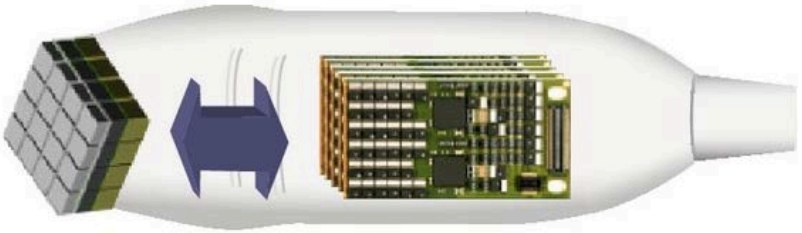
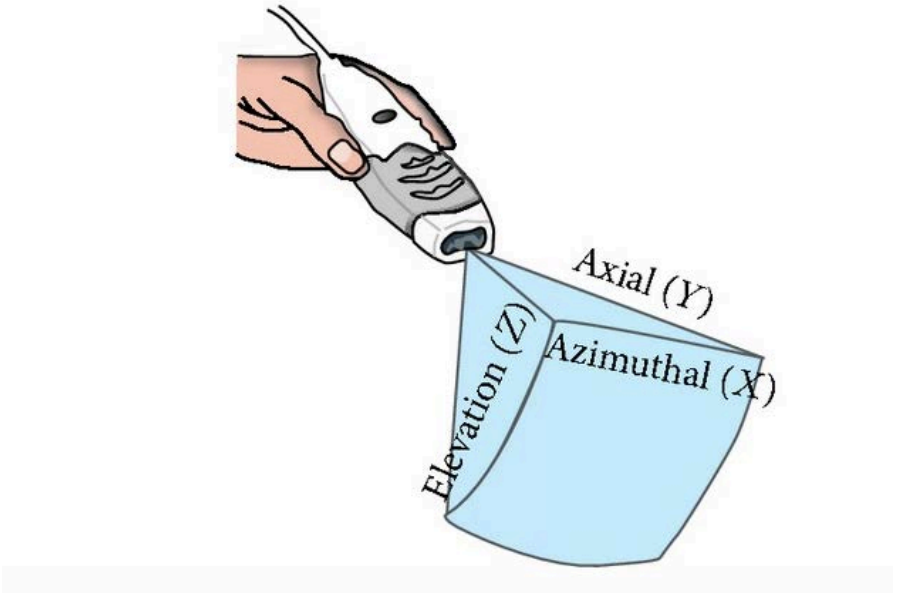
When Does 3D Echo Make a Difference?

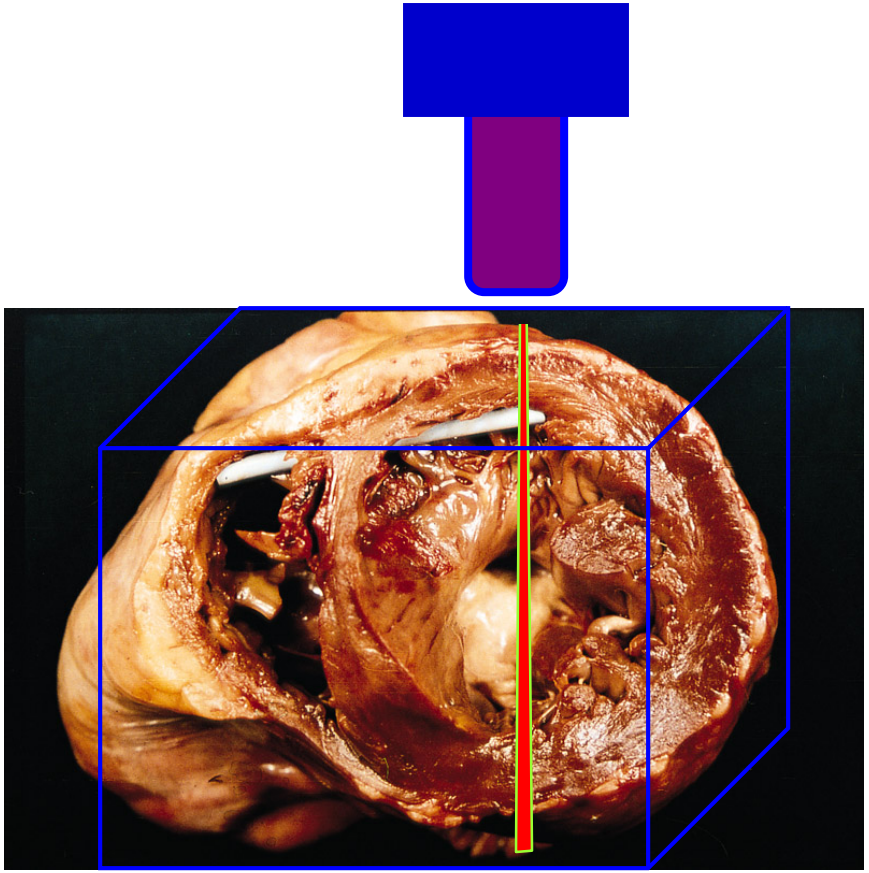
Anthony DeMaria
University of California, San Diego

No Disclosures

Why do 3D imaging ?

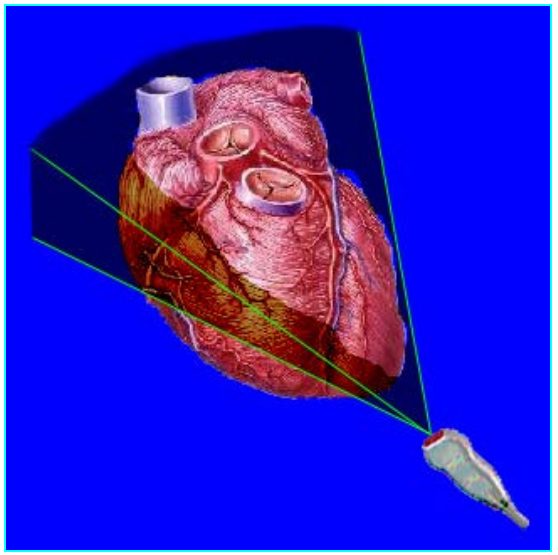


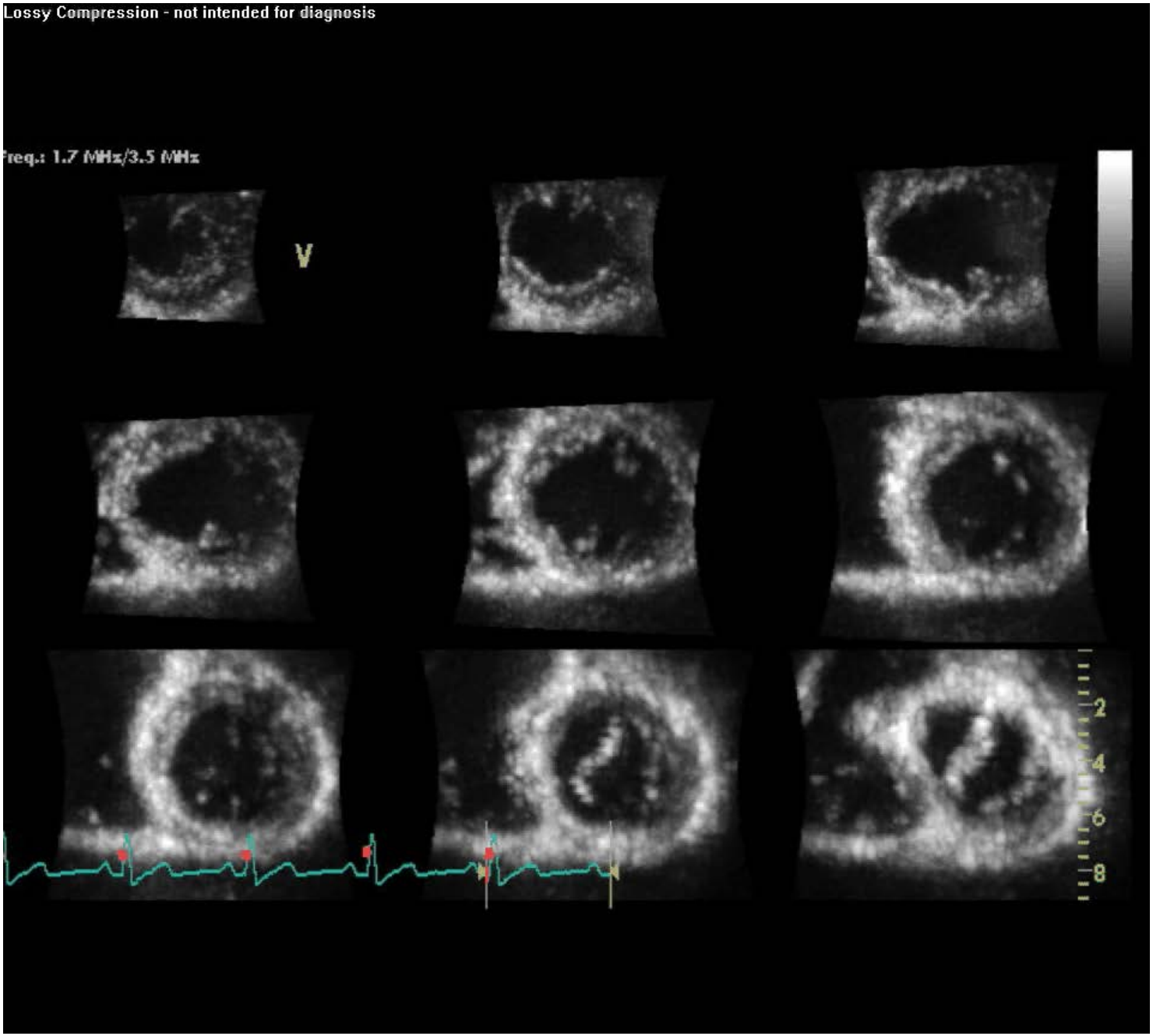




Real-time, Touch-button 3DE

- Matrix Array Transducer
- Fully sampled
- Supercomputing
- Instantaneous volume rendering
- Intelligent Navigator

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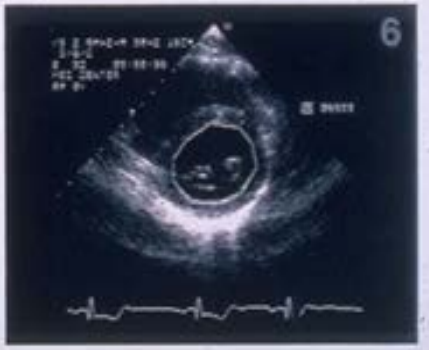
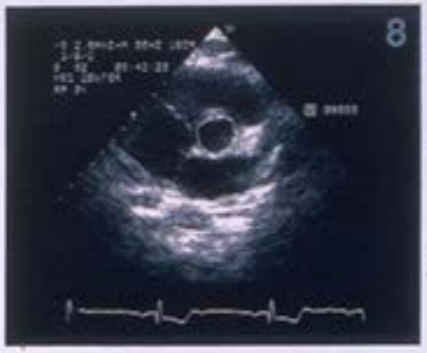
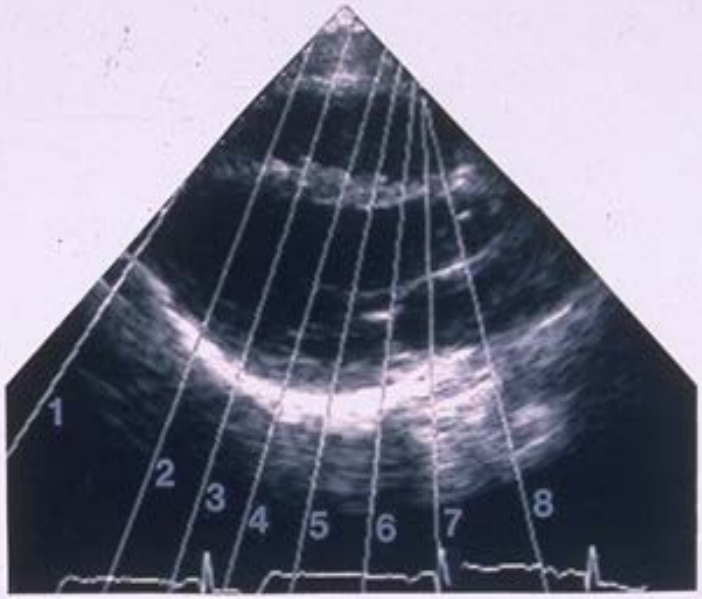
LINE OF INTERSECTION DISPLAY

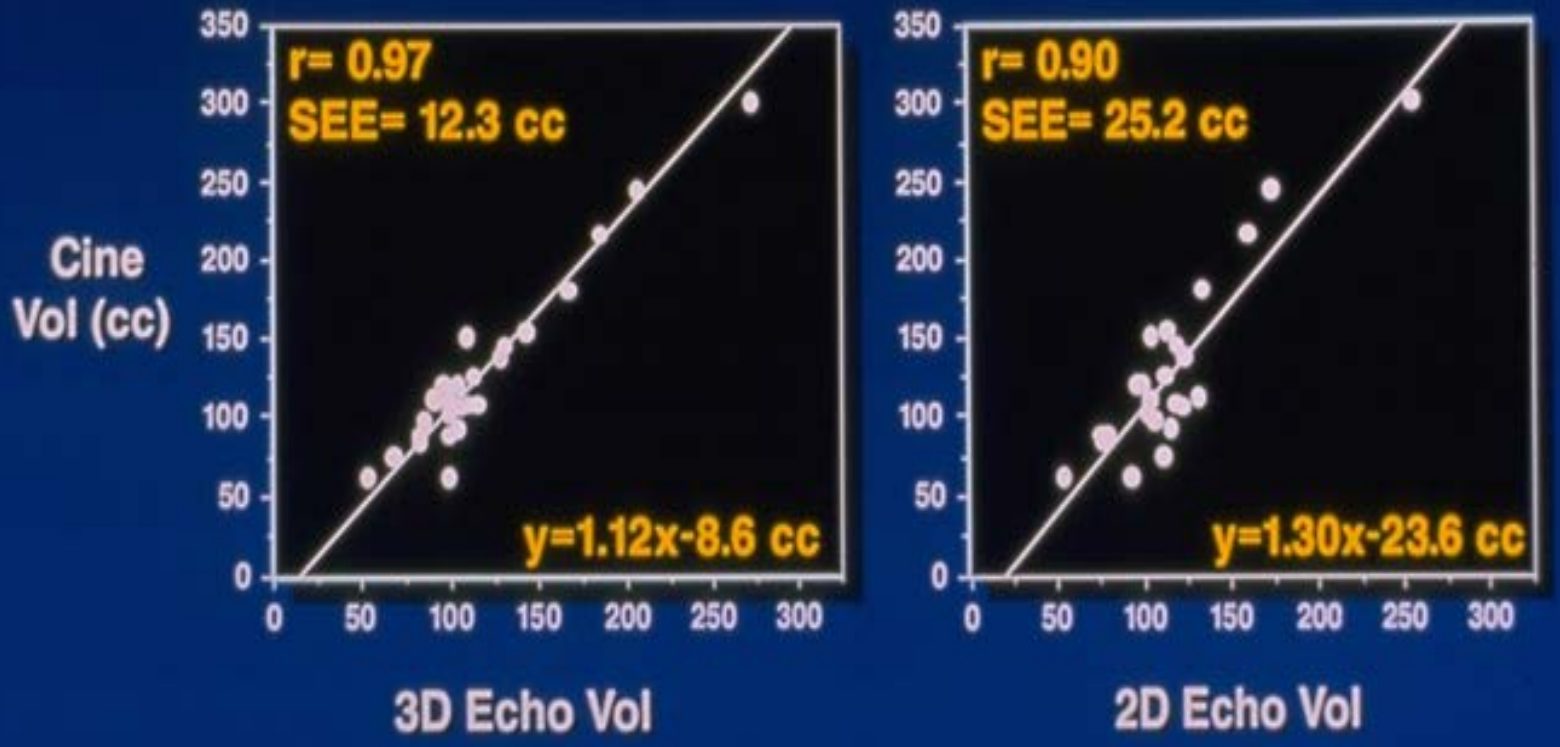




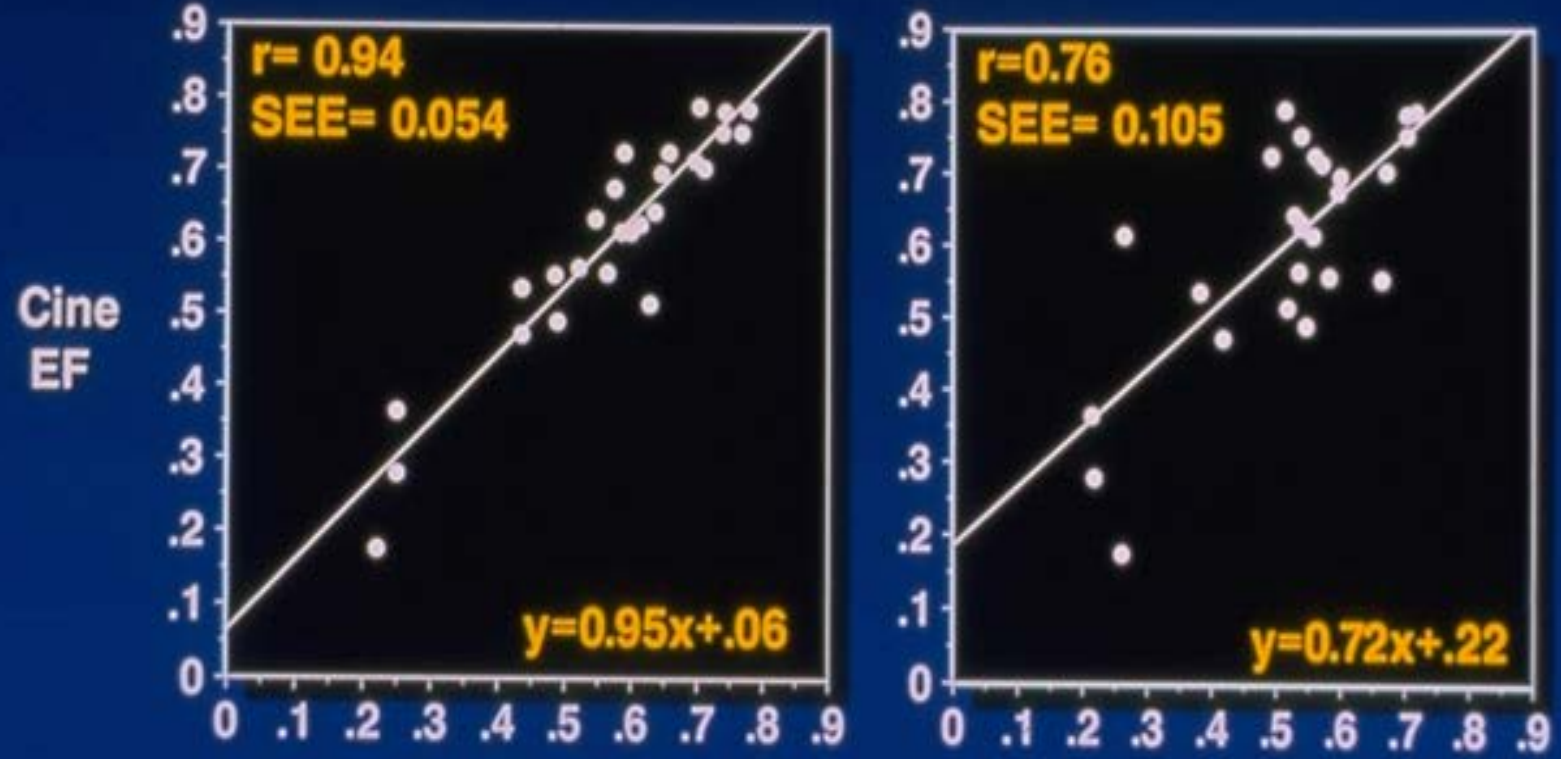


32 YEAR OLD MALE

Echo vs Cine: End Diastolic Volume



Echo vs Cine: Ejection Fraction



3D &2D vs CMR

Table 1. Differences between left ventricular volumes and function assessed by three-dimensional echocardiography and conventional two-dimensional echocardiography in comparison with cardiac magnetic resonance

