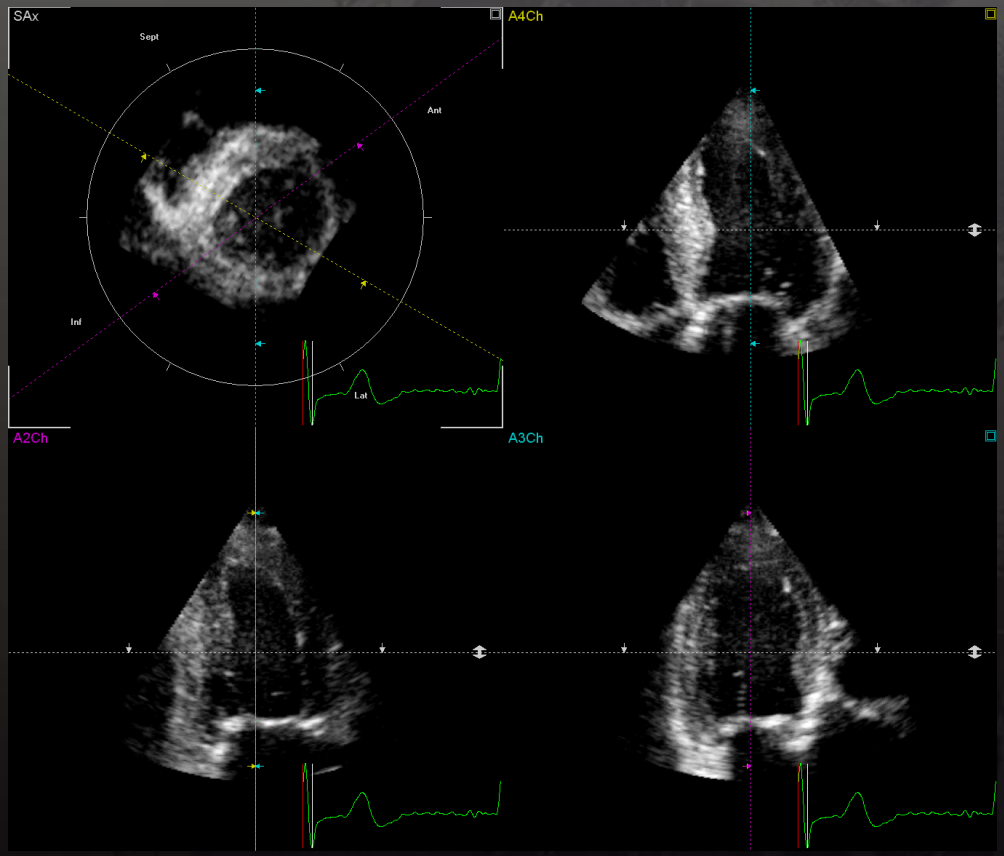
Cumulative Error= FS + IP + GA + BT

3D QUANTITATION OF LV FUNCTION

Normal Left Ventricle

3D QUANTITATION OF LV FUNCTION

Avoiding Foreshortening and IP error

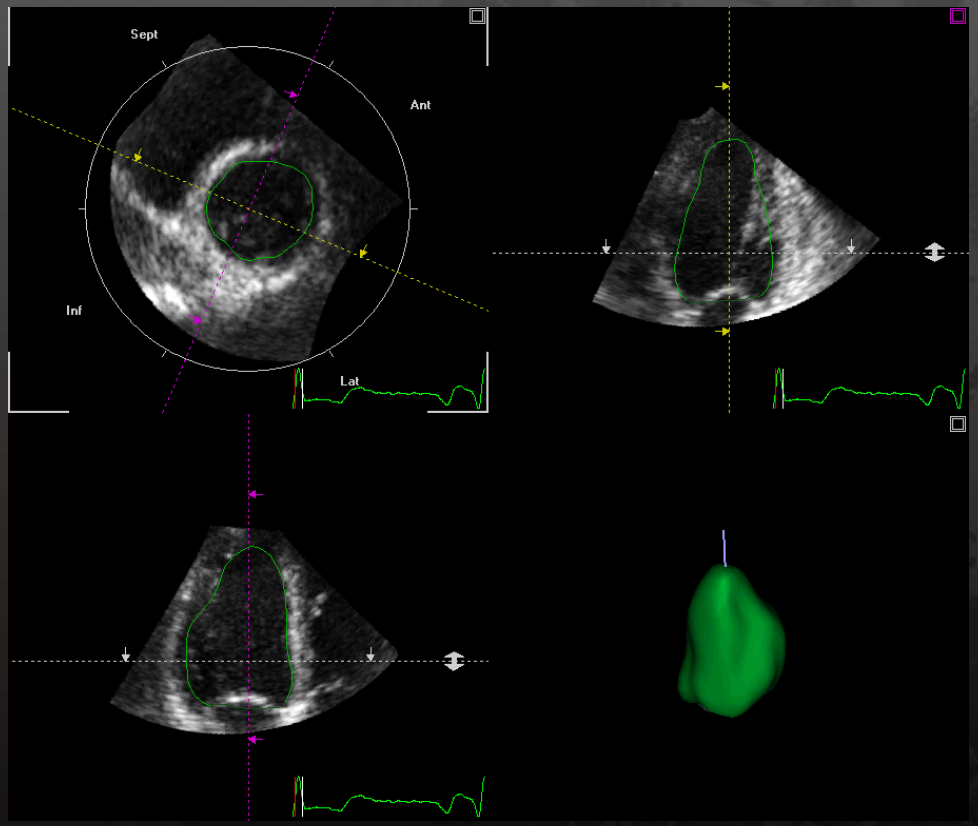


1. The voxel based dataset is sectioned into several separate 2D planes who share a common apex thus eliminating any foreshortening;
2. The relationship between 2CH and 4CH are controlled thus eliminating the Image Plane positioning error.

Residual Error= GA+ BT

3D QUANTITATION OF LV FUNCTION

Full Volume

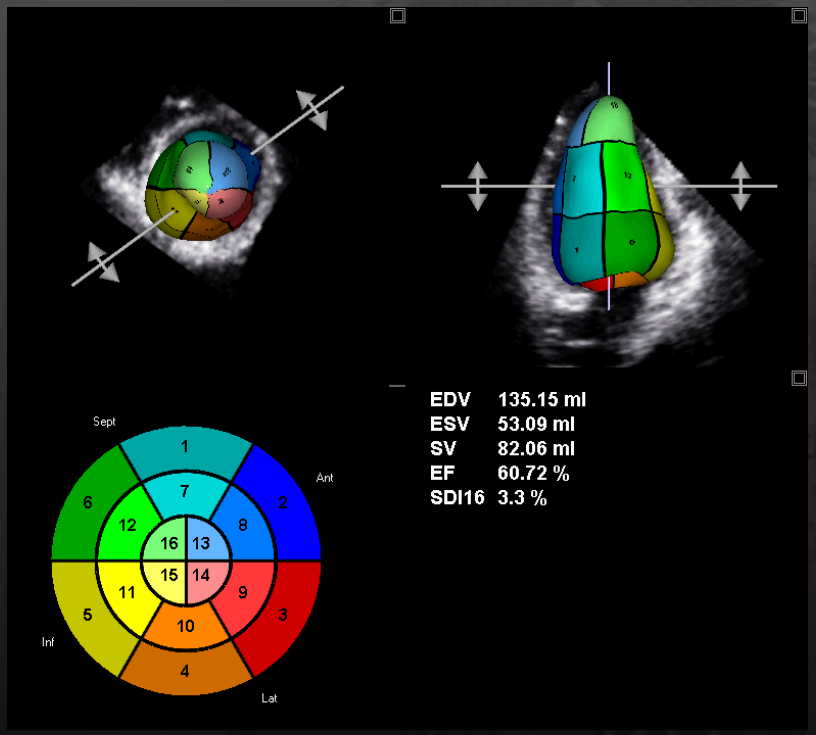


1. An apical rotation surface approximation algorhythm is used to generate volume and EF eliminating both IP and GA errors;
2. A voxel based semiautomated endocardial tracking algorhythm reduces the BT error.