Author	Three-dimensional echocardiography			Two-dimensional echocardiography		
	End-diastolic volume (mL)	End-systolic volume (mL)	Ejection fraction (%)	End-diastolic volume (mL)	End-systolic volume (mL)	Ejection fraction (%)
Jenkins et al.[4]	-4 ± 9	-3 ± 18	0 ± 7	-54 ± 33	-28 ± 28	-1 ± 13
Kühl et al.[5]	-13.6 ± 18.9	-12.8 ± 20.5	0.9 ± 4.4	-	-	-
Caiani et al.[6]	-4.1 ± 29	-3.5 ± 33	-8 ± 14	-23 ± 86	-19 ± 60	3.7 ± 16
Shiota et al.[7]	-43 ± 65	-37 ± 67	1 ± 4	-	-	-
Zeidan et al.[8]	-6 ± 11	-4 ± 9	2 ± 5	-	-	-
Chan et al.[9]	-10.4 ± 26.4	-0.9 ± 18.8	-	-	-	-
Corsi et al.[10]	2.9 ± 12	2.8 ± 7	-1 ± 5	-	-	-
Sugeng et al.[11]	-4	-1	2	-	-	-
Nikitin et al.[12]	7 ± 28	3 ± 22	-1 ± 10	-	-	-
Jacobs et al.[13]	-14 ± 17	-6.5 ± 16	-1 ± 6	-23 ± 29	-15 ± 24	1 ± 9
Gutiérrez-Chico et al.[14]	-3 ± 1	2 ± 7	0 ± 6	-	-	-
van den Bosch et al.[15]	-3 ± 12	-12 ± 31	-1 ± 7	-	-	-
Pouleur et al.[16]	-20 ± 31	-12 ± 31	1 ± 11	-	-	-
Qi et al.[17]	-22 ± 23	-15 ± 20	5 ± 10	-	-	-
Bicudo et al.[18]	-4	0.3	-2	-	-	-
Shimada et al.[19]	-9.9	-4.7	-0.13	-	-	-

Mean difference ± SD from cardiac magnetic resonance

Performance of 3-Dimensional Echocardiography in Measuring Left Ventricular Volumes and Ejection Fraction

A Systematic Review and Meta-Analysis

Jennifer L. Dorosz, MD,* Dennis C. Lezotte, PhD,† David A. Weitzenkamp, PhD,† Larry A. Allen, MD, MHS,* Ernesto E. Salcedo, MD*

Aurora, Colorado

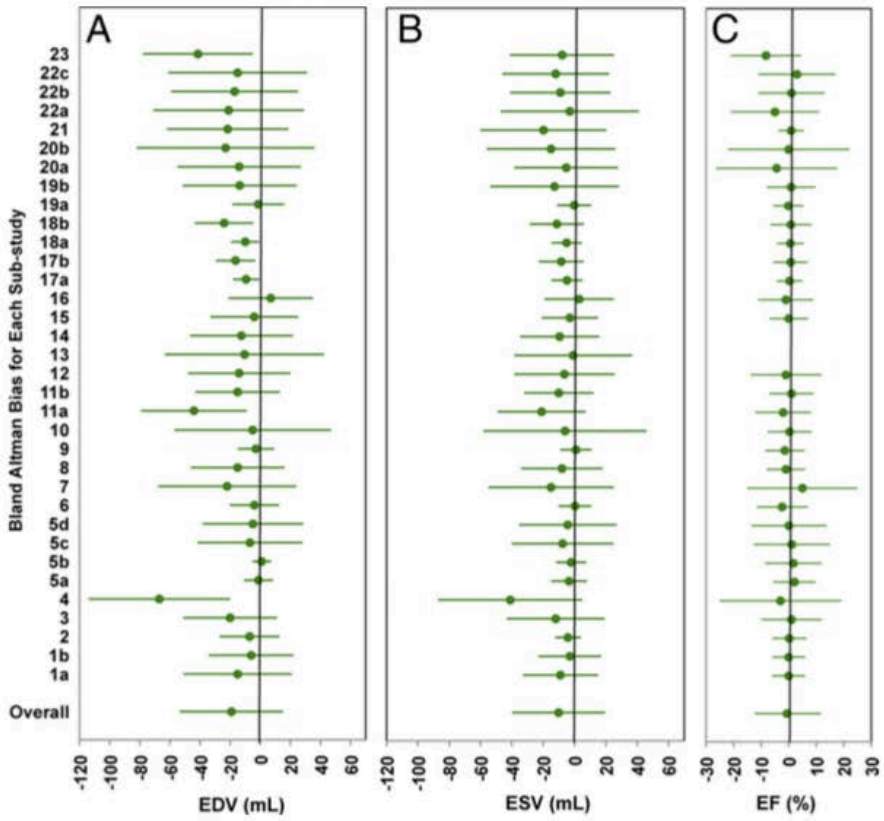


Figure 3 **Three-Dimensional Echocardiography Versus Cardiac Magnetic Resonance**

The absolute Bland-Altman difference between 3DE and CMR, expressed as bias ±2 SDs for each substudy. The overall pooled results are shown at the bottom. End-diastolic volume (EDV), end-systolic volume (ESV), and ejection fraction (EF) are shown in **A, B, and C,** respectively. Abbreviations as in Figures 1 and 2.

A Meta-Analysis and Investigation for the Source of Bias of Left Ventricular Volumes and Function by Three-Dimensional Echocardiography in Comparison With Magnetic Resonance Imaging

Yuichi J. Shimada, MD[a], and Takahiro Shiota, MD, PhD[b,*]

Determining accurate left ventricular (LV) function is clinically important. Three-dimensional echocardiography (3DE) achieves better estimation than 2-dimensional echocardiography. However, underestimation of LV volumes has often been reported without a systematic attempt to synthesize these data. This meta-analysis aimed to assess the bias of 3DE in evaluating LV volumes and ejection fraction (EF) and to investigate factors affecting that bias. Studies that compared LV volumes and/or EF between 3DE and magnetic resonance imaging were eligible. Meta-analysis of 95 studies including 3,055 subjects revealed significant underestimation of LV end-systolic volume (−4.7 ml, $p < 0.0001$) and end-diastolic volume (−9.9 ml, $p < 0.0001$), whereas measurement for EF revealed excellent accuracy (−0.13%, $p = 0.41$). Meta-regression analysis for factors of systematic bias in volumetry revealed that female gender and existence of cardiac disease were associated with more underestimation, whereas use of semiautomatic tracking and matrix-array transducers counteracted the underestimation. In conclusion, by meta-analysis synthesizing many small studies, we found underestimation of LV volumes and factors affecting the systematic bias by 3DE. These data provide a more detailed basis for analyzing and improving the accuracy of 3DE, an indispensable step toward further clinical application in LV assessment. (Am J Cardiol 2011;107:126–138)

3D Makes a Difference

- LV volumes and EF
  - Choosing pharmacologic therapy
  - Using resynchronization
  - Implanting defibrillators
  - Cardio-oncology
- RV structure and function
- Mitral Valve Disease
  - Prolapse
  - Stenosis
- Tricuspid Valve Disease

Published Trials in Which EF was Part of the Entry Criteria (Partial List)

- SOLVD Treatment Trial
- SOLVD Prevention Trial
- SAVE
- US Cravedilol Trials
- MERIT-HF
- CIBIS 1 & 2
- COPERNICUS
- CAPRICORN
- RALES
- ELITE 1 & 2
- Val-HEFT
- PRAISE 1 & 2
- OVERTURE
- CHARM
- PARADIGM

PRACTICE GUIDELINE

2012 ACCF/AHA/HRS Focused Update Incorporated Into the ACCF/AHA/HRS 2008 Guidelines for Device-Based Therapy of Cardiac Rhythm Abnormalities

A Report of the American College of Cardiology Foundation/American Heart Association Task Force on Practice Guidelines and the Heart Rhythm Society

Cynthia M. Tracy, MD, FACC, FAHA, Chair; Andrew E. Epstein, MD, FACC, FAHA, FHRS, Vice Chair*; Dawood Darbar, MD, FACC, FHRS†; John P. DiMarco, MD, PHD, FACC, FHRS*‡; Sandra B. Dunbar, RN, DSN, FAAN, FAHA†; N.A. Mark Estes III, MD, FACC, FAHA, FHRS*§; T. Bruce Ferguson, JR, MD, FACC, FAHA*‖¶; Stephen C. Hammill, MD, FACC, FHRS‡; Pamela E. Karasik, MD, FACC, FHRS†; Mark S. Link, MD, FACC, FHRS*†; Joseph E. Marine, MD, FACC, FHRS†; Mark H. Schoenfeld, MD, FACC, FAHA, FHRS*†; Amit J. Shanker, MD, FACC, FHRS‡; Michael J. Silka, MD, FACC†; Lynne Warner Stevenson, MD, FACC*#; William G. Stevenson, MD, FACC, FAHA, FHRS***; Paul D. Varosy, MD, FACC, FHRS†

RECOMMENDATIONS FOR CARDIAC RESYNCHRONIZATION THERAPY IN PATIENTS WITH SYSTOLIC HEART FAILURE

Class I Recommendations

CRT is indicated for patients who have*

- LVEF ≤ 35%
- Left Bundle Branch Block (LBBB)
- NYHA class II, III, or ambulatory Class IV symptoms
- Sinus rhythm
- QRS duration ≥ 150 ms
- Guideline-Directed Medical Therapy

(Level of Evidence: A for NYHA class III/IV; Level of Evidence: B for NYHA class II)

Tracy CM, Epstein AE, Darbar D, et al. 2012 ACCF/AHA/HRS Focused Update of the 2008 Guidelines for Device-Based Therapy of Cardiac Rhythm Abnormalities. *J Am Coll Cardiol*. October 2, 2012;60(14):1297-1313.

Guidelines for Cardiac Resynchronization

Class IIa Recommendations

CRT can be useful for patients who have:
- LVEF ≤ 35%
- Sinus rhythm
- LBBB
- QRS duration 120 to 149 ms
- NYHA class II, III, or ambulatory Class IV symptoms
- Guideline-Directed Medical Therapy

(Level of Evidence: B)

CRT can be useful for patients who have:
- LVEF ≤ 35%
- Sinus rhythm
- Non-LBBB pattern
- QRS duration ≥ 150 ms
- NYHA class III, or ambulatory Class IV symptoms
- Guideline-Directed Medical Therapy

(Level of Evidence: A)

CRT can be useful for patients who have:
- Atrial fibrillation
- LVEF ≤ 35%
- Guideline-Directed Medical Therapy

If a) the patient requires ventricular pacing or otherwise meets CRT criteria and b) AV nodal ablation or pharmacologic rate control will allow near 100% ventricular pacing with CRT.

(Level of Evidence: B)

CRT can be useful for patients who have:
- LVEF ≤ 35%
- Guideline-Directed Medical Therapy
- Anticipated requirement for significant (> 40%) ventricular pacing

(Level of Evidence: C)

RECOMMENDATIONS FOR IMPLANTABLE CARDIOVERTER DEFIBRILLATORS

Class I Recommendations

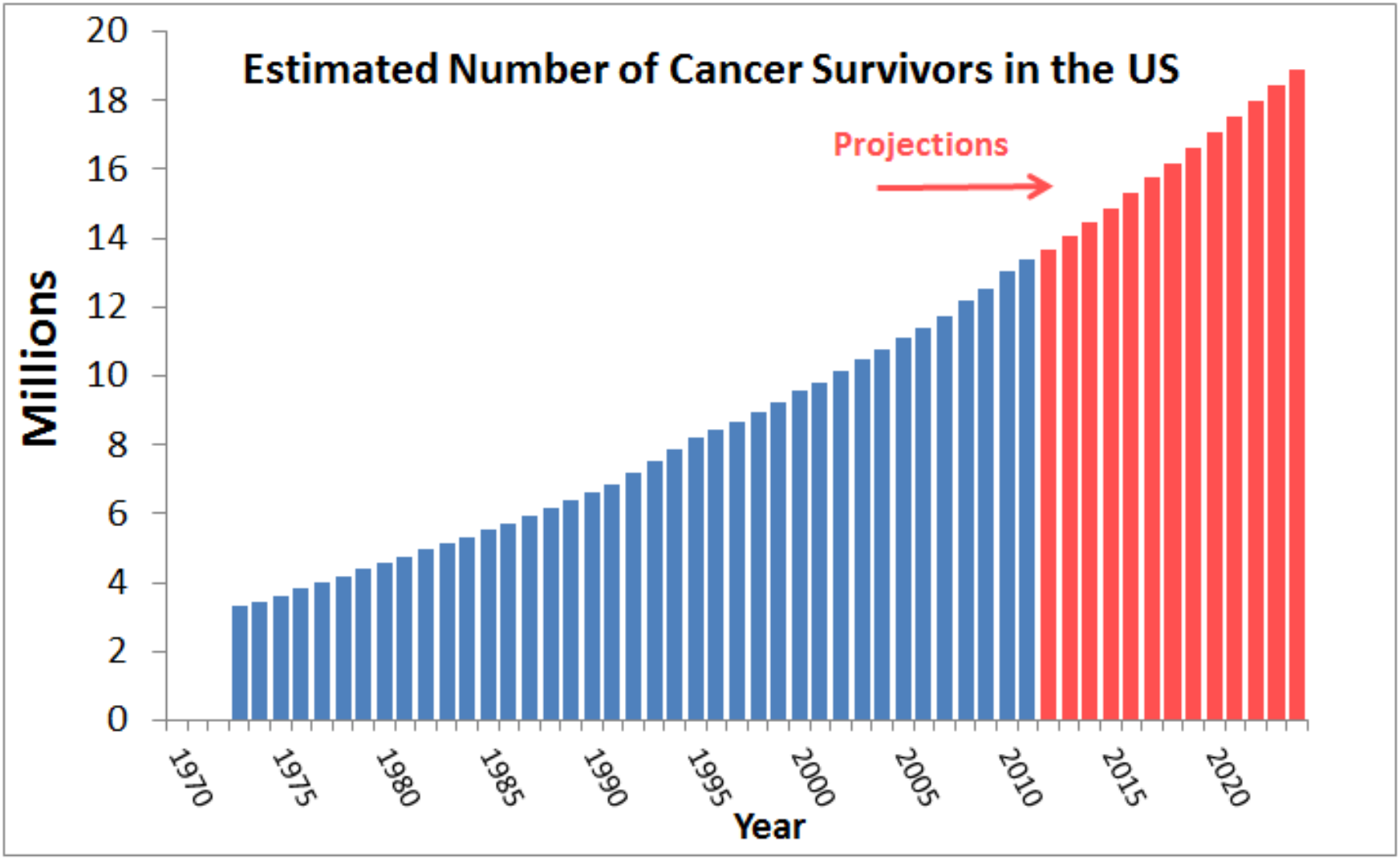
ICD therapy is indicated in patients*:

Level of Evidence: A

- With LVEF ≤ 35% due to prior MI who are at least 40 days post-MI and are in NYHA Functional Class II or III
- With LV dysfunction due to prior MI who are at least 40 days post-MI, have an LVEF ≤ 30%, and are in NYHA Functional Class I
- Who are survivors of cardiac arrest due to VF or hemodynamically unstable sustained VT after evaluation to define the cause of the event and to exclude any completely reversible causes

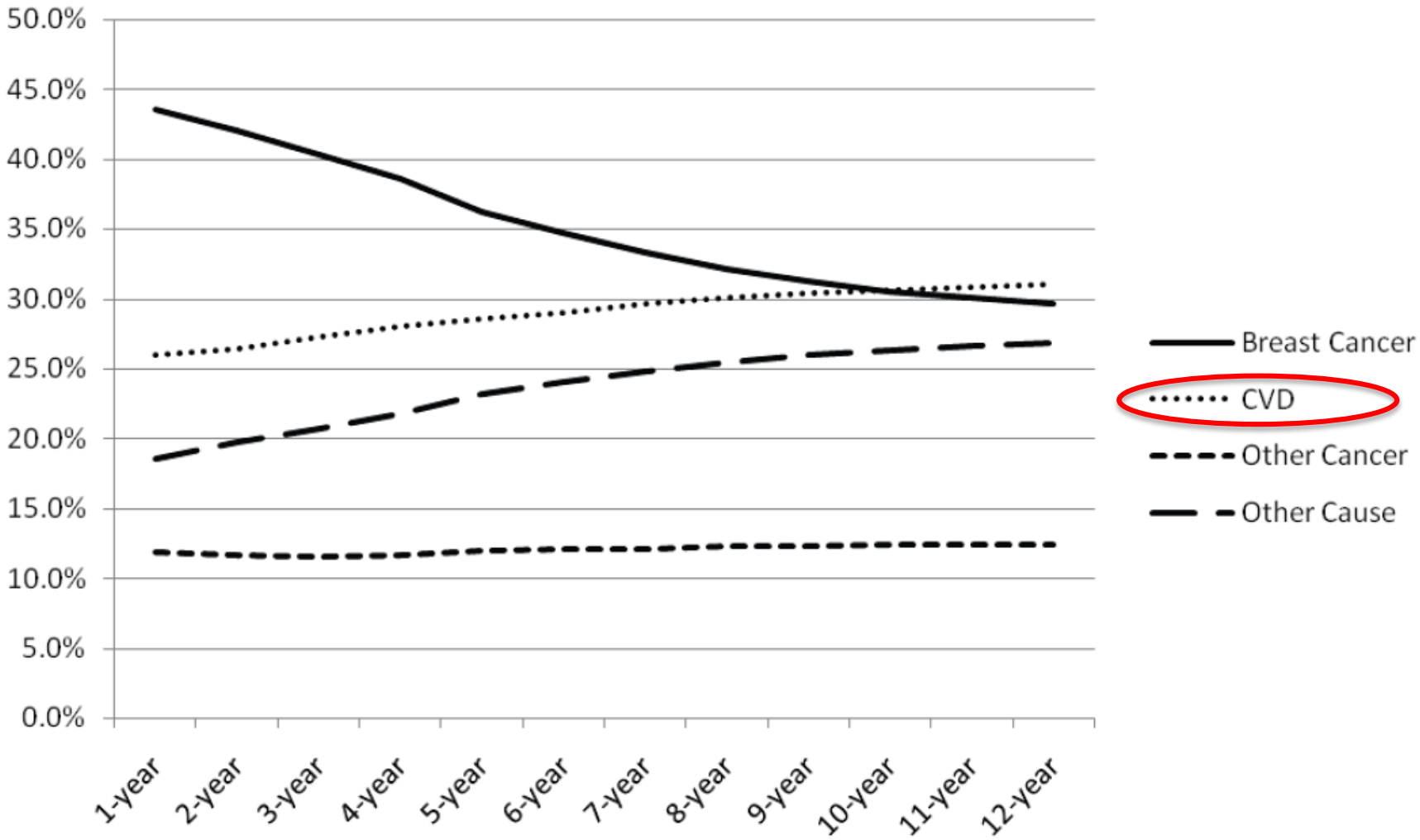
Level of Evidence: B

- With nonischemic DCM who have an LVEF ≤ 35% and who are in NYHA Functional Class II or III
- With nonsustained VT due to prior MI, LVEF < 40%, and inducible VF or sustained VT at electrophysiological study
- With structural heart disease and spontaneous sustained VT, whether hemodynamically stable or unstable
- With syncope of undetermined origin with clinically relevant, hemodynamically significant sustained VT or VF induced at electrophysiological study



[1] DeSantis C, Chunchieh L, Mariotto AB, et al. (2014). Cancer Treatment and Survivorship Statistics,

LEADING CAUSES OF DEATH AFTER BREAST CANCER DIAGNOSIS



CARDIOVASCULAR COMPLICATIONS OF CANCER THERAPY

Condition	Survivors (N = 10,397)	Siblings (N = 3034)	Relative Risk (95% CI)
	percent		
Major joint replacement*	1.61	0.03	54.0 (7.6–386.3)
Congestive heart failure	1.24	0.10	15.1 (4.8–47.9)
Second malignant neoplasm†	2.38	0.33	14.8 (7.2–30.4)
Cognitive dysfunction, severe	0.65	0.10	10.5 (2.6–43.0)
Coronary artery disease	1.11	0.20	10.4 (4.1–25.9)
Cerebrovascular accident	1.56	0.20	9.3 (4.1–21.2)
Renal failure or dialysis	0.52	0.07	8.9 (2.2–36.6)
Hearing loss not corrected by aid	1.96	0.36	6.3 (3.3–11.8)
Legally blind or loss of an eye	2.92	0.69	5.8 (3.5–9.5)
Ovarian failure‡	2.79	0.99	3.5 (2.7–5.2)