No Residual Error

3D QUANTITATION OF LV FUNCTION

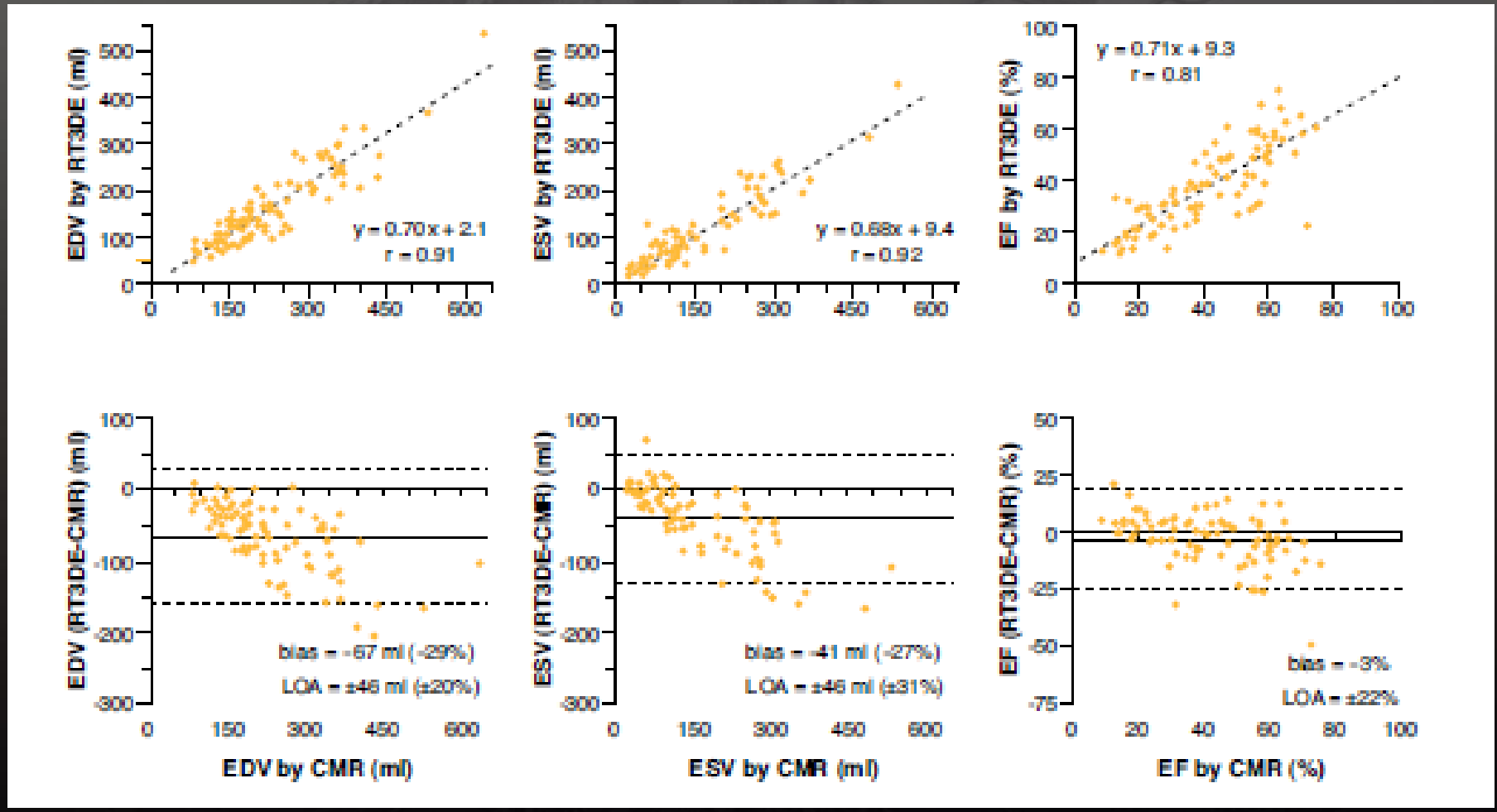
Reliable Measurement of LV Geometry and Function



		Mean difference ±SD vs MRI	
		RT3DE	2DE
Jenkins 2004	EDV (ml)	-4±9	-54±33
	ESV (ml)	-3±18	-28±28
	EF (%)	0±7	-1±13
Caiani 2005	EDV (ml)	-4±29	-23±86
	ESV (ml)	-4±33	-19±60
	EF (%)	-8±14	+4±16
Jacobs 2006	EDV (ml)	-14±17	-23±29
	ESV (ml)	-7±16	-15±24
	EF (%)	-1±6	1±9

3D QUANTITATION OF LV FUNCTION

Reproducibility of Volumes and Ejection Fraction



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Mor-Avi V et al. JACC Imaging 2009

Department of Cardiology Padua

3D QUANTITATION OF LV FUNCTION

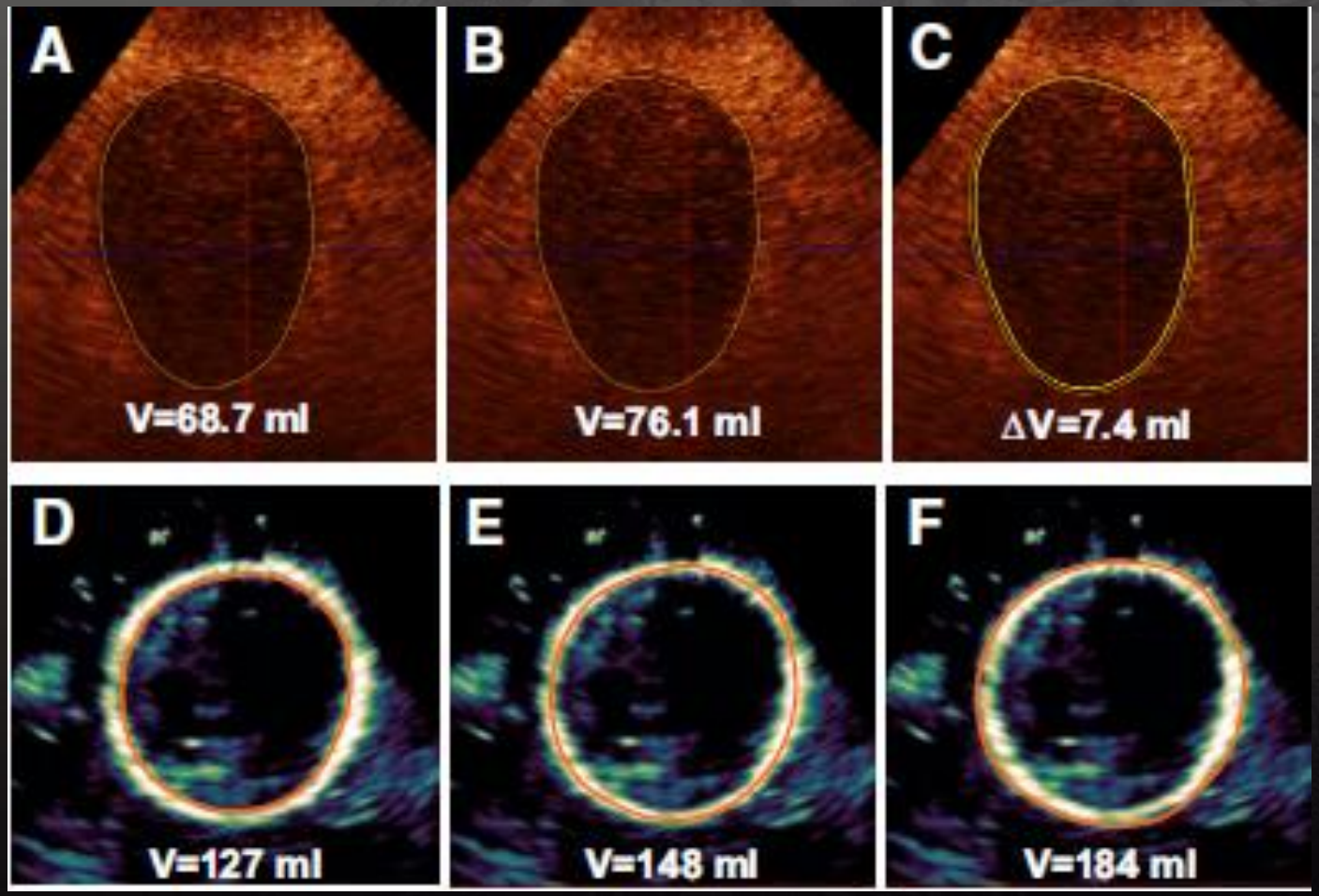
Accuracy of Volumes by Center Experience

	EDV		ESV		
	r	Bias	r	Bias	
All Patients	**0.91**	**−67 ± 47 ml**	**−29 ± 20%**	**0.93**	**−41 ± 46 ml**	**−27 ± 30%**
Site A	0.93	−37 ± 27 ml	−19 ± 13%	0.92	−18 ± 30 ml	−15 ± 25%
Site B	0.95	−63 ± 43 ml	−29 ± 20%	0.96	−31 ± 42 ml	−24 ± 32%
Site C	0.92	−72 ± 55 ml	−29 ± 22%	0.94	−44 ± 54 ml	−26 ± 32%
Site D	0.89	−89 ± 33 ml	−36 ± 13%	0.90	−63 ± 39 ml	−39 ± 24%