CHEMOTHERAPY ASSOCIATED WITH MYOCARDIAL DYSFUNCTION

Chemotherapy Agents	Incidence (%)	Frequency of Use
Anthracyclines		
Doxorubicin (Adriamycin) (6,7)	3–26*	+++
Epirubicin (Ellence) (10)	0.9–3.3	++
Idarubicin (Idamycin PFS) (8)	5–18	+
Alkylating agents		
Cyclophosphamide (Cytoxan) (8,11–13)	7–28	+++
Ifosfamide (Ifex) (8,14)	17	+++
Antimetabolites		
Clofarabine (Clolar) (10)	27	+
Antimicrotubule agents		
Docetaxel (Taxotere) (10,15,16)	2.3–8	++
Monoclonal antibody-based tyrosine kinase inhibitors		
Bevacizumab (Avastin) (10,18,19)	1.7–3	++
Trastuzumab (Herceptin) (20–28)	2–28	++
Proteasome inhibitor		
Bortezomib (Velcade) (10,17)	2–5	++
Small molecule tyrosine kinase inhibitors		
Dasatinib (Sprycel) (10)	2–4	++
Imatinib mesylate (Gleevec) (34,35)	0.5–1.7	+
Lapatinib (Tykerb) (32)	1.5–2.2	+
Sunitinib (Sutent) (36,37)	2.7–11	+++

EXPERT CONSENSUS STATEMENT

JASE 2014

Expert Consensus for Multimodality Imaging Evaluation of Adult Patients during and after Cancer Therapy: A Report from the American Society of Echocardiography and the European Association of Cardiovascular Imaging

Juan Carlos Plana, MD, FASE, Chair, Maurizio Galderisi, MD, FESC, Co-Chair, Ana Barac, MD, PhD, Michael S. Ewer, MD, JD, Bonnie Ky, MD, FASE, Marielle Scherrer-Crosbie, MD, PhD, FASE, Javier Ganame, MD, PhD, FASE, Igal A. Sebag, MD, FASE, Deborah A. Agler, RCT, RDCS, FASE, Luigi P. Badano, MD, PhD, FESC, Jose Banchs, MD, FASE, Daniela Cardinale, MD, PhD, FESC, Joseph Carver, MD, Manuel Cerqueira, MD, Jeanne M. DeCara, MD, FASE, Thor Edvardsen, MD, PhD, FESC, Scott D. Flamm, MD, MBA, Thomas Force, MD, Brian P. Griffin, MD, Guy Jerusalem, MD, PhD, Jennifer E. Liu, MD, FASE, Andreia Magalhães, MD, Thomas Marwick, MBBS, PhD, MPH, Liza Y. Sanchez, RCS, FASE, Rosa Sicari, MD, PhD, FESC, Hector R. Villarraga, MD, FASE, and Patrizio Lancellotti, MD, PhD, FESC, *Cleveland, Ohio; Naples, Padua, Milan, and Pisa, Italy; Washington, District of Columbia; Houston, Texas; Philadelphia, Pennsylvania; Boston, Massachusetts; Hamilton, Ontario and Montreal, Quebec, Canada; Chicago, Illinois; Oslo, Norway; Liege, Belgium; New York, New York; Lisbon, Portugal; Hobart, Australia; Rochester, Minnesota*

ASE Recommendations for echo surveillance of chemo-induced cardiotoxicity

- Anthracycline-based regimen:

  echo at baseline, upon completion of therapy and 6 months after

- HER-2 inhibitors (Herceptin/trastuzumab):

  echo at baseline, and every 3 months during therapy, and once after completion of therapy

MINIMAL DETECTABLE CHANGE BETWEEN SERIAL EXAMS FOR EF MEASUREMENT WITH SIMPSON'S BIPLANE METHOD IS 12%

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Cardiac Imaging

Reproducibility of Echocardiographic Techniques for Sequential Assessment of Left Ventricular Ejection Fraction and Volumes

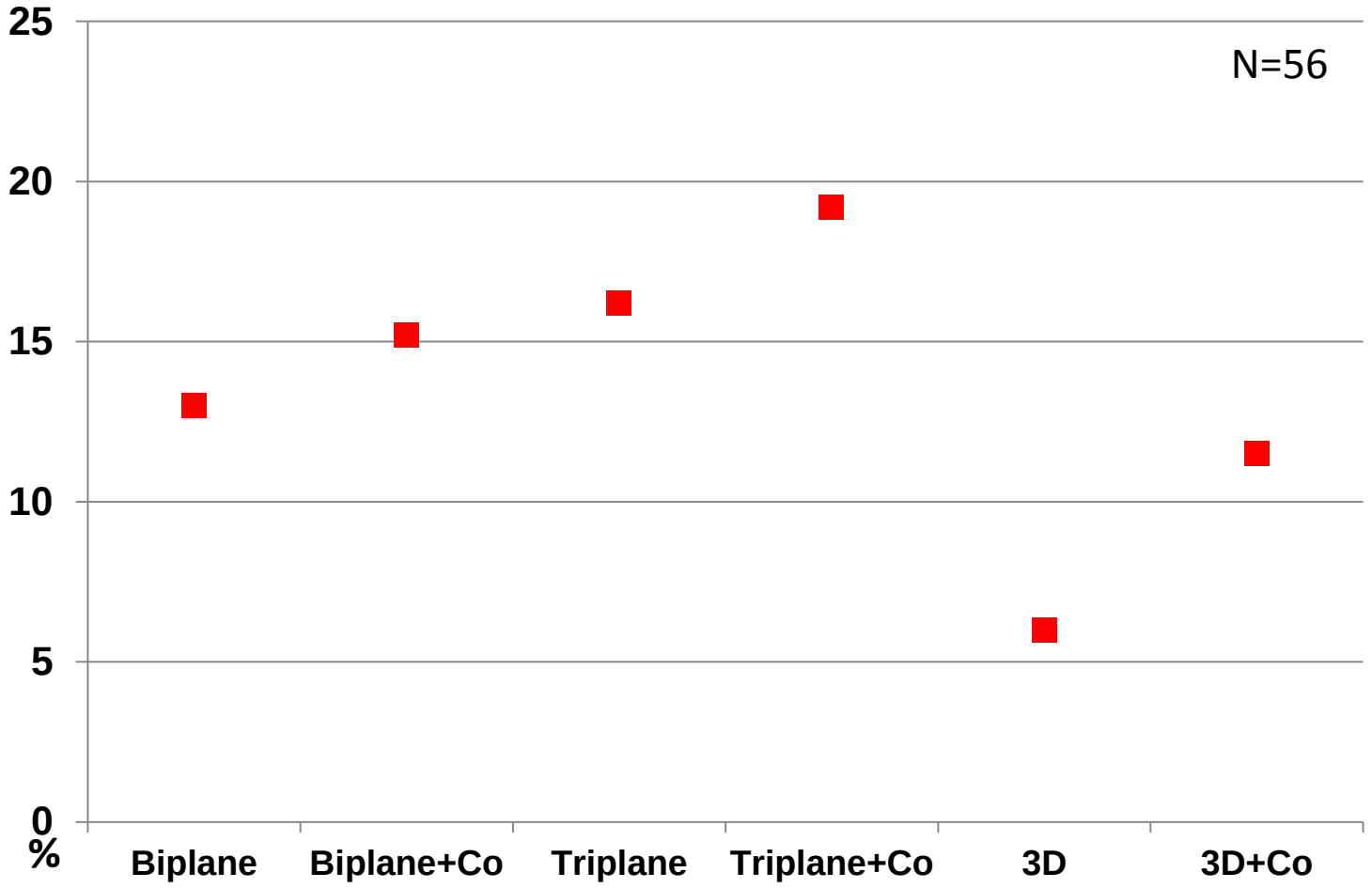
Application to Patients Undergoing Cancer Chemotherapy

Paaladinesh Thavendiranathan, MD, MSc, Andrew D. Grant, MD, Tomoko Negishi, MD, Juan Carlos Plana, MD, Zoran B. Popović, MD, PhD, Thomas H. Marwick, MD, PhD, MPH

Cleveland, Ohio

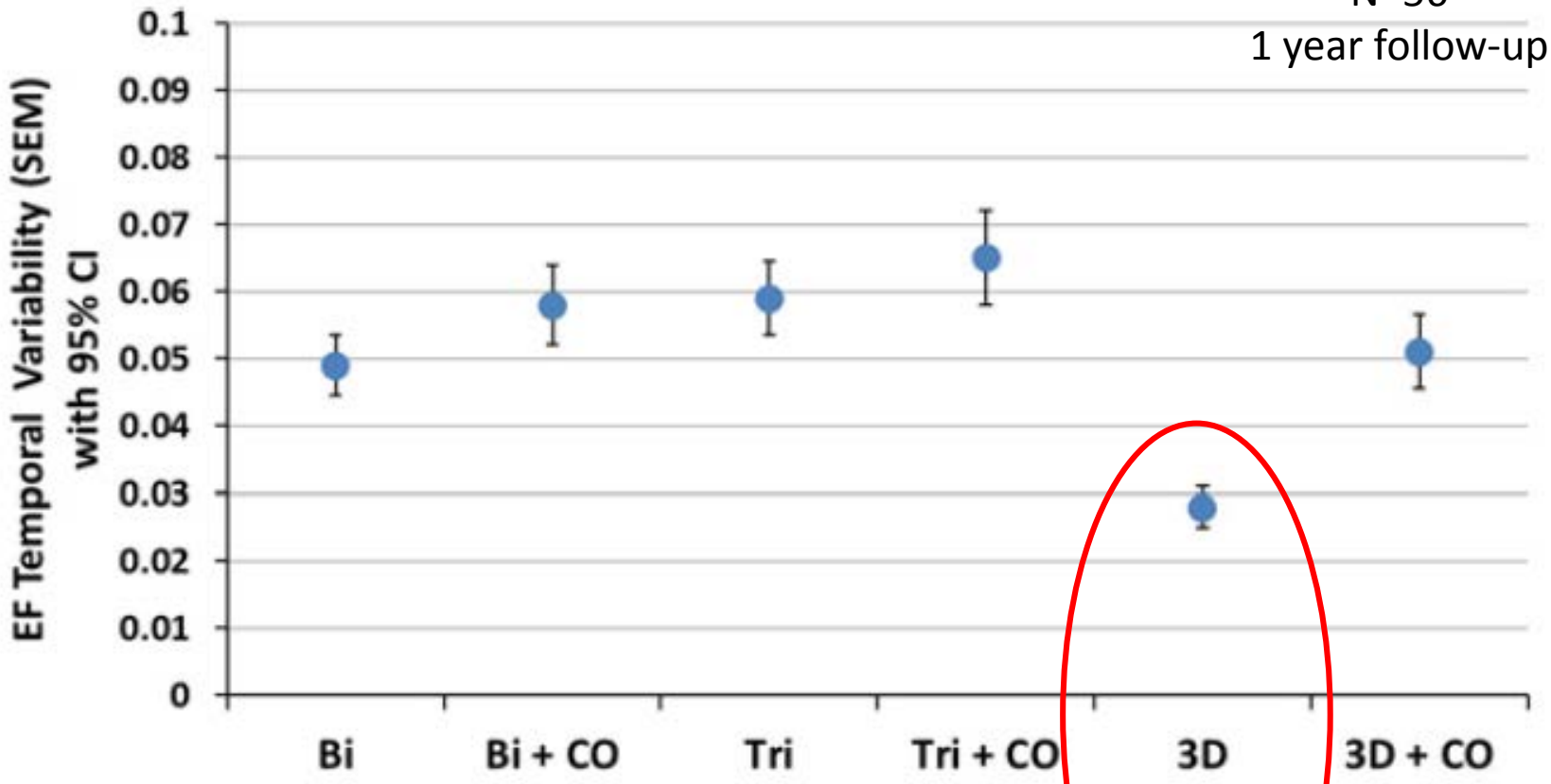
Thavendiranathan, 2013

MINIMAL DETECTABLE CHANGE FOR EF MEASUREMENT



TEMPORAL VARIABILITY OF EF

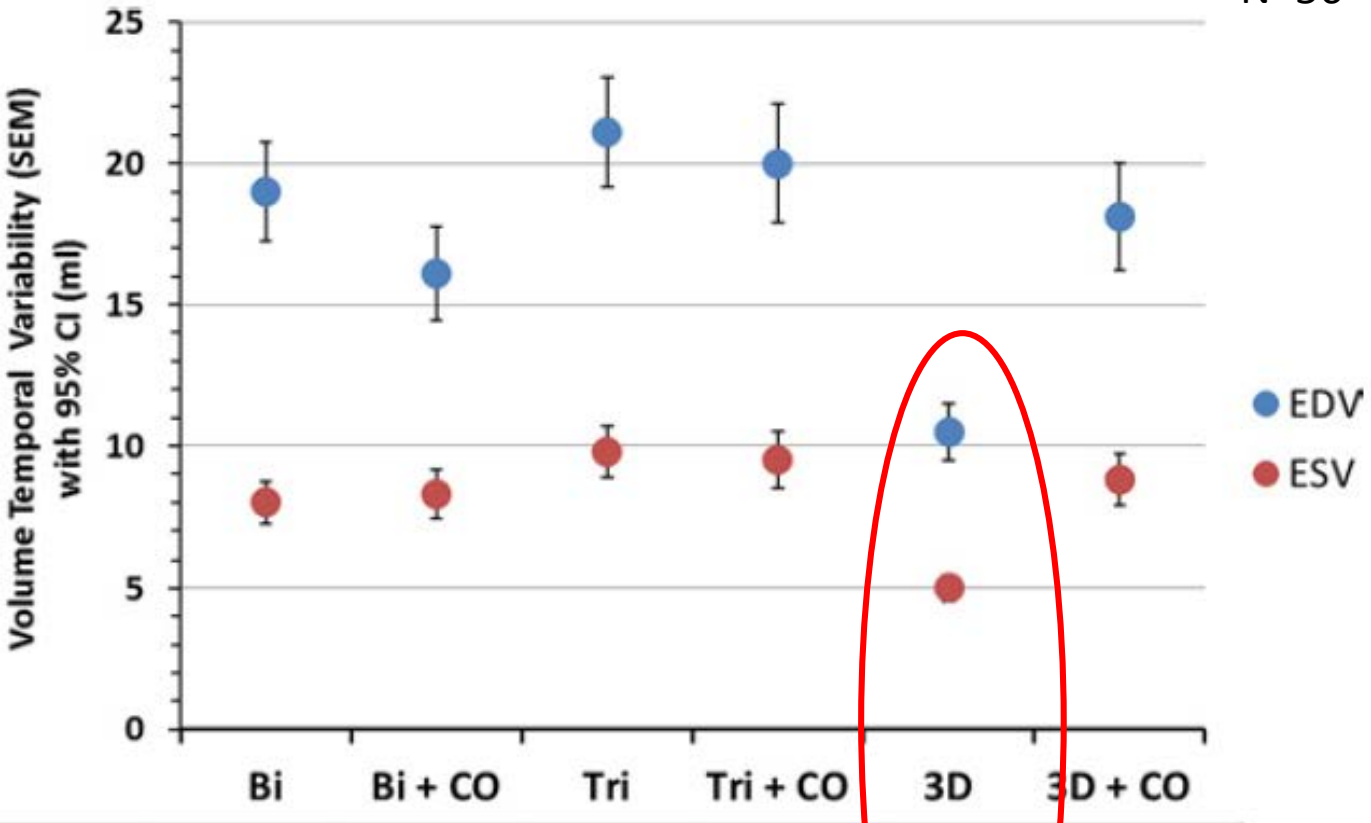
N=56
1 year follow-up



EF SEM 95% CI	0.049 (0.045–0.054)	0.058 (0.053–0.065)*	0.059 (0.054–0.065)	0.065 (0.058–0.072)	0.028 (0.025–0.031)	0.051 (0.046–0.057)*