Mor-Avi V et al. JACC Imaging 2009

3D QUANTITATION OF LV FUNCTION

Accuracy of Volumes by Tracing Modality

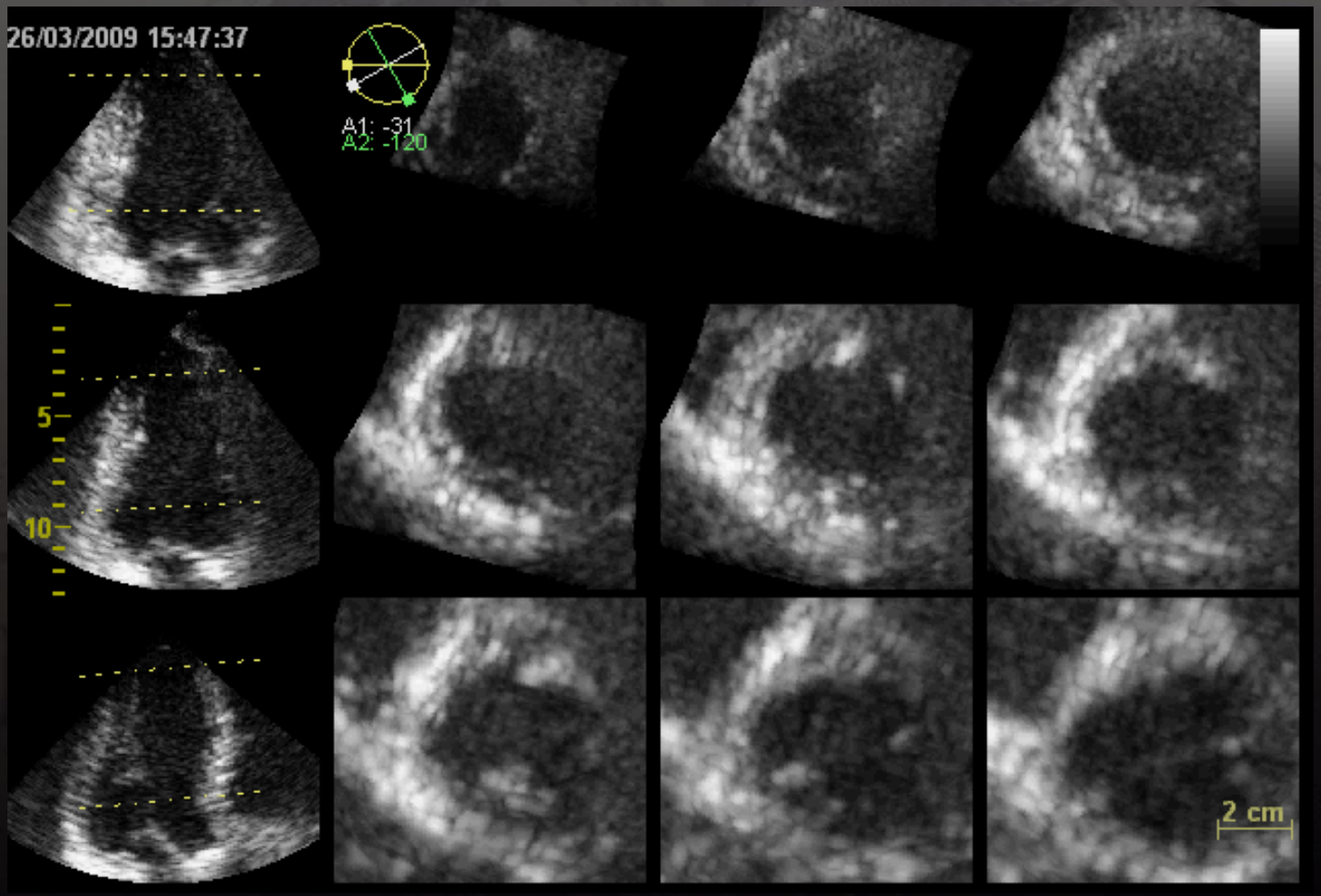


Actual Volume= 150 ml

Mor-Avi V et al. JACC Imaging 2009

3D QUANTITATION OF LV FUNCTION

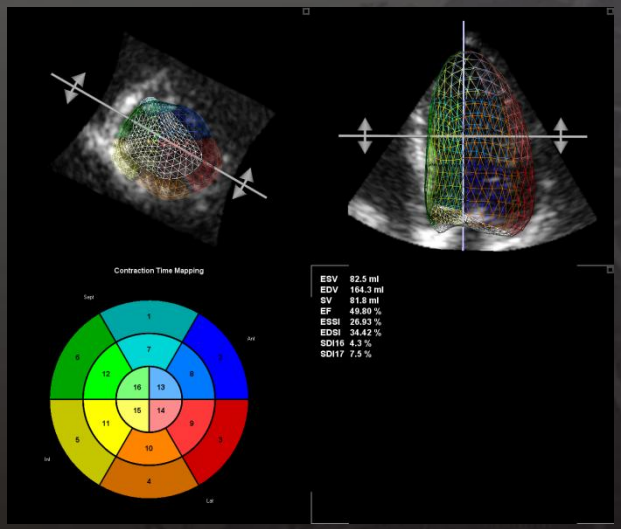
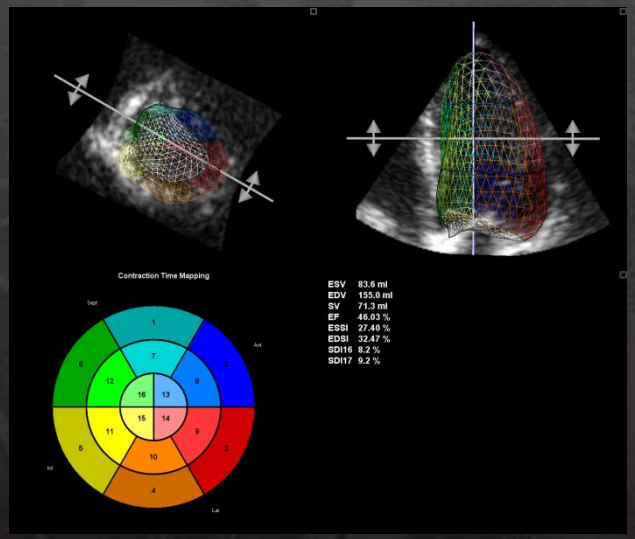
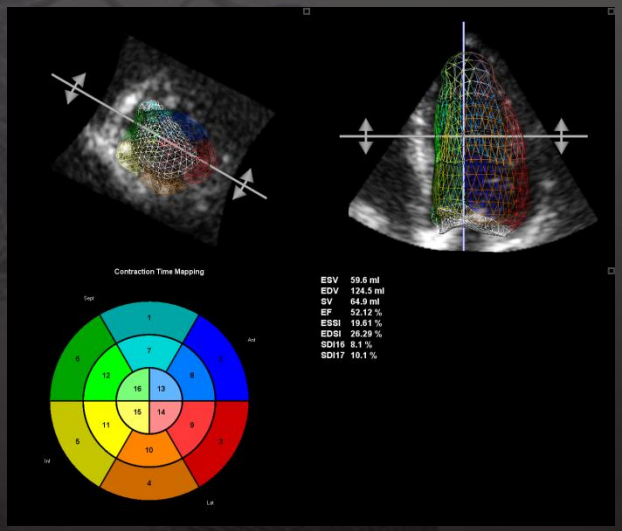
Technical Factors Affecting LV Assessment



Muraru D, Badano LP. *Eur J Echocard 2009 (Abstract)*

3D QUANTITATION OF LV FUNCTION

Semiautomatic Border Detection Sensitivity

25%	50%	75%
		
LV EDV= 164 ml LV ESV= 83 ml LV EF= 50% ED Shape= 34% ES Shape= 27%	LV EDV= 155 ml LV ESV= 84 ml LV EF= 46% ED Shape= 32% ES Shape= 27%	LV EDV= 125 ml LV ESV= 60 ml LV EF= 52% ED Shape= 26% ES Shape= 20%

Muraru D, Badano LP. *EurJ Echocard 2009 (Abstract)*

3D QUANTITATION OF LV FUNCTION

Reproducibility of Volumes and Ejection Fraction

	Interobserver Agreement			Intraobserver Agreement		
	Intraclass correlation	95% CI		Intraclass correlation	95%CI	
2D						
End-diastolic volume	0.58	-0.08	0.89	0.80	0.35	0.95
End-systolic volume	0.83	0.41	0.96	0.89	0.58	0.97
Ejection Fraction	0.94	0.74	0.99	0.92	0.70	0.98
3D						
End-diastolic volume	0.99	0.96	1.00	1.00	0.97	1.00
End-systolic volume	1.00	0.96	1.00	0.99	0.93	1.00
Ejection Fraction	0.98	0.89	1.00	0.99	0.94	1.00

Gutierrez-Chico JL et al. Am J Cardiol 2005

3D QUANTITATION OF LV FUNCTION

Test-retest Variability vs MRI!

Magnetic Resonance Imaging vs. RT-3DE vs 2DE (n= 50)

	Baseline	1-yr F-Up	p	r ΔRT-3DE	r ΔRT-2DE
EDV (ml)	192±53	187±60	<0.01	0.47 (<0.01)	0.02 (NS)
ESV (ml)	104±51	95±53	<0.01	0.44 (<0.01)	0.17 (NS
EF (%)	48±12	51±12	<0.01	0.58 (<0.01)	-0.03 (NS)

Jenkins C. et al. Am J Cardiol 2007

3D QUANTITATION OF LV FUNCTION

Effect of LV Size on Test-retest Variability

Correlations vs Magnetic Resonance Imaging				
	RT-3DE		2DE	
	EDV< 180 ml	EDV> 180 ml	EDV< 180 ml	EDV> 180 ml
EDV (ml)	r= 0.69 p<0.01	r= 0.37 p= 0.05	r= 0.11 p=0.63	r= 0.14 p= 0.49
ESV (ml)	r= 0.83 p<0.01	r= 0.34 p= 0.08	r= 0.20 p=0.37	r= 0.17 p= 0.39
EF (%)	r= 0.64 p<0.01	r= 0.32 p= 0.10	r= -0.15 p= 0.51	r= 0.03 p= 0.87

Jenkins C. et al. Am J Cardiol 2007

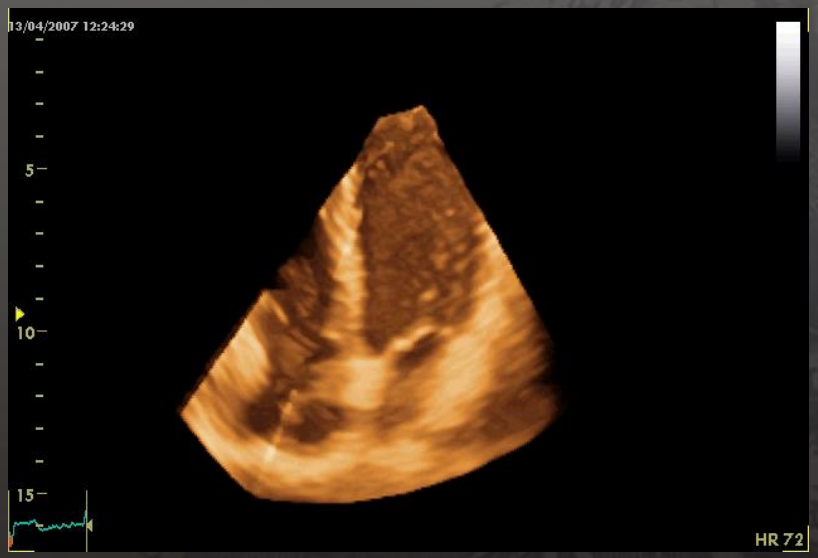
3D QUANTITATION OF LV FUNCTION

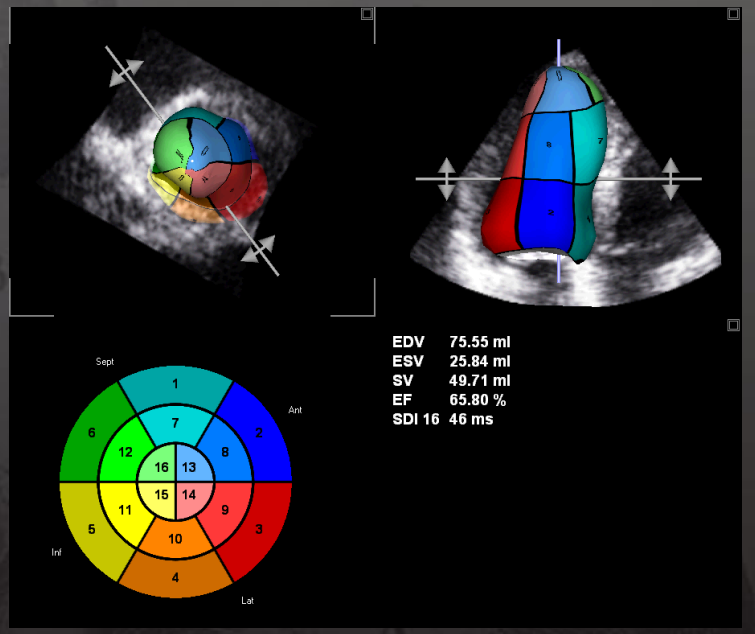
Effect of Image Quality on Test-retest Variability

Correlations vs Magnetic Resonance Imaging				
	RT-3DE		2DE	
	Good Images	Poor Images	Good Images	Poor Images
EDV (ml)	r= 0.79 p<0.01	r= 0.57 p< 0.01	r= 0.16 p<0.63	r= -0.07 p= 0.76
ESV (ml)	r= 0.74 p<0.01	r= 0.45 p= 0.05	r= 0.31 p<0.19	r= 0.19 p= 0.38
EF (%)	r= 0.58 p<0.01	r= 0.57 p< 0.01	r= -0.08 p<0.68	r= 0.16 p= 0.51

Jenkins C. et al. Am J Cardiol 2007

3D QUANTITATION OF LV FUNCTION





Pros:

- No LV foreshortening
- No geometric assumption about LV shape
- Semiautomatic tracking
- Accurate
- Reproducible

Cons:

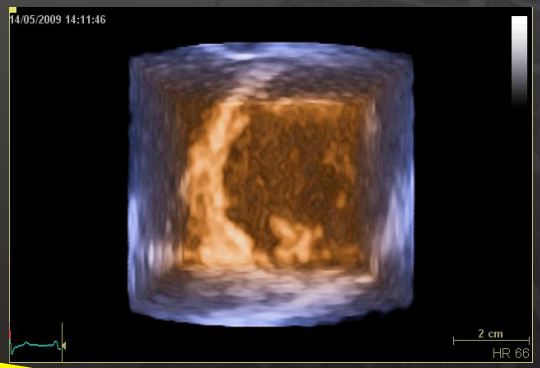
- Multiple heart beat acquisition (AF?)
- Off-line process
- Frame-rate 20-25 fps
- Feasibility
- Time consuming
- Costs

3D QUANTITATION OF LV FUNCTION

3rd Generation 3D Scanners: Single- vs Multi-beat Acquisition

- Lower spatial resolution

- Low FR (13±**3 vps)**



+ No breathhold

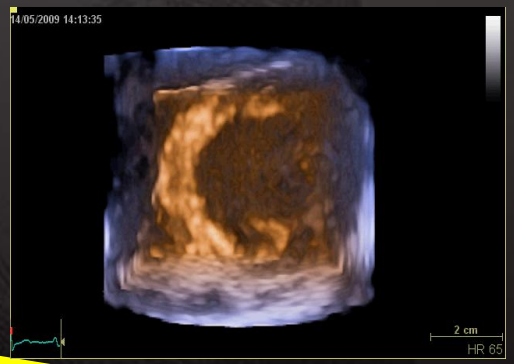
+ Irregular rhythm (AFib)

+ Instantaneous acquisition

+ Real-time

+ Higher spatial resolution

+ Superior FR (52±**16 vps)**



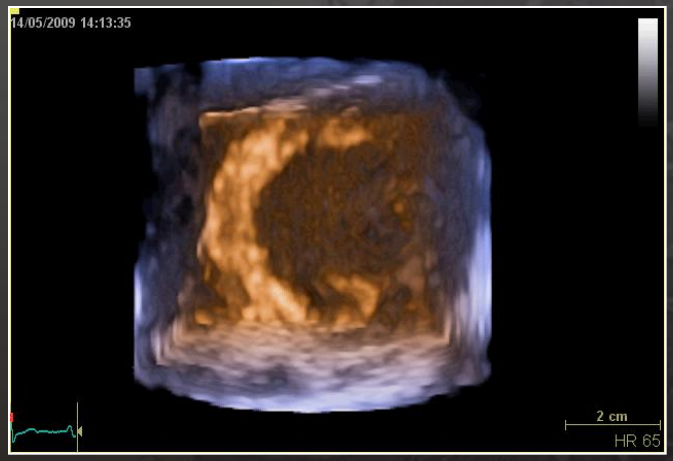
- Breathhold

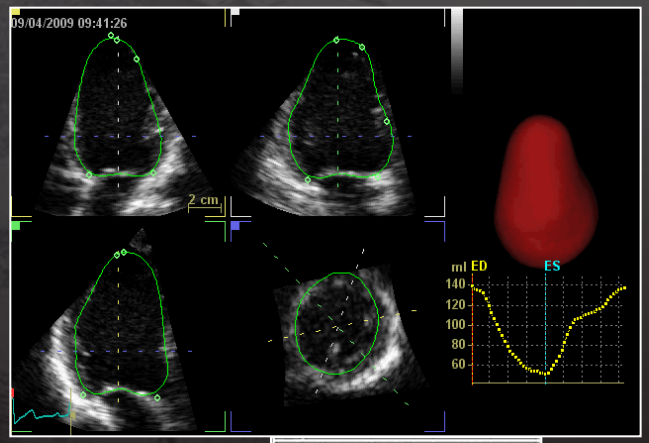
- Regular rhythm

- 4x acquisition time

3D QUANTITATION OF LV FUNCTION

Rapid on-board LV quantitation: *4D AutoLVQ*





LVEDV(4D)	139 ml
LVESV(4D)	51 ml
EF(4D)	63 %
SV(4D)	88 ml
CO(4D)	6.27 l/min
HR	71 BPM