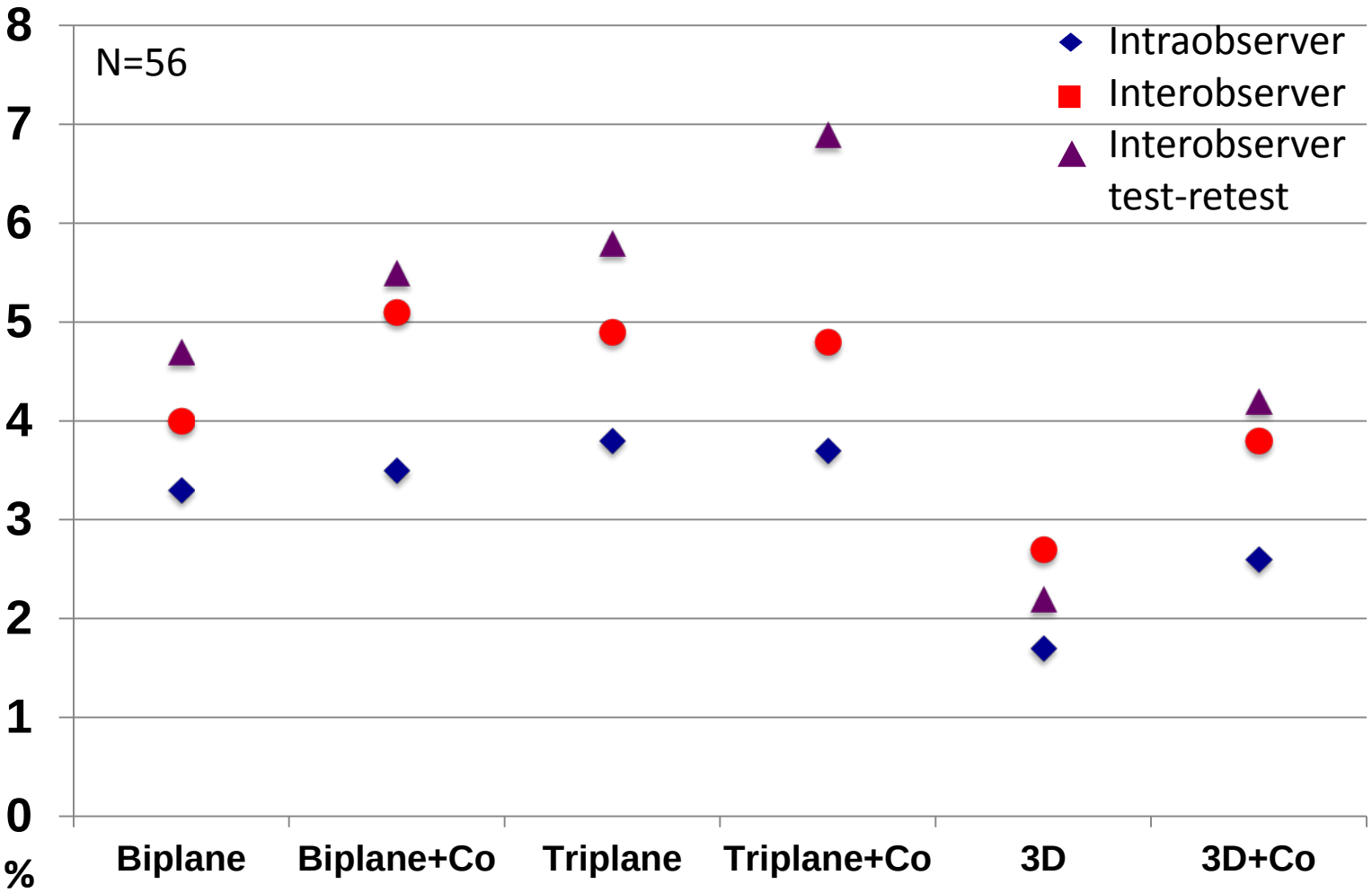
TEMPORAL VARIABILITY IN EDV AND ESV

N=56

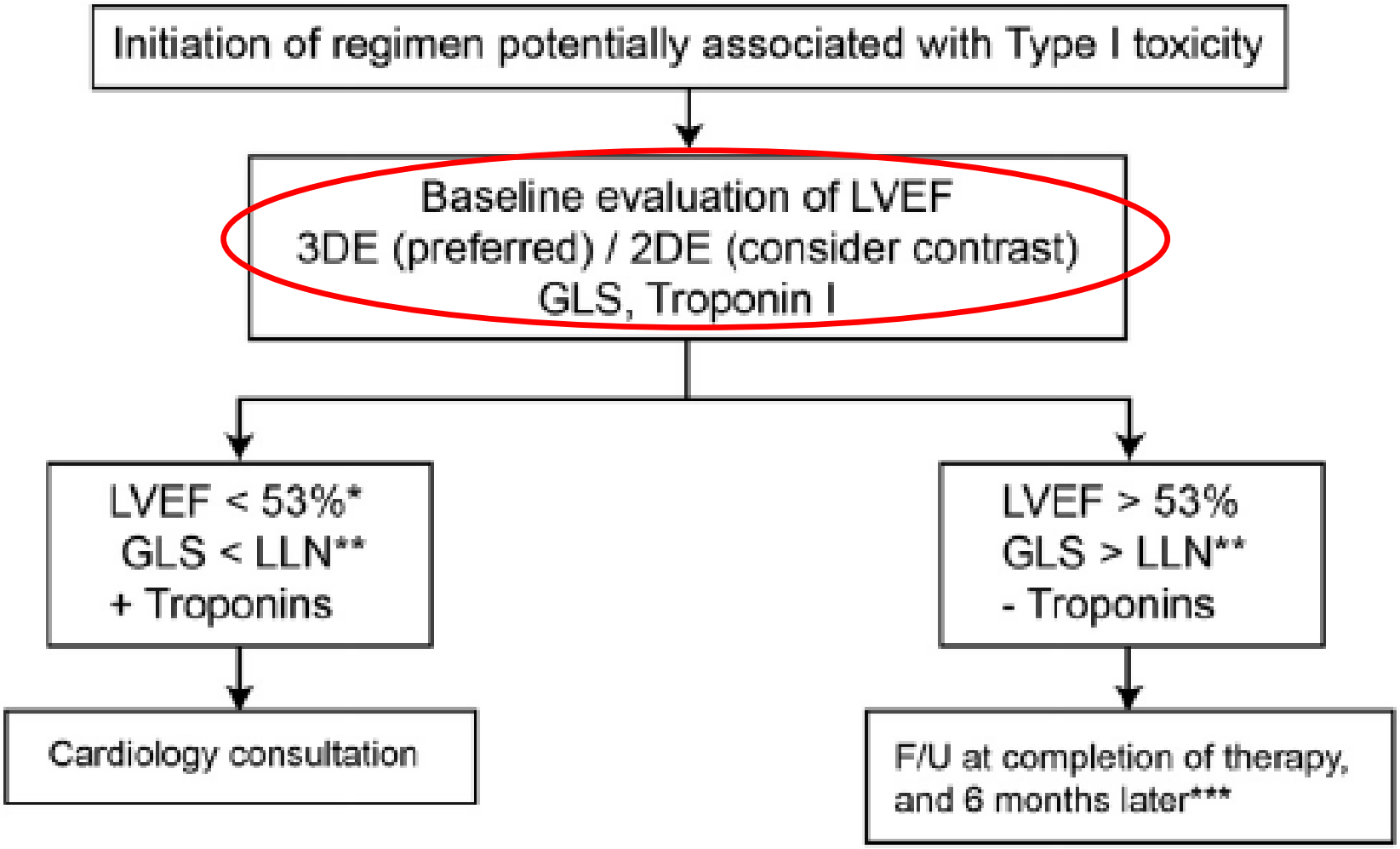


	Bi	Bi + CO	Tri	Tri + CO	3D	3D + CO
EDV SEM (ml) (95% CI)	19.0 (17.4–20.9)	16.1 (14.6–17.9)*	21.1 (19.3–23.2)	20.0 (18.0–22.2)	10.5 (9.6–11.6)	18.1 (16.4–20.2)*
ESV SEM (ml) (95% CI)	8.0 (7.3–8.8)	8.3 (7.5–9.2)	9.8 (8.9– 0.7)	9.5 (8.6–10.6)	5.0 (4.6–5.5)	8.8 (8.0–9.8)*

INTEROBSERVER AND INTRAOBSERVER VARIABILITY FOR EF MEASUREMENT



ASE RECOMMENDATION FOR ECHO SURVEILLANCE OF ANTHRACYCLINE CARDIOTOXICITY



Dynamic Assessment of Right Ventricular Volumes and Function by Real-Time Three-Dimensional Echocardiography: A Comparison Study With Magnetic Resonance Imaging in 100 Adult Patients

Gregor Leibundgut, MD, Andreas Rohner, MD, Leticia Grize, Alain Bernheim, MD, Arnheid Kessel-Schaefer, MD, Jens Bremerich, MD, Michael Zellweger, MD, Peter Buser, Prof, and Michael Handke, Prof, *Basel, Switzerland*

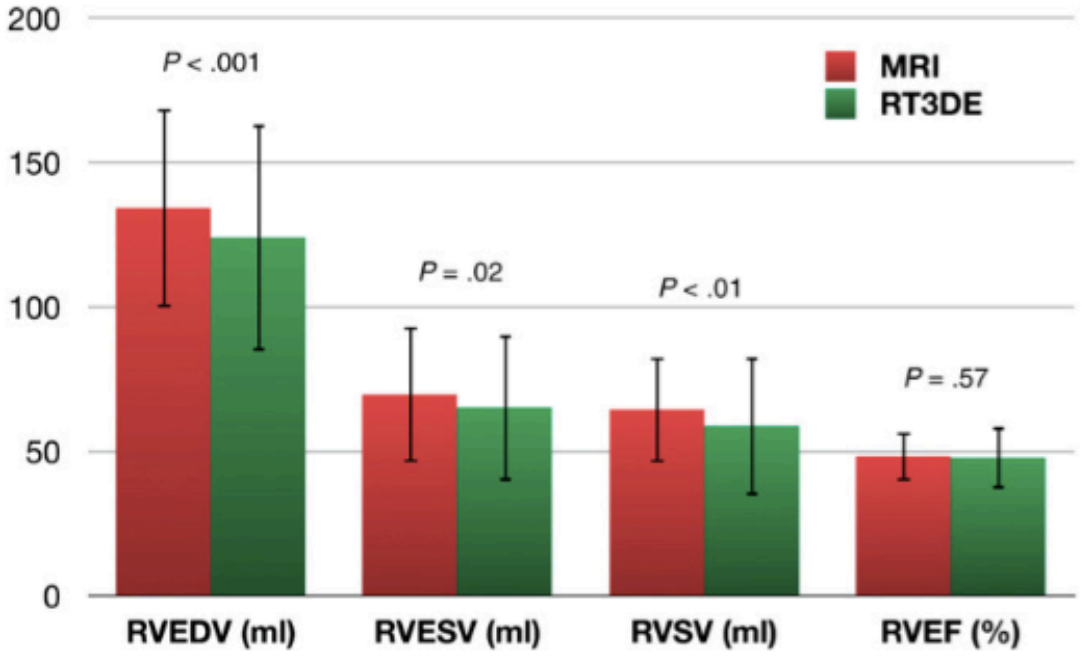
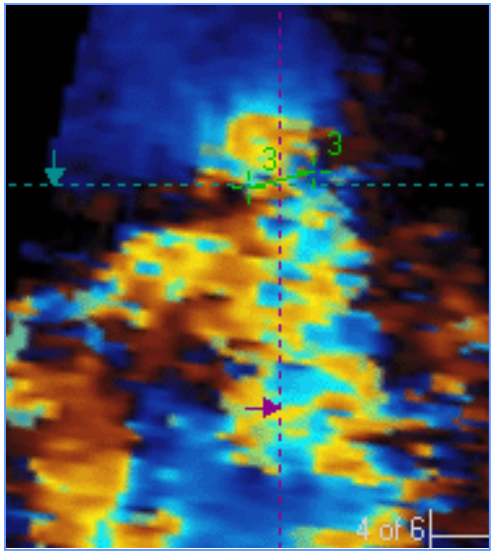
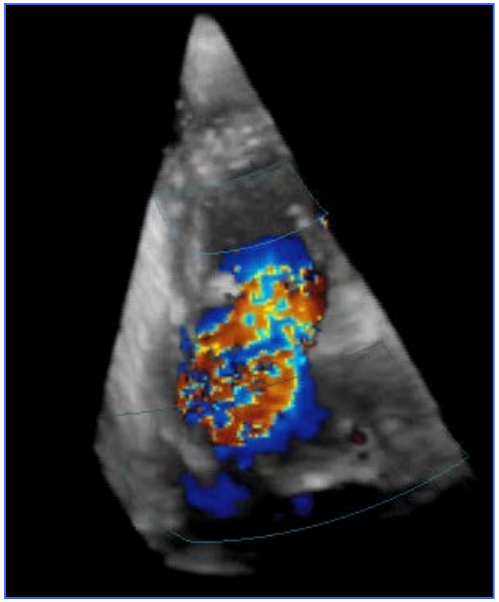


Figure 5 Mean values of RV volumes and ejection fraction obtained by MRI versus RT3DE imaging. Error bars indicate the standard deviation of measurements. *RVEDV*, RV end-diastolic volume; *RVEF*, RV ejection fraction; *RVESV*, RV end-systolic volume; *RVSV*, RV stroke volume.

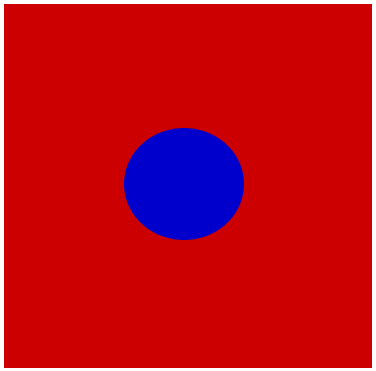
3D in Mitral Valve Disease





Regurgitation

Round hole
In a flat object



Perfect PISA
hemisphere

Circular
Vena Contrata

PISA, Vena Contracta Pitfalls

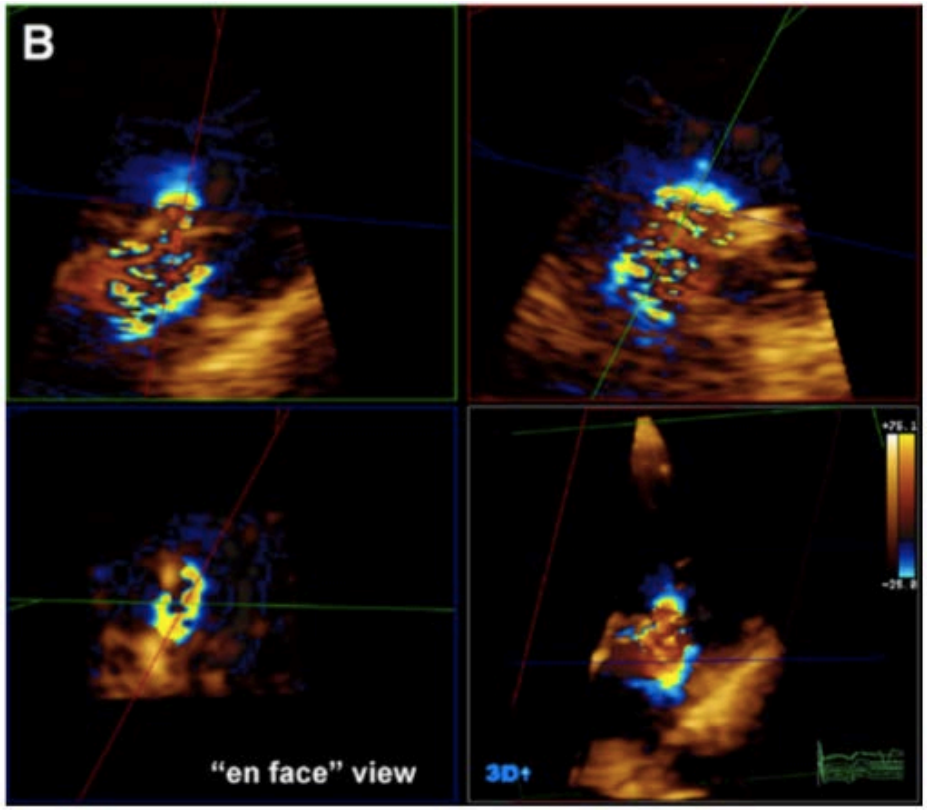
Assumptions

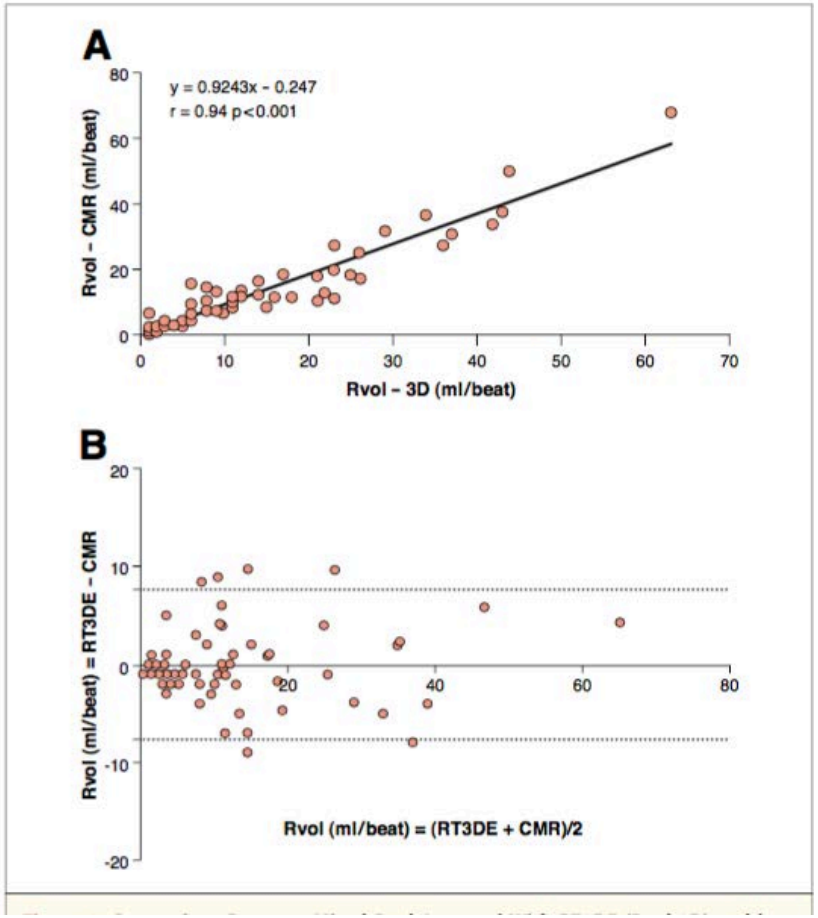
- “Regurgitant orifice circular”
- “Flow convergence perfect hemisphere”
- “Vena contracta circular”
- “1 frame in 1 view reflects whole Regurg”
- “There is only one regurgitant orifice”

Quantification of Functional Mitral Regurgitation by Real-Time 3D Echocardiography

Comparison With 3D Velocity-Encoded Cardiac Magnetic Resonance

Nina Ajmone Marsan, MD,*§ Jos J. M. Westenberg, PhD,† Claudia Ypenburg, MD,* Victoria Delgado, MD,* Rutger J. van Bommel, MD,* Stijntje D. Roes, MD,‡ Gaetano Nucifora, MD,* Rob J. van der Geest, PhD,† Albert de Roos, MD, PhD,‡ Johan C. Reiber, PhD,† Martin J. Schalij, MD, PhD,* Jeroen J. Bax, MD, PhD*





3D Imaging to study Cardiac Remodeling

What is Cardiac Remodeling ?

Remodeling

Remaking
Adjustment
Adaptation
Alteration
Conversion
Refitting
Transformation
Reformation
Reshaping
Distortion
Enlargement

Ventricular Remodeling

… more than

chamber enlargement …

Ventricular Remodeling

Athletes
Normal Growth

Ischemia
Other diseases


www.forartis

Cardiac Remodeling

Injury

Inflammation

Increased Load

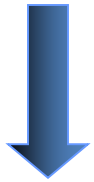
Molecular Pathways

Metabolic Pathways

Mechanical Pathways

Adaptive

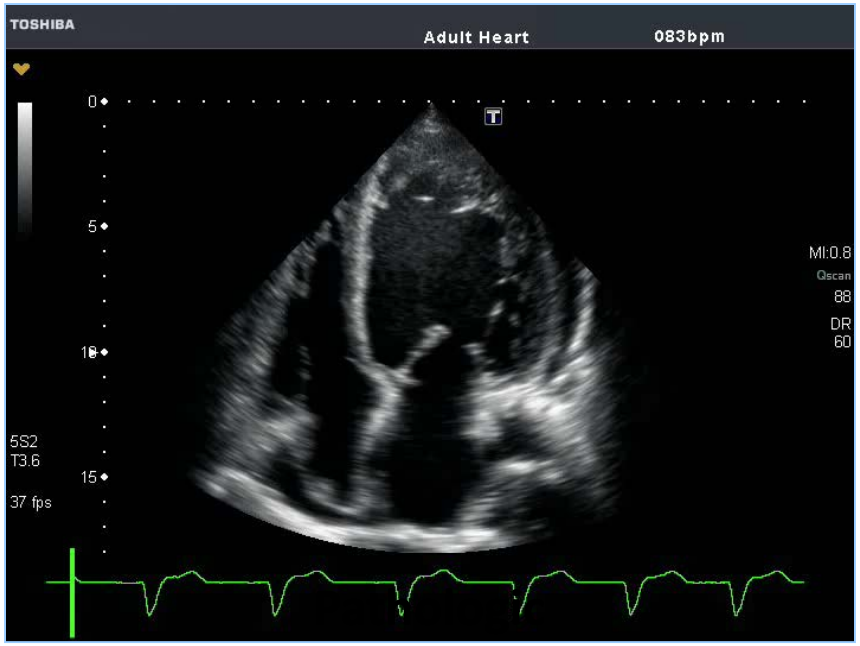
Remodeling



Adverse

Remodeling

LV Remodeling



Ventricular Remodeling

- **Structural Remodeling**

  Size, Mass, Shape

Ventricular Remodeling

- **Structural Remodeling**

  Size, Mass, Shape

- **Mechanical Remodeling**

  Systole, Diastole

Ventricular Remodeling

- **Structural Remodeling**

  Size, Mass, Shape

- **Mechanical Remodeling**

  Systole, Diastole

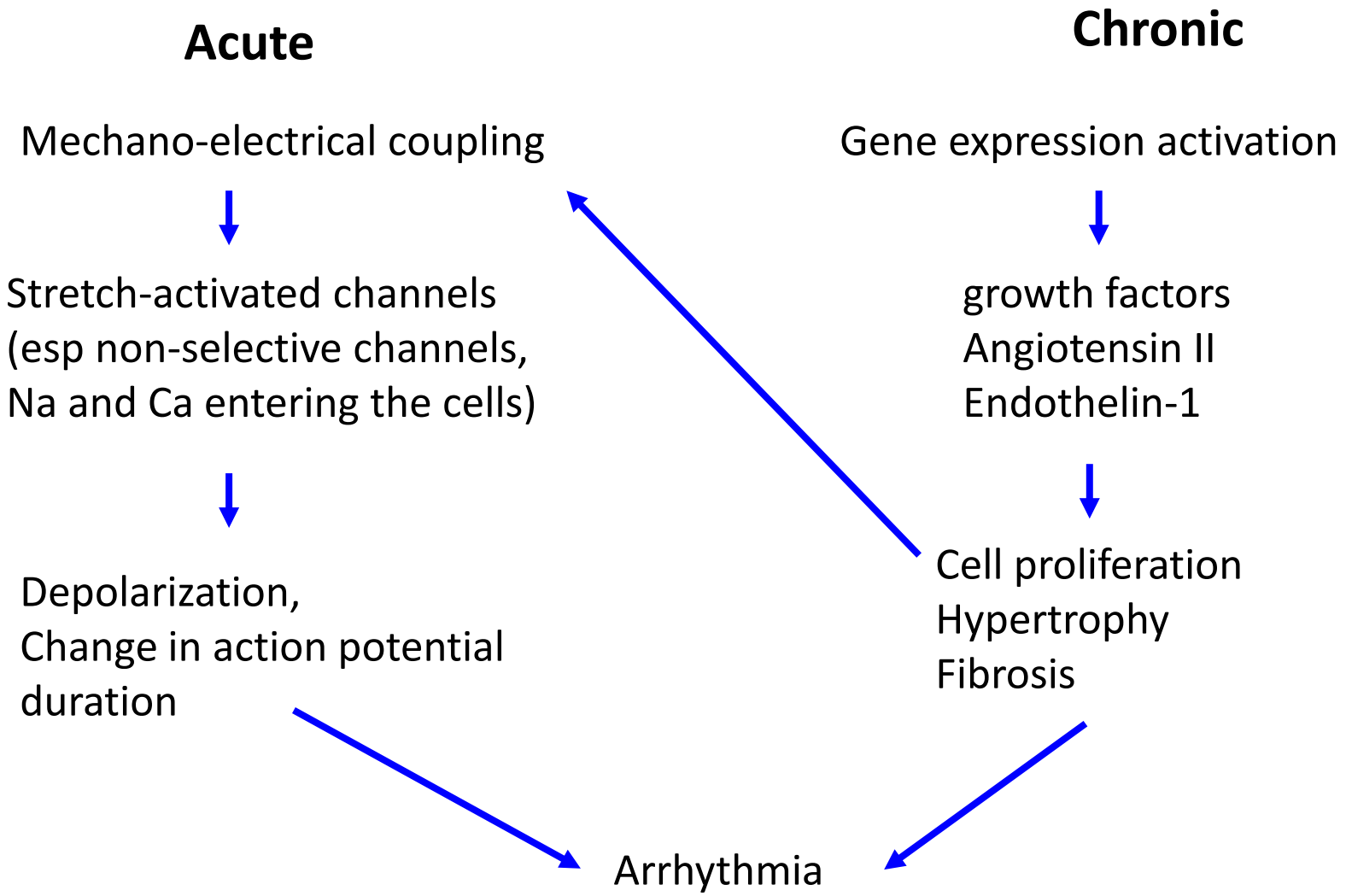
- **Electrical Remodeling**

  Arrhythmias

Ventricular Remodeling

Why worry about
Ventricular Remodeling ?