Step 1 *Step 2* *Step 3* *Step 4* *Step 5*

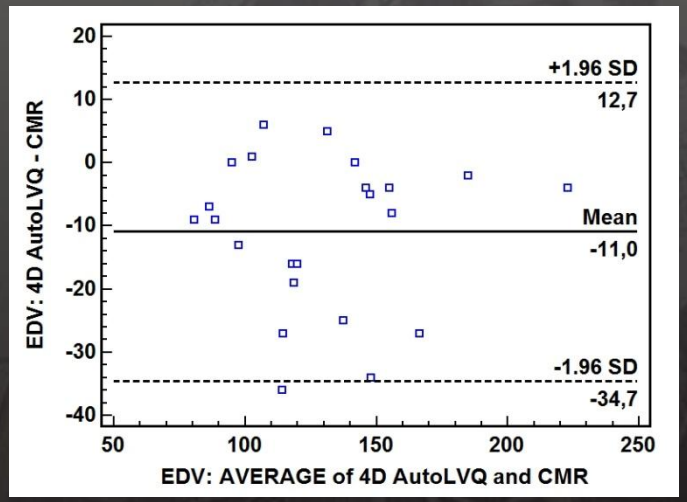
1'52" ± 30"

Muraru D, Badano LP et al. Eur J Echocardiogr 2010

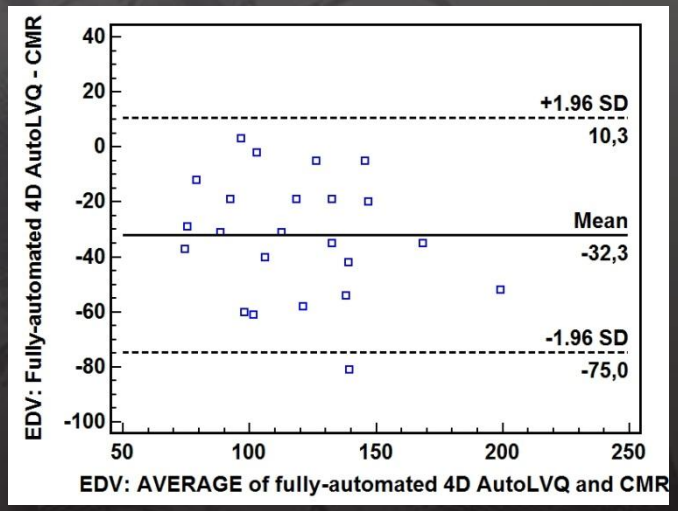
3D QUANTITATION OF LV FUNCTION

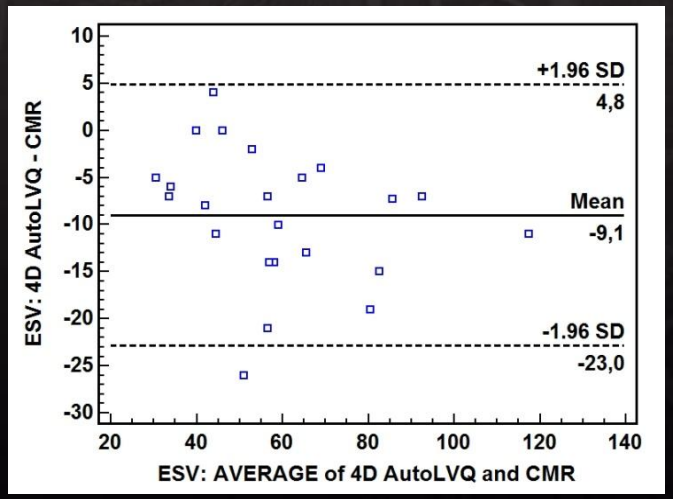
Agreement of *4D AutoLVQ* volumes with CMR

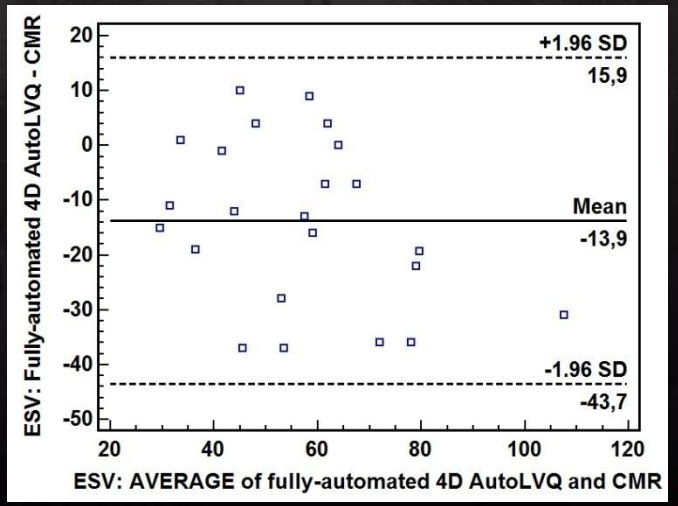
Manual correction



No manual correction







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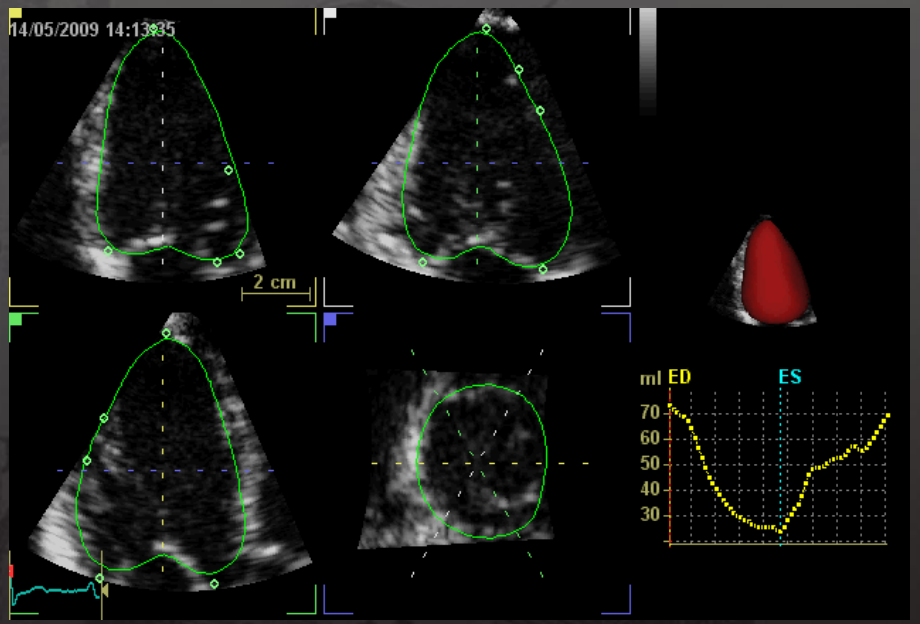
3D QUANTITATION OF LV FUNCTION

3rd Generation 3D Echo Scanners



Pros:

- No LV foreshortening
- No geometric assumption about LV shape
- Up to 10 equivalent planes
- Semiautomatic tracking
- Accurate
- Reproducible

Cons:

- Single &/or Multiple heartbeat acquisition
- Off-line process
- Frame rate 20-25 fps
- Feasibility
- Time consuming
- Costs

Pros:

- Multiple heartbeat acquisition (AF?)
- On-line process
- Frame rate 30-52 vps
- Feasibility
- Time saving

Cons:

- (Costs)

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3D QUANTITATION OF LV FUNCTION

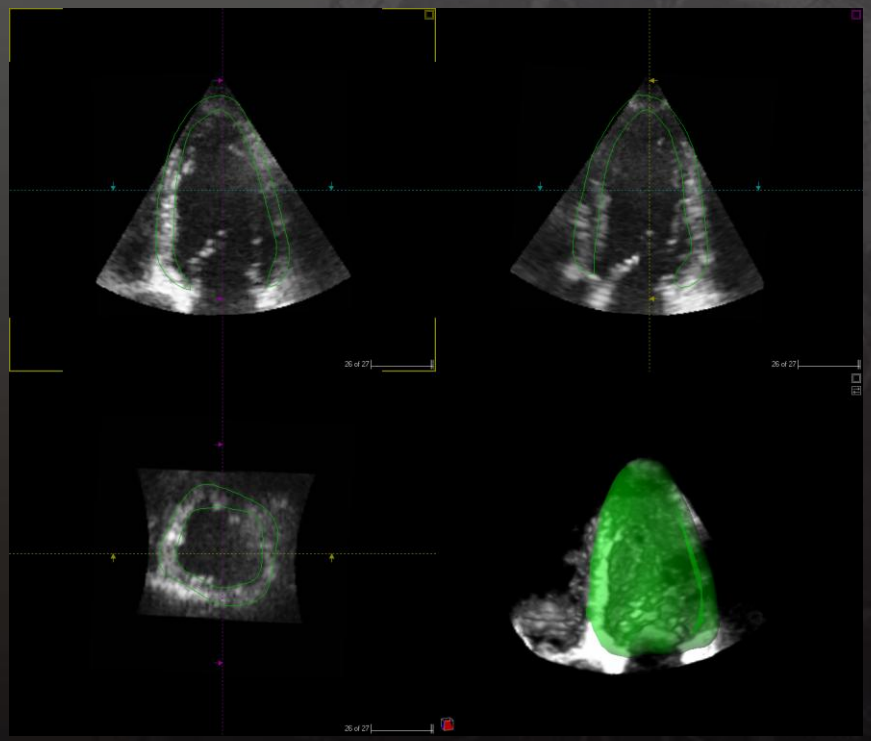
Clinical Significance of Increased Accuracy

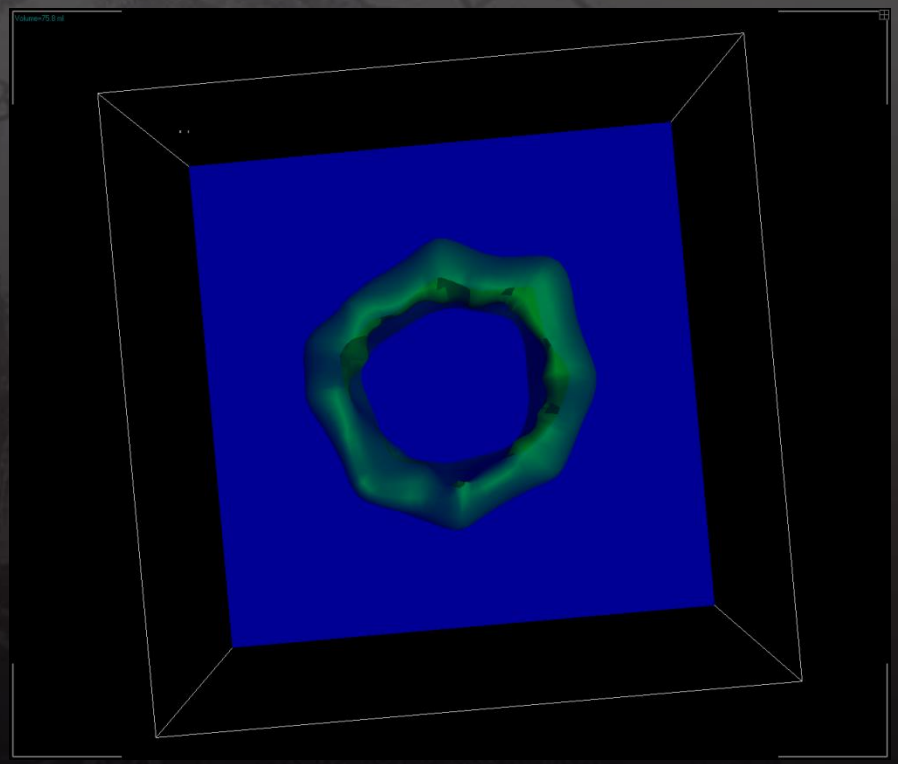
2D EF band	2D pts (no)	Re-allocation by EF 35%	Re-allocation by EF 40%
≤ 25%	32	2 (6%)	1 (3%)
26-35%	36	14 (39%)	5 (14%)
36-40%	13	1 (8%)	7 (54%)
41-45%	10	2 (20%)	5 (50%)
> 45%	129	0	2 (2%)