Ventricular Dilatation
Myocardial Stretch



Ravens. Progress in Biophysics and Molecular Biology 2003; 82:255-266

Dilatation of LV and Arrhythmia After Myocardial Infarction

Dilation of the infarcted/non-infarcted zones

Increased dispersion in the refractoriness

Early afterdepolarizations

(caused by an increased in wall stress; contraction-excitation feedback)

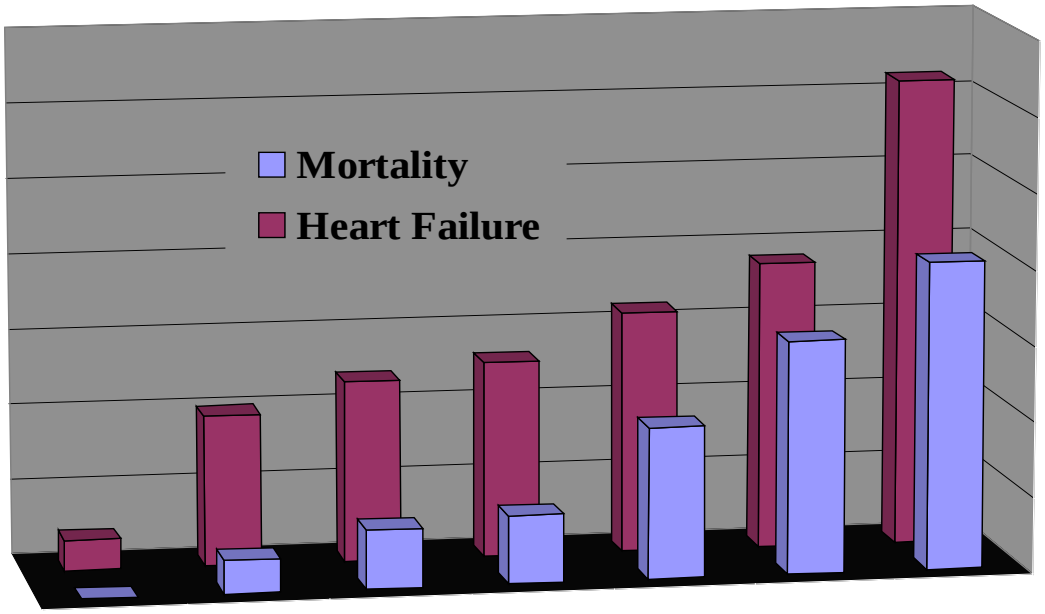
LVESV: continued enlargement in 1 year

associated with high frequency of arrhythmias

(CATS: captril and thrombolysis study)

J Cardiac Failure 1994; 1:3-11.

End Systolic Volume Index and Prognosis

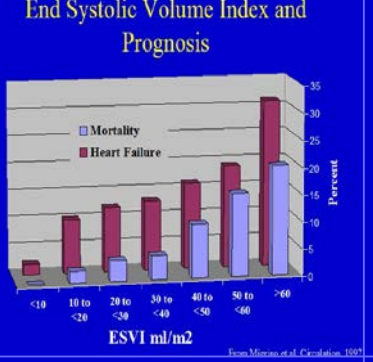


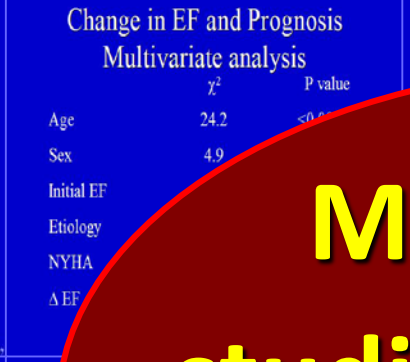
From Migrino et al, Circulation, 1997.

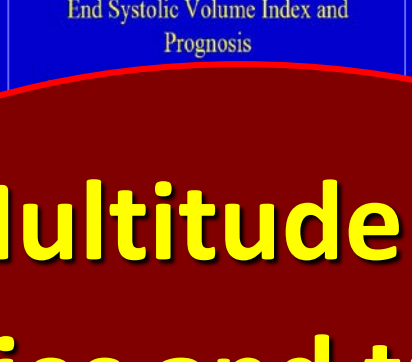
Multitude of studies and trials…

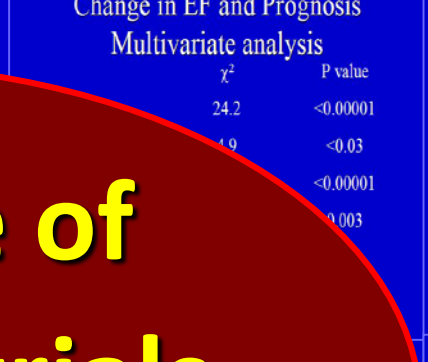
Systolic Function

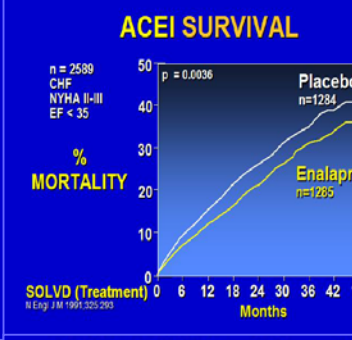
Diagnosis | **Prognosis** | **Therapy**

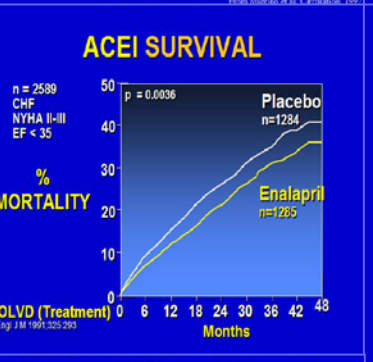


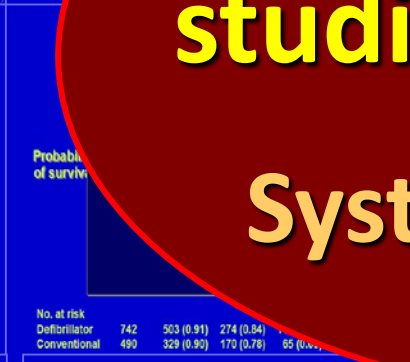


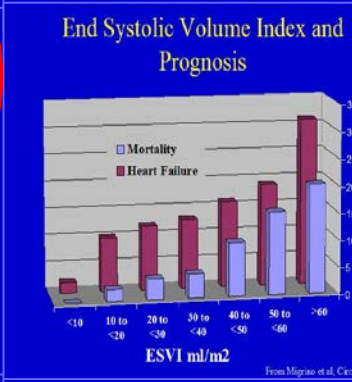


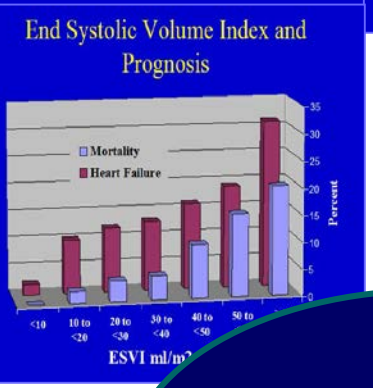


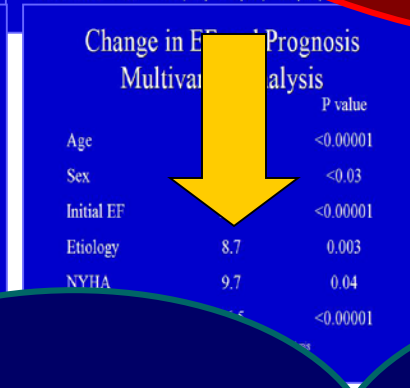


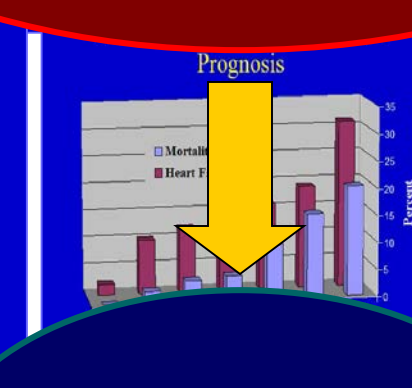


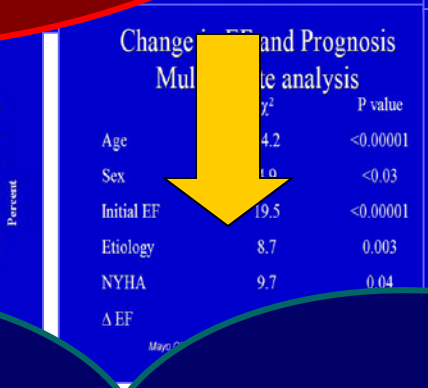


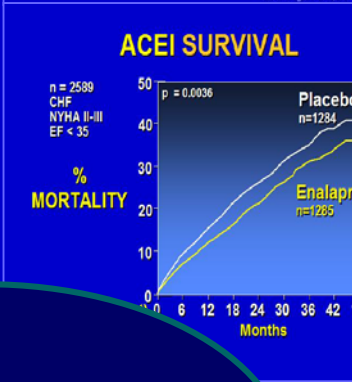


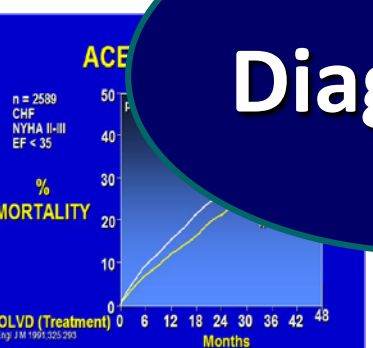


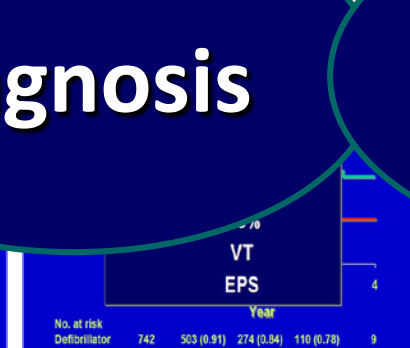


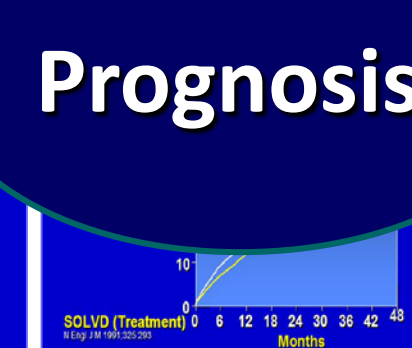


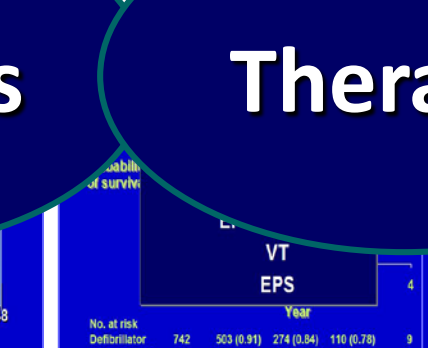


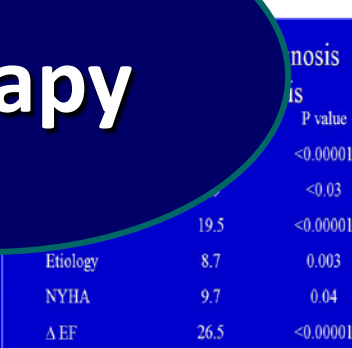




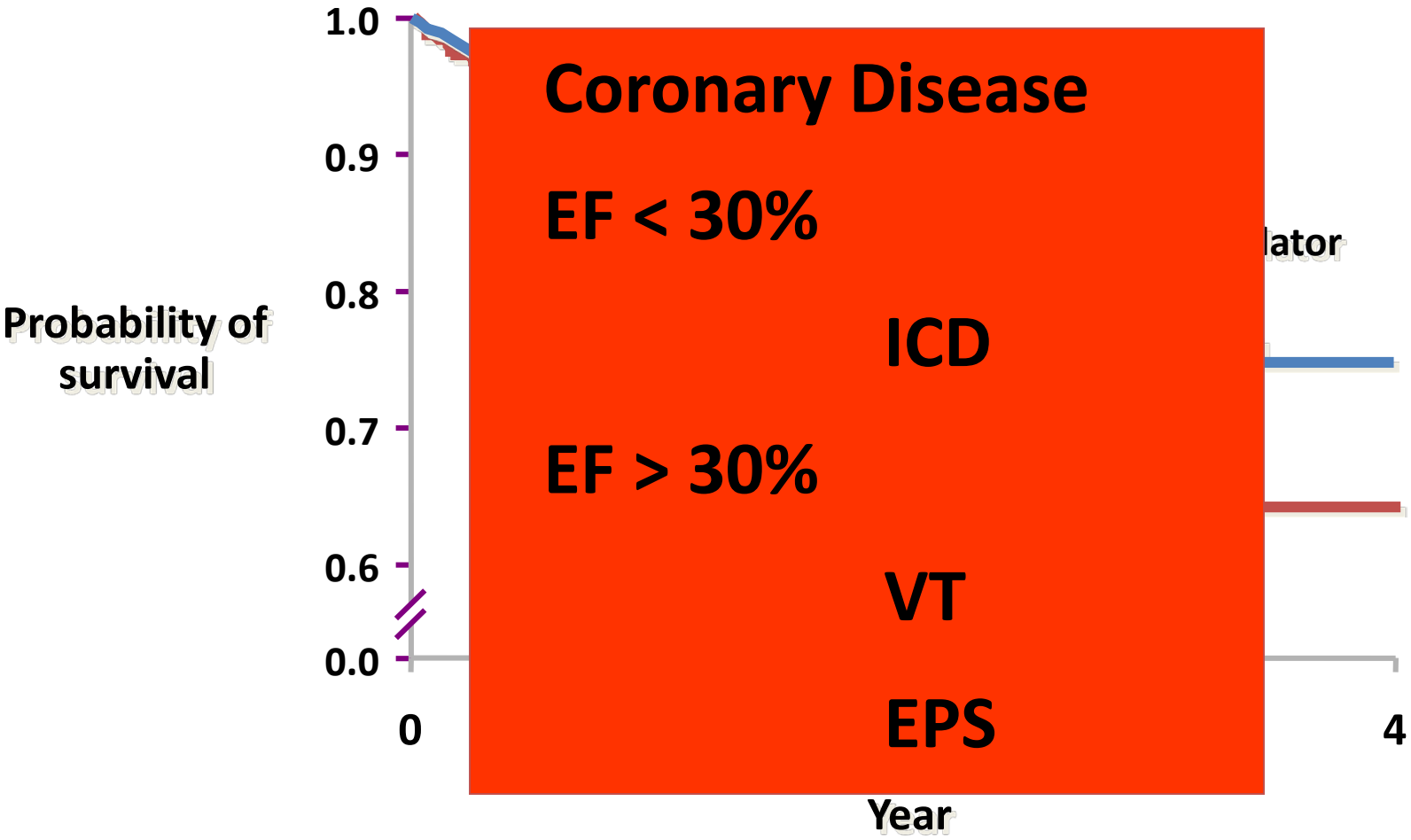








MADIT II



No. at risk					
Defibrillator	742	503 (0.91)	274 (0.84)	110 (0.78)	9
Conventional	490	329 (0.90)	170 (0.78)	65 (0.69)	3

LV Mass

Chiang et al. Circulation 41:31, 1970

Koyanagi et al. Circulation 65:1192, 1982

Casale et al. Ann Int Med 105:173, 1986

Marcus et al. Circulation 75:119, 1987

Cooper et al. 65:441, 1990

Levy et al. NEJM 322:1561, 1990

Verdecchia et al. Circulation 97:48, 1998

Devereux et al. AJC 86:1090, 2000

Aurigemma et al. JACC 37:1042, 2001

Gardin et al. AJC 87:1051, 2001

LV Mass

Chiang et al. Circulati

Koyanagi

Ca

Independent Predictor of Morbidity

Independent Predictor of Mortality

Marker of Sudden Death

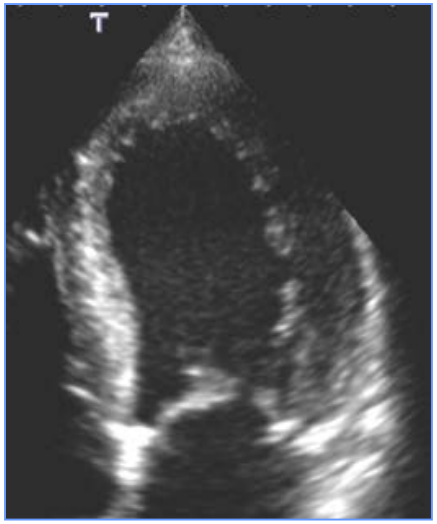
Both in Preserved and Decreased EF

Independent of Diastolic Dysfunction

Neurohormonal Activation

Deranged Myocyte Perfusion

LV Shape



Diagnostic Implications

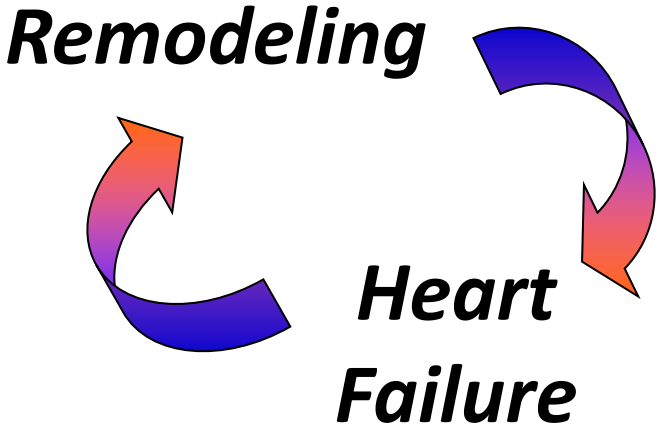
Prognostic Connotations

Therapeutic Value

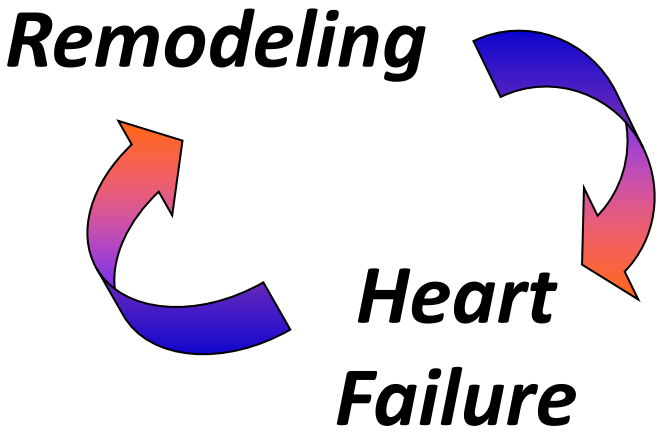
Ventricular Remodeling

- **Determinant of heart failure and related complications**

Ventricular Remodeling



Ventricular Remodeling



- **Impacts Survival**

Need to reverse the process

Ventricular Remodeling

What methods to study Ventricular Remodeling?