Hare JL et al. Heart 2008

3D QUANTITATION OF LV FUNCTION

Not Just Volumes and Ejection Fraction





LV MASS

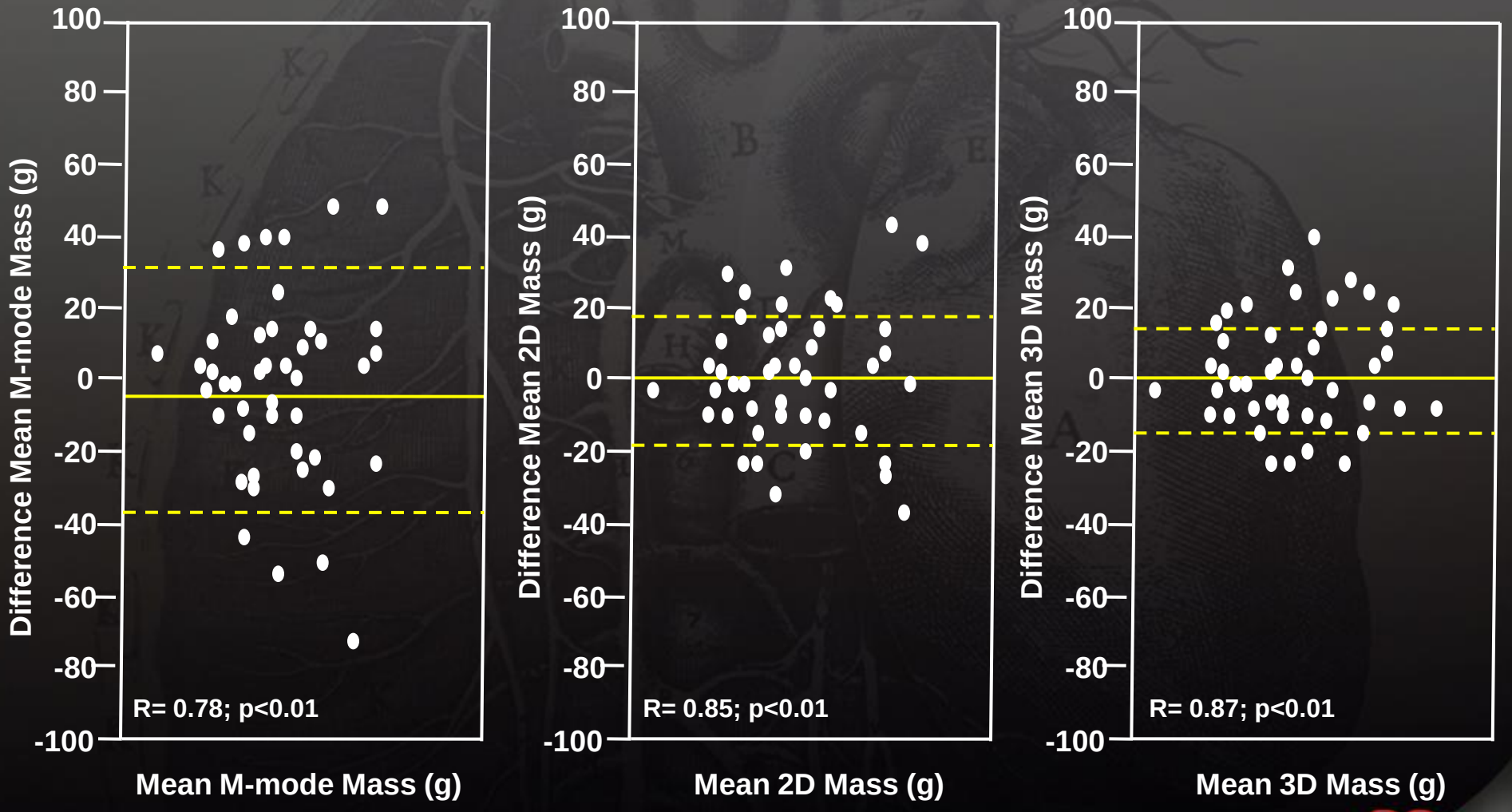
3D QUANTITATION OF LV MASS

LV Mass Assessment vs MRI

	r	SEE (g)	p	Bias	Width Limit (g)
M-mode (ASE)	0.4	47	0.03	14	188
2D Area-length (ASE)	0.2	40	0.3	6	168
RT3DE	0.9	13	<0.0001	-2	50

3D QUANTITATION OF LV MASS

Test-retest Comparison of Sequential Measurements



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Jenkins C. et al. J Am Coll Cardiol 2004

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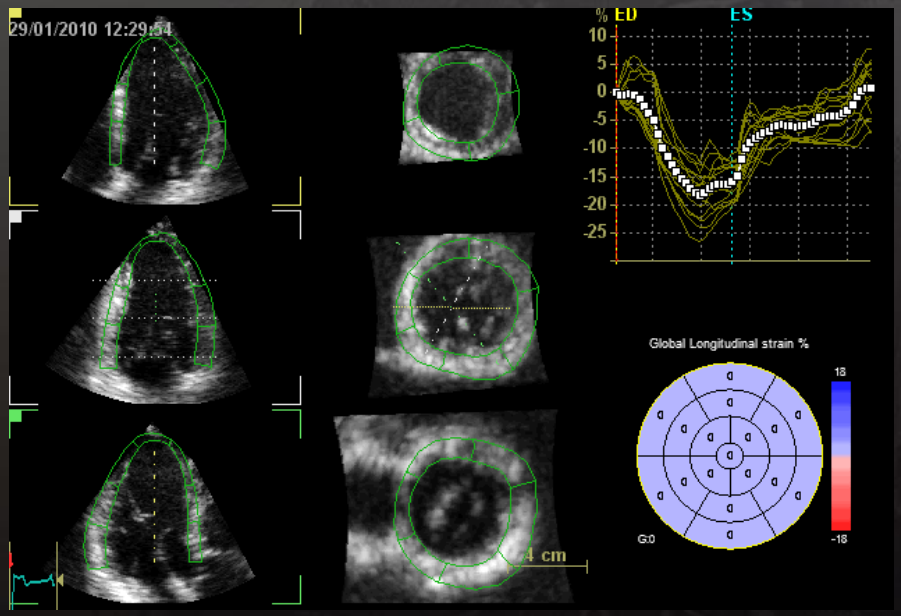
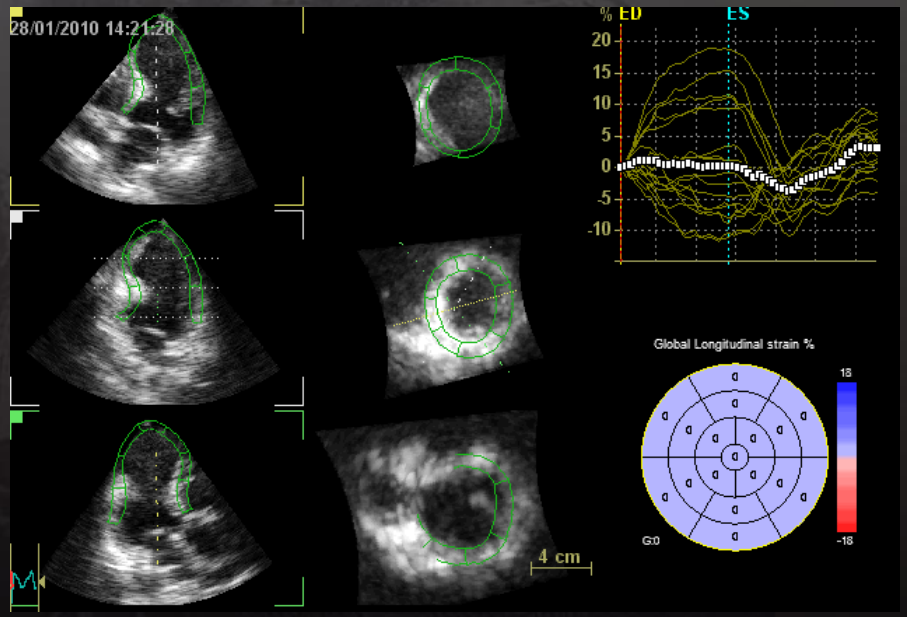
3D QUANTITATION OF LV FUNCTION

Not Just Volumes and Ejection Fraction

3D Strain



Normal Subject



Ischemic Heart Disease

3D ECHO TO QUANTITATE VENTRICULAR CAVITY SIZE AND FUNCTION

Conclusions

- 3DE provides more accurate volumetric information than conventional 2D echo in patients in whom LV quantification is critical for management;
- 3rd generation 3D echo scanners are equipped with new semiautomated contour detection programs that work fairly rapid with limited operator interaction;
- Volume quantification with 3D works when the operator knows how to do it and its limitations;
- These novel algorhythms compete in accuracy with cardiac magnetic resonance, but only 3DE can be used in every patient at his/her patient bedside.

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