Ventricular Remodeling

- Echocardiography
- Radionuclide Anhiography
- Magnetic Resonance
- Computed Tomography

Echocardiography

Increasd LVEDV and LVESV

Concentric or Eccentric Hypertrophy

Increased Volume/Mass Ratio

Altered Geometry

Reduced Ejection Fraction

Increased global/regional wall stress

Impaired diastolic function

Ventricular dyssynchrony

RV remodeling

Atrial remodeling

Valvular Disorder

Echocardiography

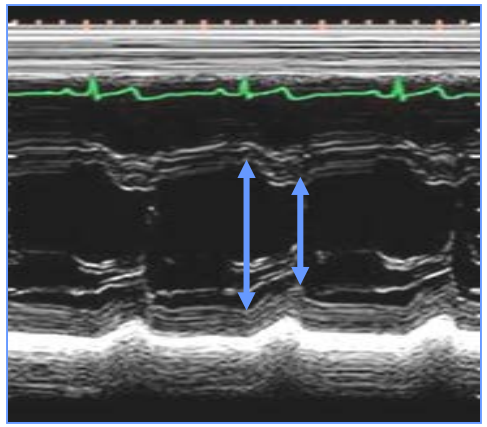
- **M-mode:** Dimension, %FS
- **2D Echo:** Volumes, EF, Shape, Mass
- **Doppler:** Hemodynamics Flow disorders

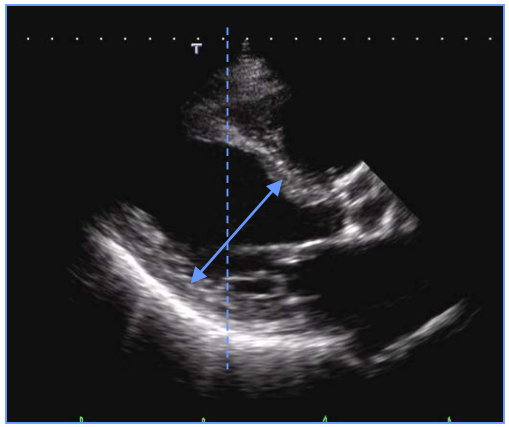
Ventricular Remodeling

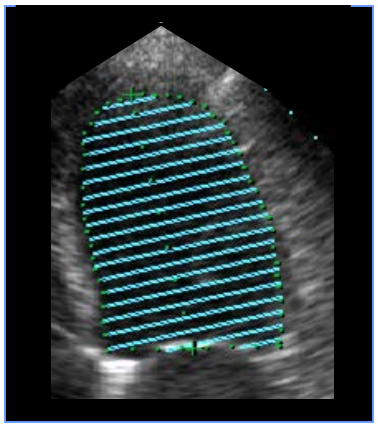
… more than

dimension/area increase …

M-mode, 2DE
Limitations

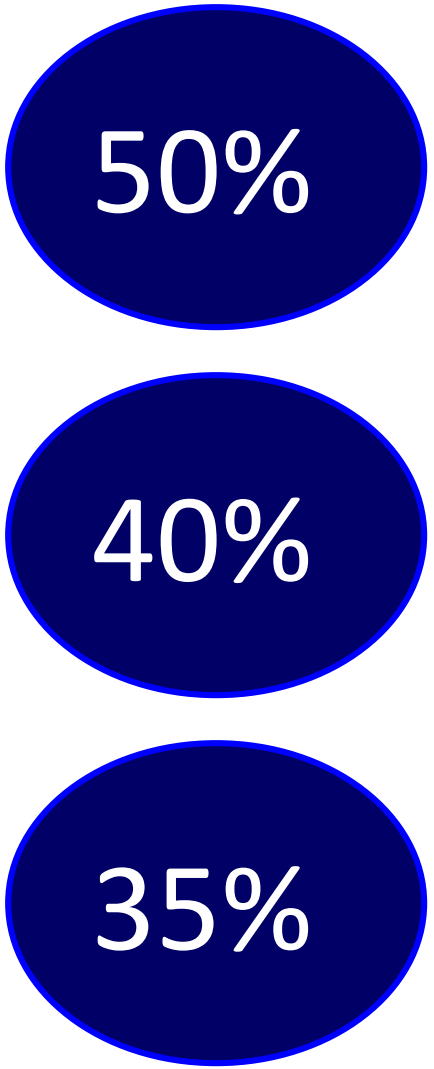






Ejection Fraction

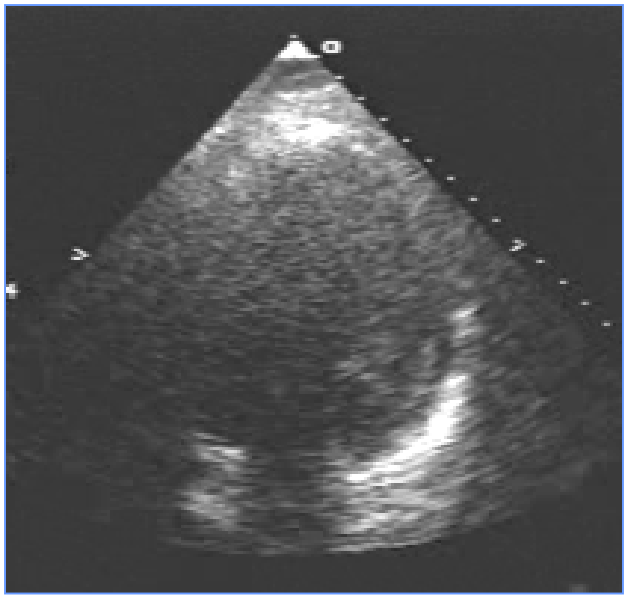
Impact Numbers

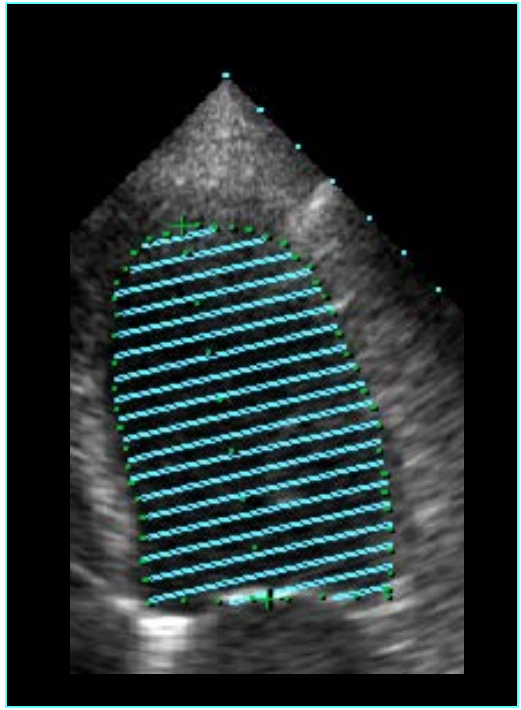


Problems in the 2D Echo Quantification of Volumes and EF :

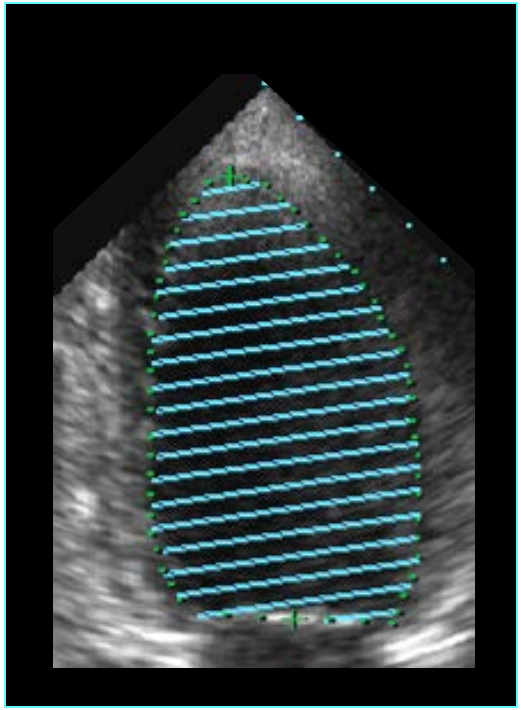
- Can’t see the borders
- Foreshortened views
- Off-axis views
- Translational motion

Life is not always easy …





118 ml



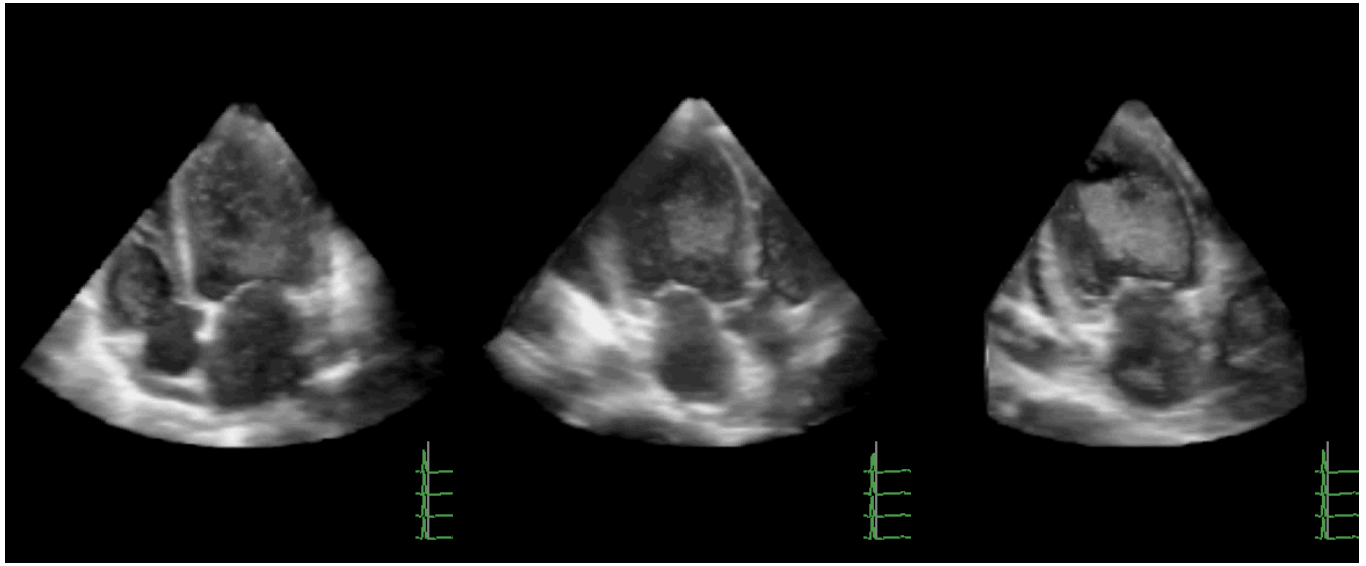
142 ml

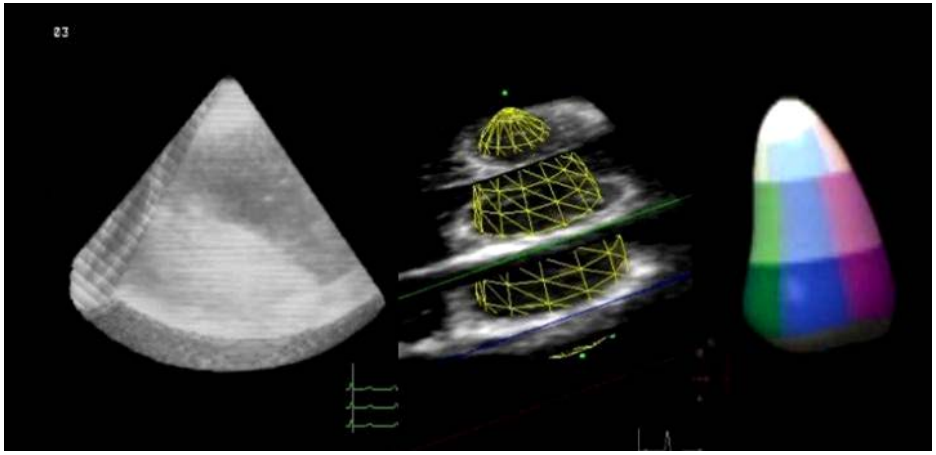
Problems in the 2D Echo Quantification of Volumes and EF :

- **Foreshortened views**
- **Off-axis views**
- **Translational motion**

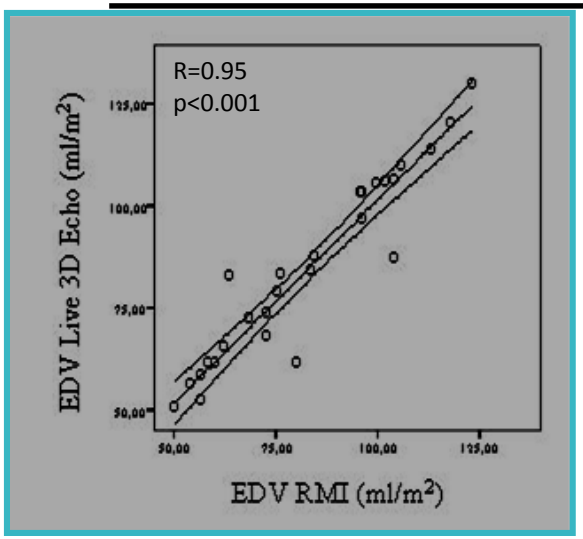
3D Echo improves the accuracy

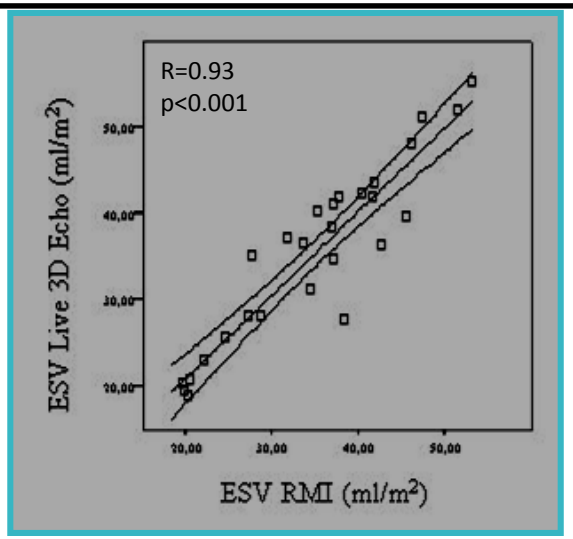
3D Echo Quantification

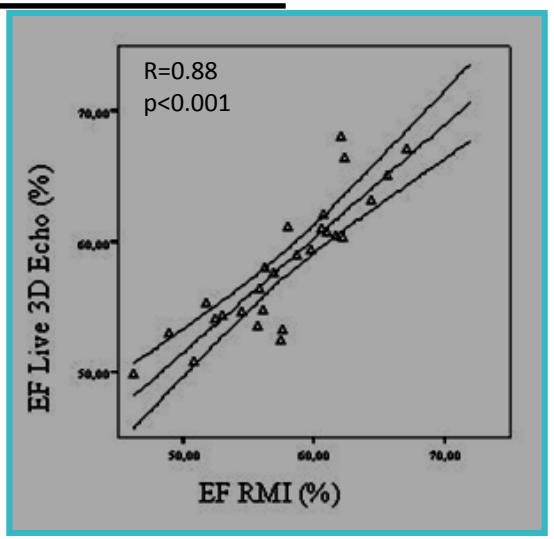


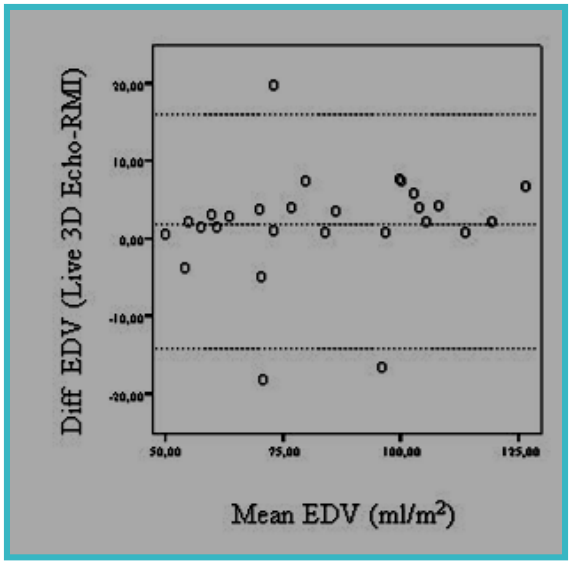


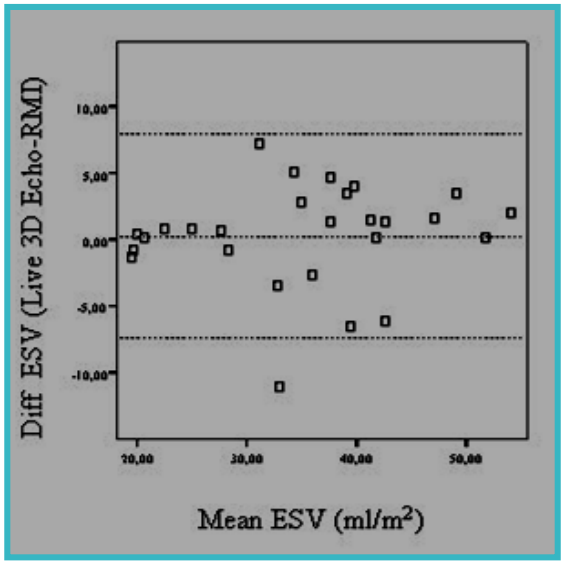
3D Echo vs MRI for LV Volumes and EF

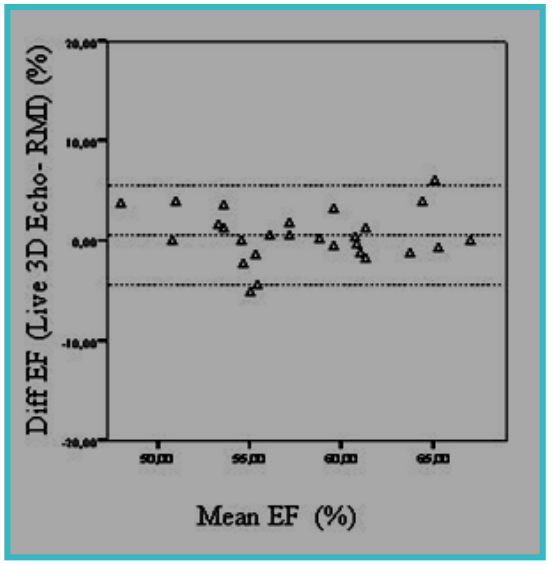




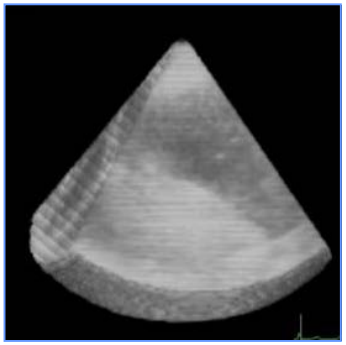
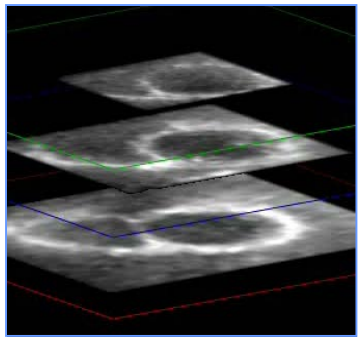
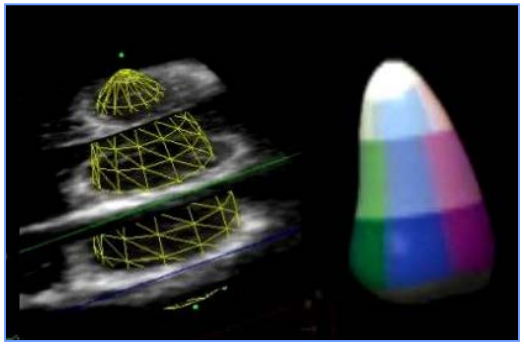
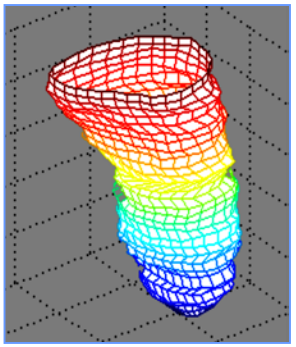




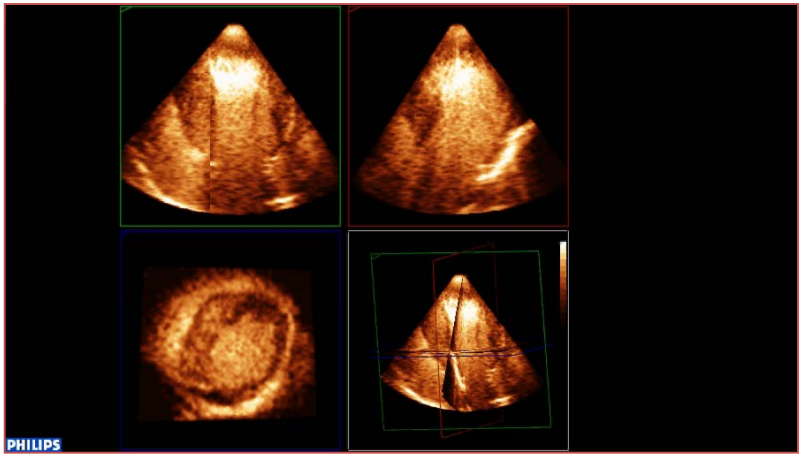


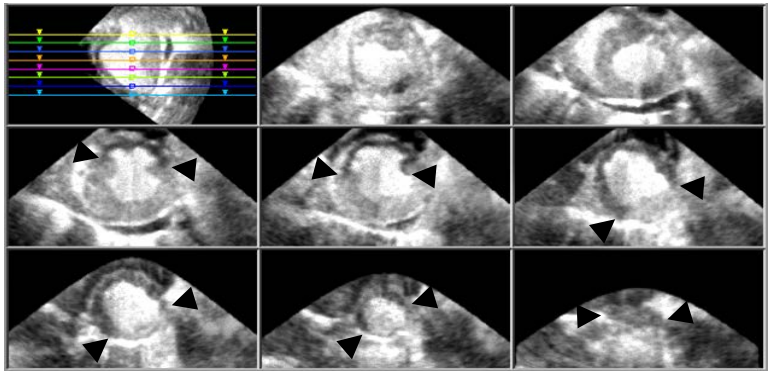


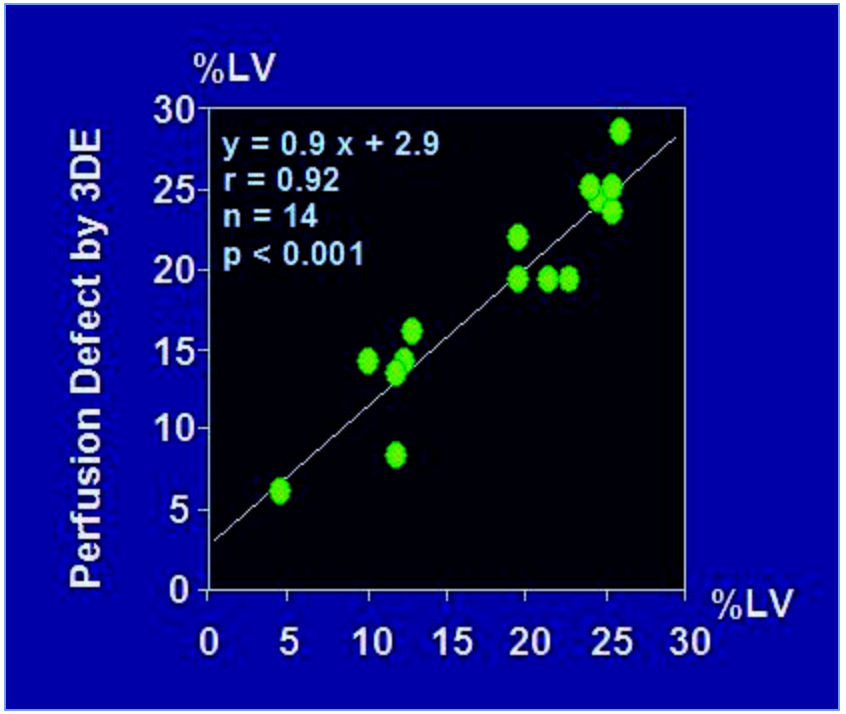
3D quantitation of LV Geometry

3D Echo Quantitation of Ischemic Mass







The left atrial function and volume: prognostic markers in different cardiac diseases (arrhythmias, valvular and congenital disease)

Left Atrial Volume

A Powerful Predictor of Survival After Acute Myocardial Infarction

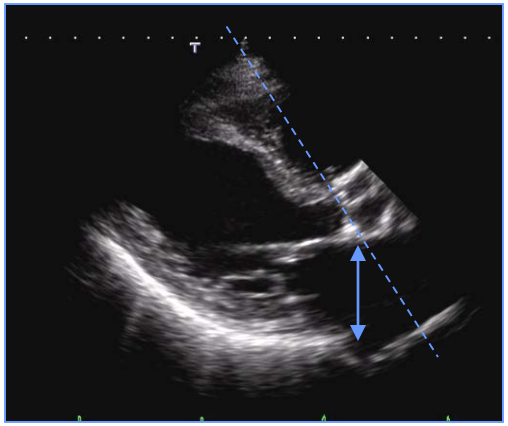
Jacob E. Møller, MD, PhD; Graham S. Hillis, MBChB, PhD; Jae K. Oh, MD; James B. Seward, MD; Guy S. Reeder, MD; R. Scott Wright, MD; Seung W. Park, MD, PhD; Kent R. Bailey, PhD; Patricia A. Pellikka, MD

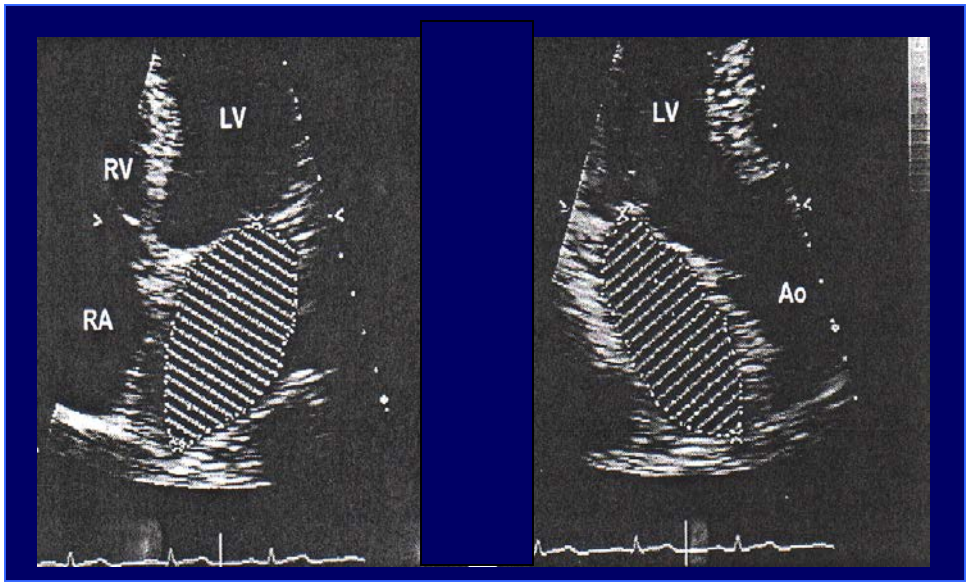
Left Atrial Volume as an Index of Left Atrial Size: A Population-Based Study

Allison M. Pritchett, MD,* Steven J. Jacobsen, MD, PHD,† Douglas W. Mahoney, MS,‡ Richard J. Rodeheffer, MD, FACC,* Kent R. Bailey, PHD,‡ Margaret M. Redfield, MD, FACC*

Rochester, Minnesota

M-mode and 2D methods to measure LA size





Monoplane volume (M-mode, Teicholz formula)

$(EDD^3 x\ 7)/(2.4 + EDD)$

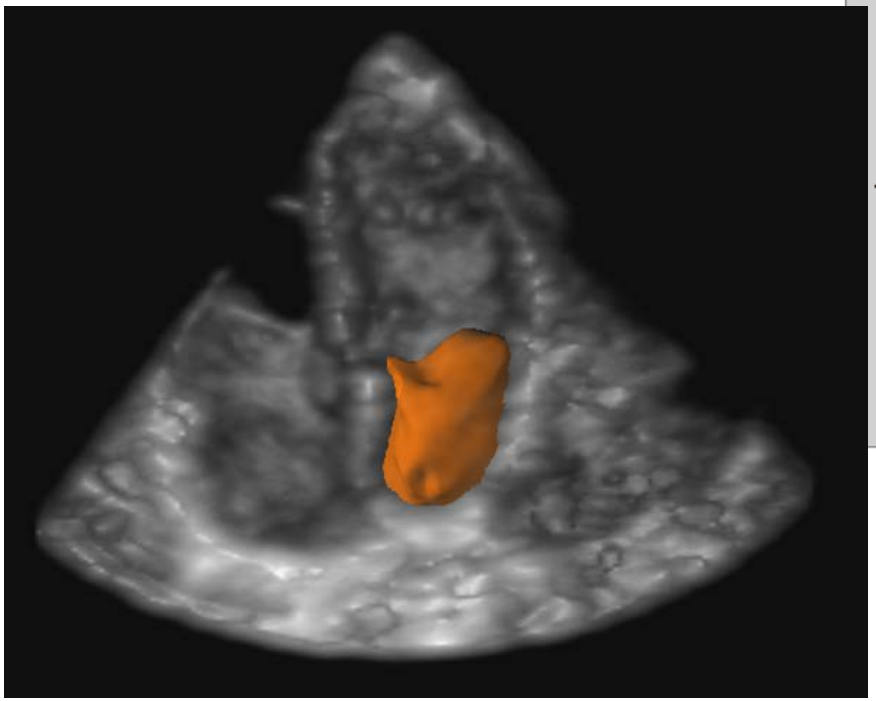
Monoplane volume (area/length, Dodge correction)

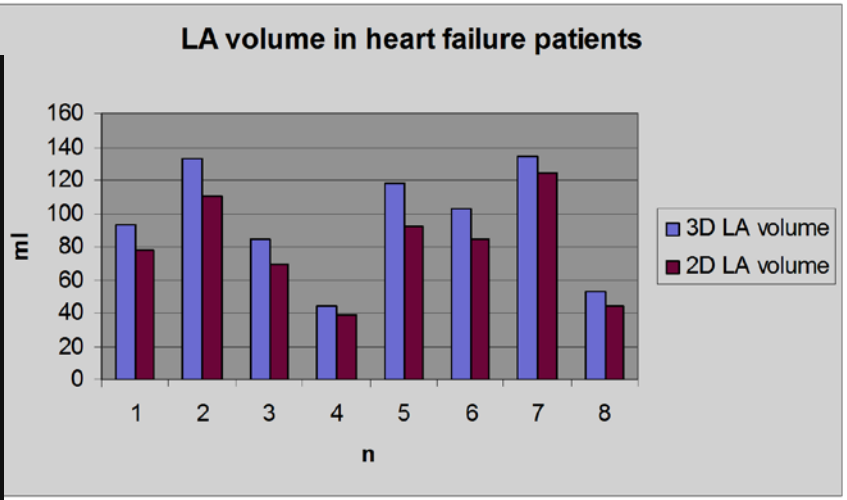
$((\text{area planimetry}^2 \times 8)/(3 \times \pi \times \text{long axis})) \times 0.951) - 3$

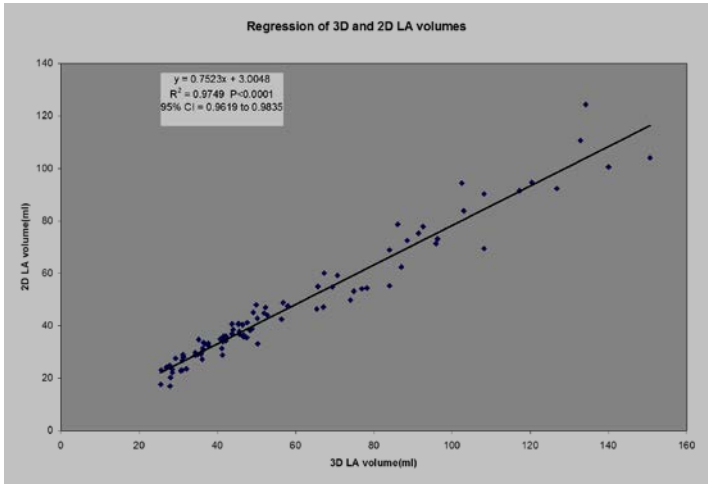
Biplane volume(area/length, Dodge correction)

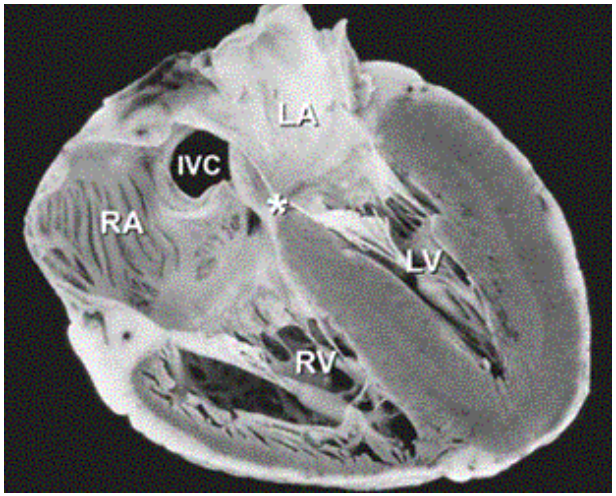
(area planimetry 1 x area planimetry 2 x 8)/(3 x π x smallest long axis)

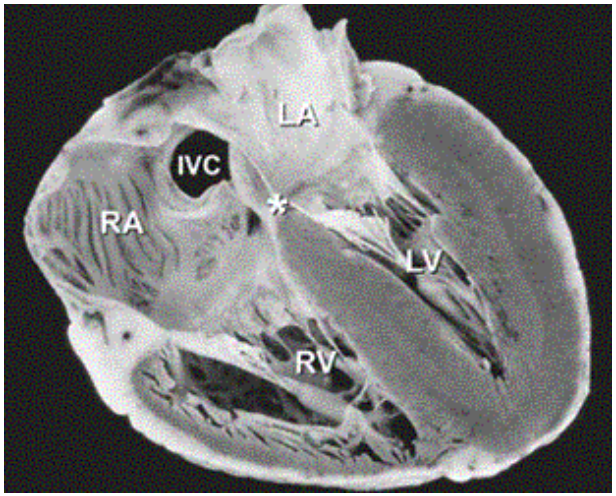
LA Volumes



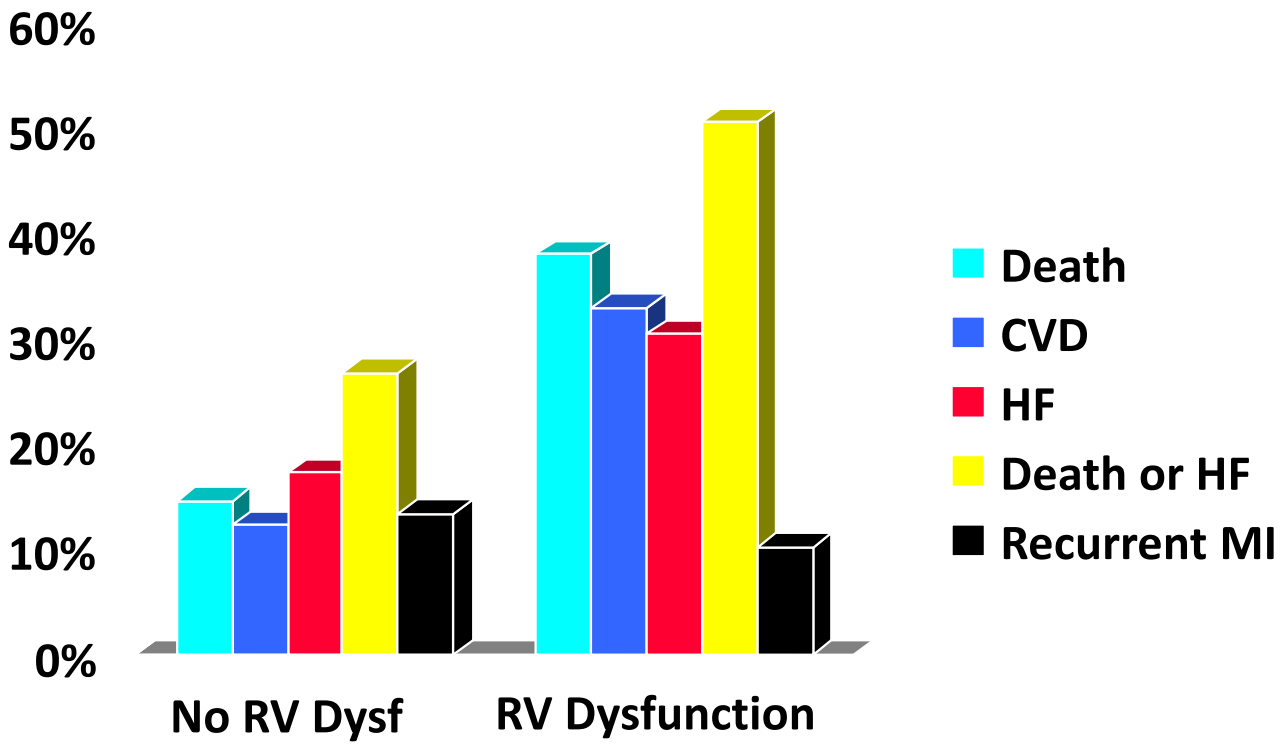

LA volume in heart failure patients
160
140
120
100
80
60
40
20
0
ml
1
2
3
4
5
6
7
8
n
3D LA volume
2D LA volume


Regression of 3D and 2D LA volumes
y = 0.7523x + 3.0048
R² = 0.9749 P<0.0001
95% CI = 0.9619 to 0.9835
2D LA volume(ml)
3D LA volume(ml)
0
20
40
60
80
100
120
140
160


LA
IVC
RA
*
LV
RV

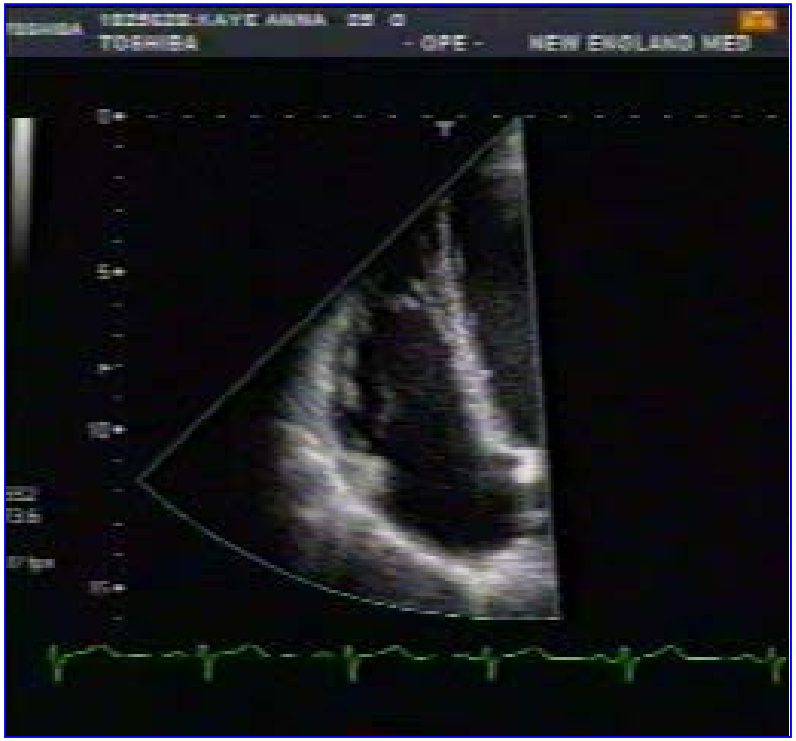

LA
IVC
RA
*
LV
RV

RV Dysfunction and Outcome



SAVE Investigators

J Am Coll Cardiol 2002 May 1;39(9):1450-5



Studies examining RV Function and Outcomes in Heart Failure

Study	Date	#pts	NYHA	Technique	Endpoint
Polak JF, et al.	1983	34	N/A	RVG	survival
Baker BJ, et al.	1984	25	N/A	RVG	exer capacity
Lewis JF, et al.	1993	67	II-IV	ECHO(rva/lva)	survival
DiSalvo TG, et al.	1995	67	III-IV	RVG	ex/surv
Gavazzi A, et al.	1995	142	III-IV	Thermodilution	survival
Julliere Y, et al.	1997	62	II-IV	Thermodilution	survival
Sun JP, et al.	1997	100	I-IV	ECHO(rva/lva)	survival
DeGroote P, et al.	1998	205	II-III	RVG	survival
Karasatakis GT, et al.	1998	40	II-IV	ECHO(tapse)	survival
Hung J, et al.	1998	117	II-IV	ECHO(tr)	survival
Ghio S, et al.	2000	140	II-IV	ECHO(tapse)	survival
Ghio S, et al.	2001	377	II-IV	Thermodilution	survival

Diagnosis
Clinical expression
Prognosis
Therapeutic decision making
Implications for assist devices

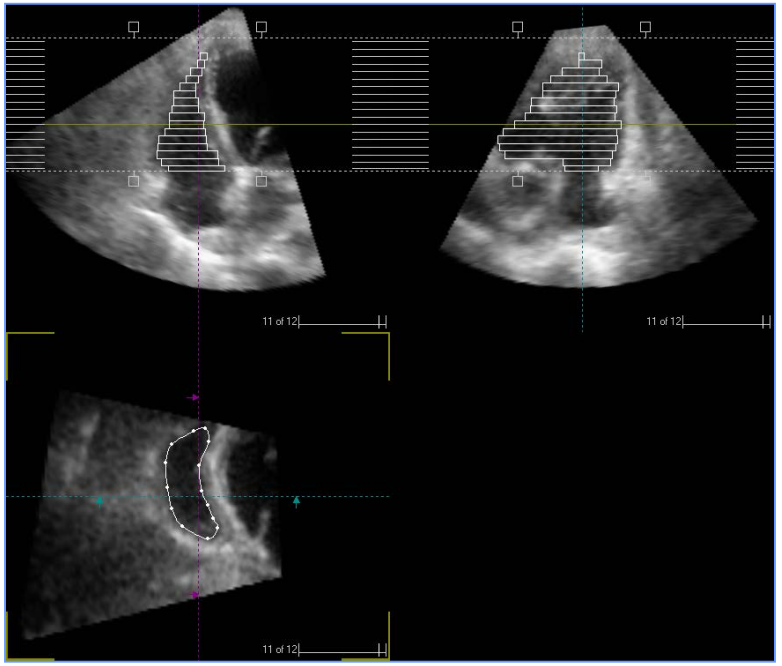
Patients waiting
For Transplant

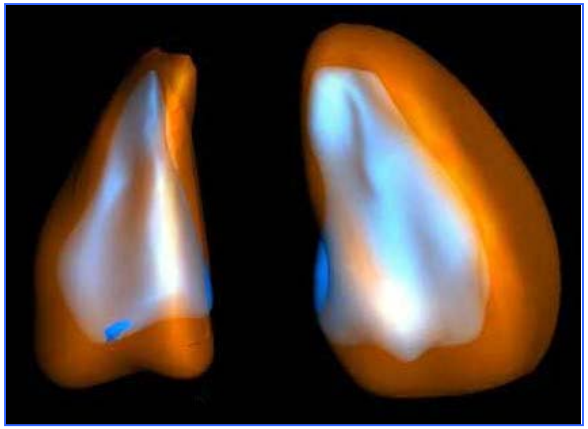
LVAD, RVAD or Both ?

Tricuspid Annulur Velocity in the Identification of Systolic RV dysfunction (RV EF < 40%)

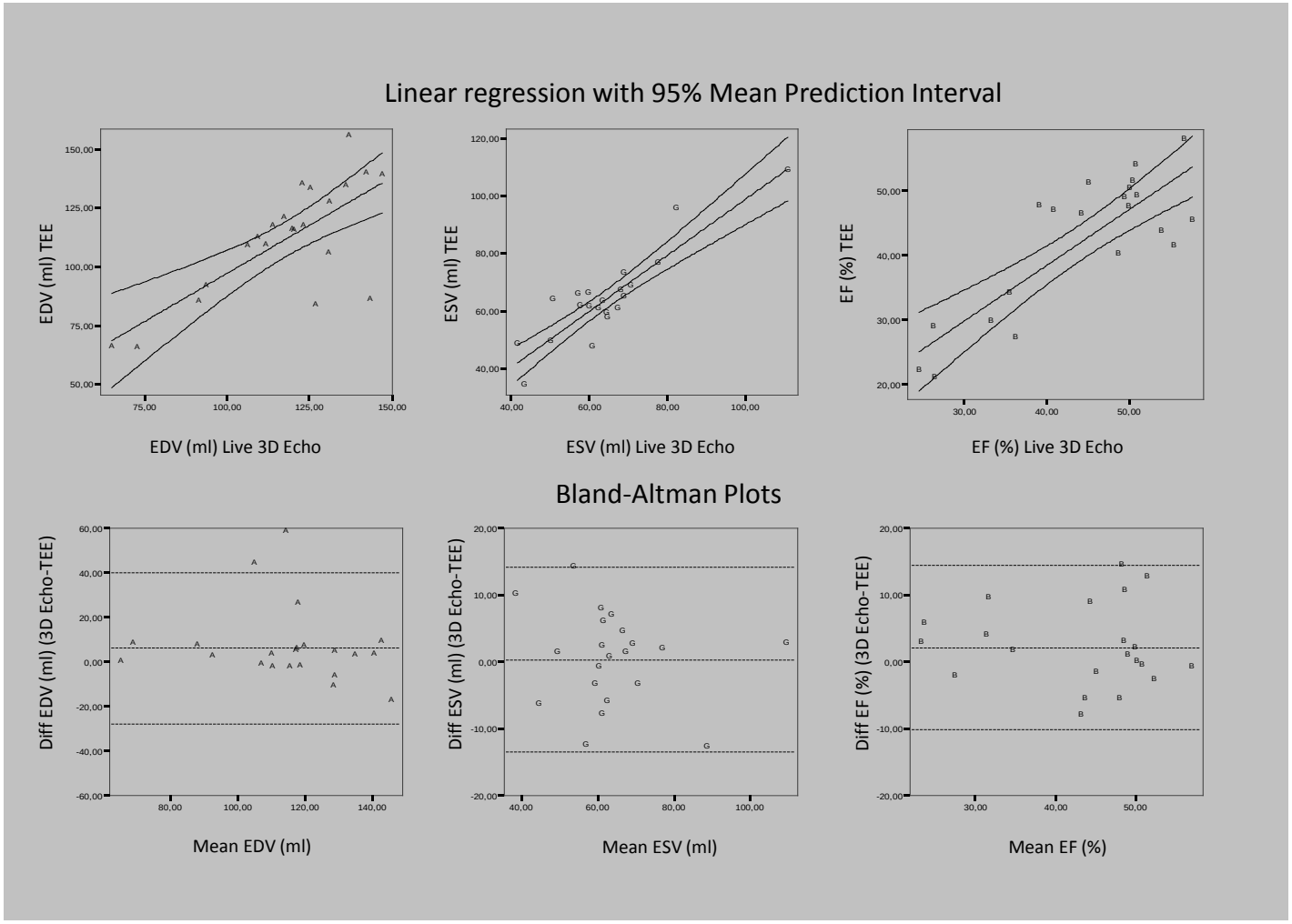
	TDI < 9	TDI < 10
Sensitivity	57% (95%CI 35-79%)	57% (95%CI 35-79%)
Specificity	92% (95%CI 80-100%)	77% (95%CI 58-95%)
Accuracy	80% (95%CI 62-97%)	70% (95%CI 50-90%)
PPV	80% (95%CI 62-97%)	57% (95%CI 35-79%)
NPV	80% (95%CI 62-97%)	77% (95%CI 58-95%)

Quantitation of RV volumes, EF

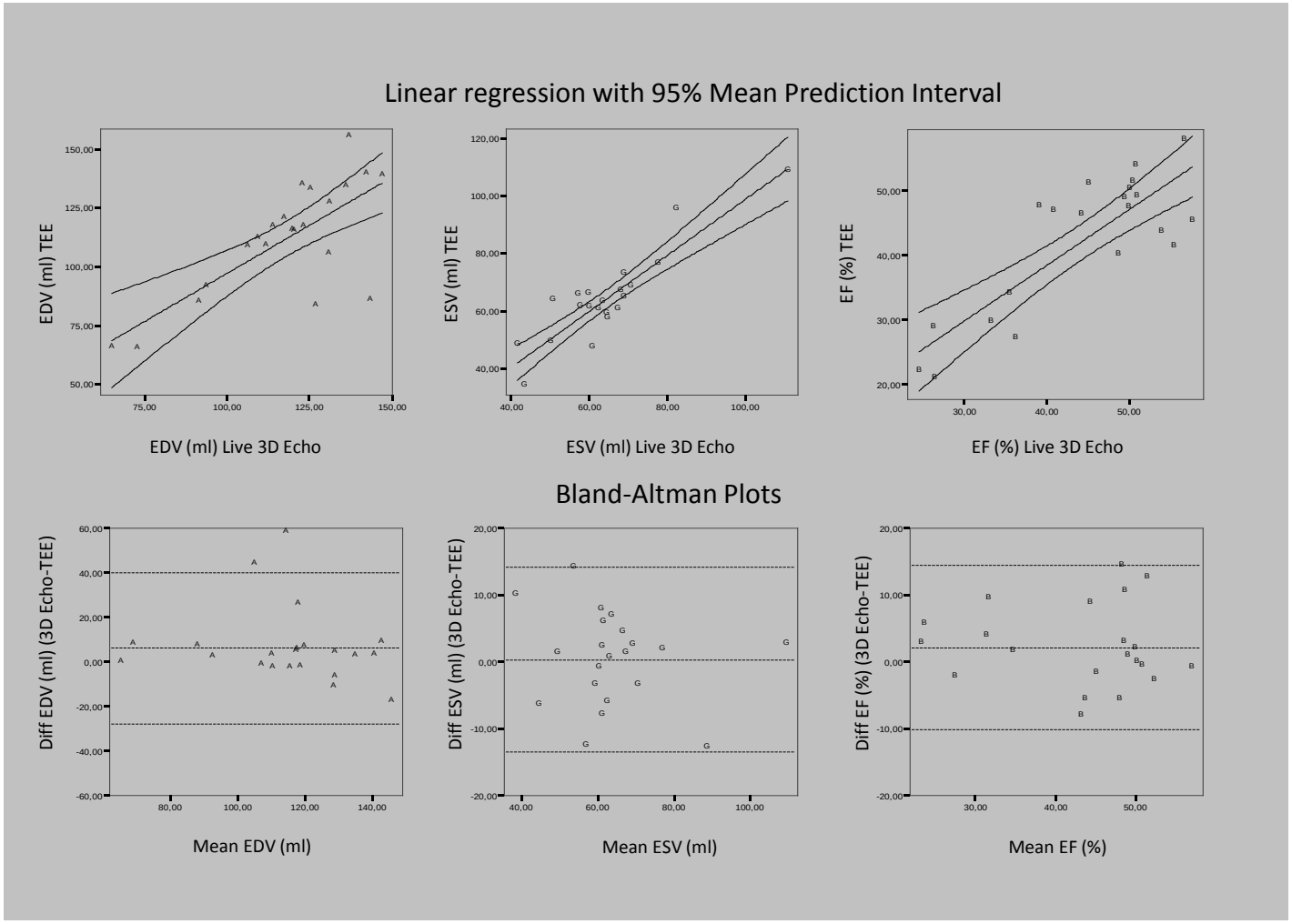




RV Volumes by Live 3D Echo



RV Volumes by Live 3D Echo



Heart Failure

Pharmacologic Rx

Mechanical Interventions

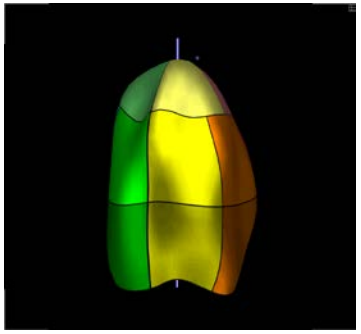
Transplantation

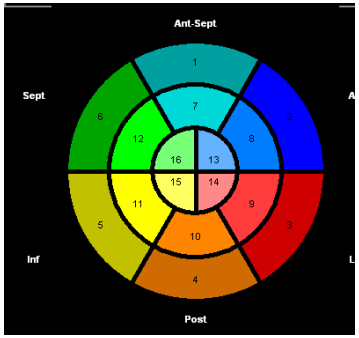
Novel Therapy

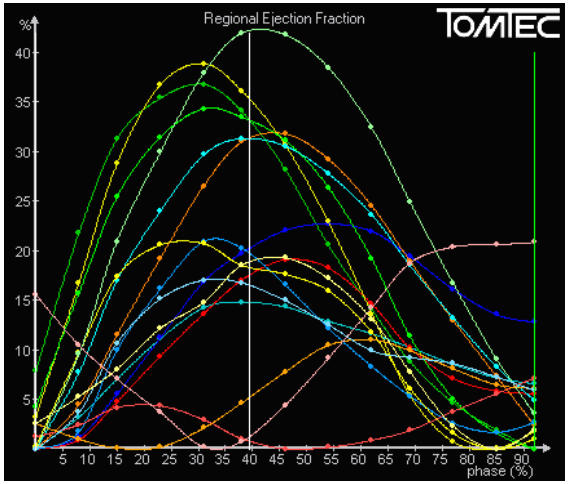
CRT - Issues

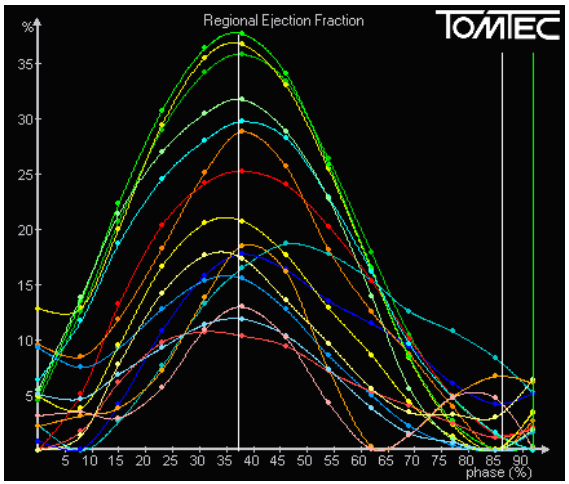
- QRS does not predict response
- QRS does not represent true dyssynchrony

Assessment of Dyssynchrony by 3D Echo







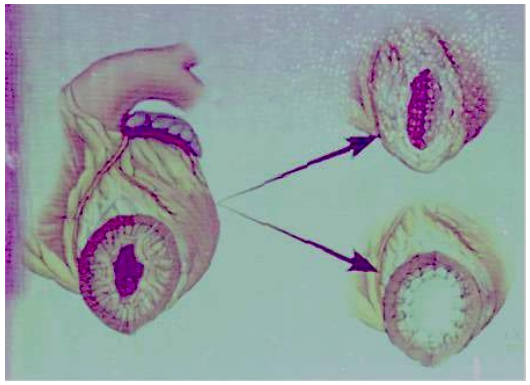


Before CRT

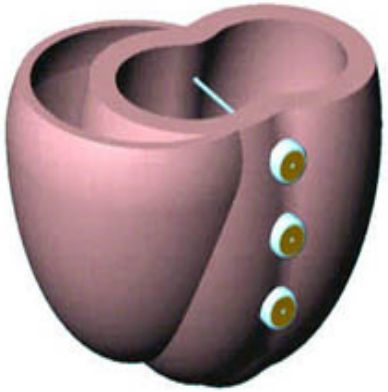
After CRT

Geometric Procedures For Heart Failure

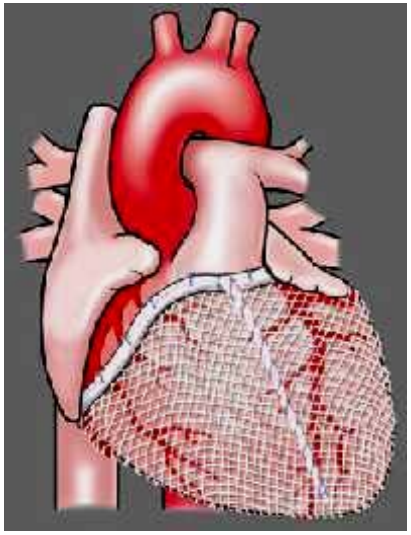
Surgical Ventricular Restoration

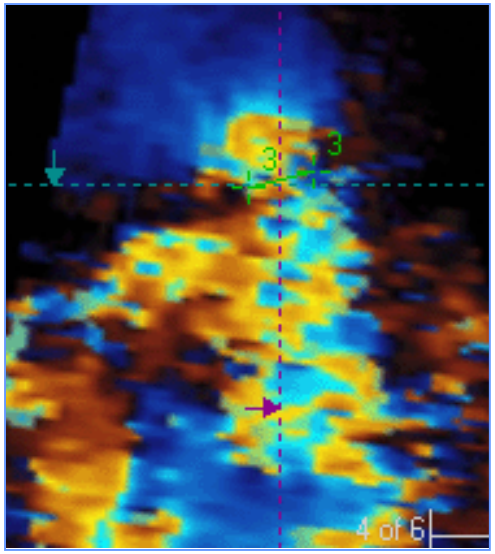


Constraint Devices



Support Device





PISA technique

Regurgitant volume
Regurgitant fraction
Regurgitant Orifice Area

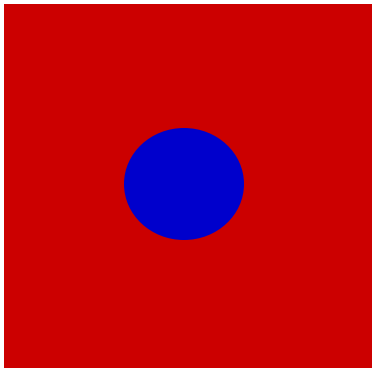
PISA, Vena Contracta

Assumptions

- “Regurgitant orifice circular”
- “Flow convergence perfect hemisphere”
- “Vena contracta circular”
- “1 frame in 1 view reflects whole AR”
- “There is only one regurgitant orifice

Regurgitation

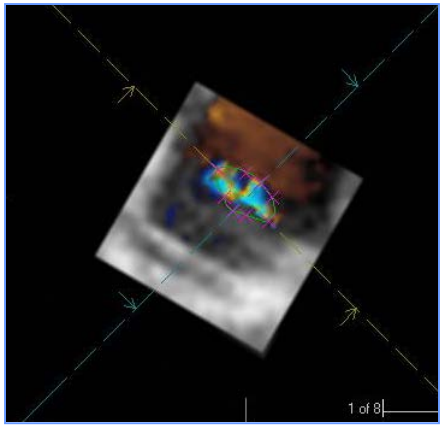
Round hole In a flat object

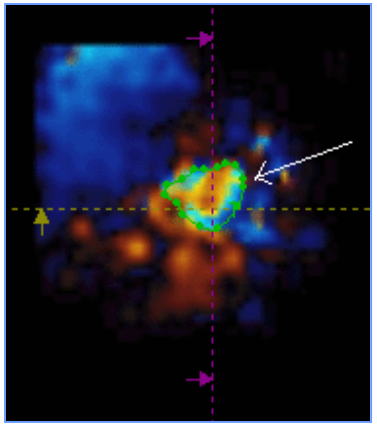


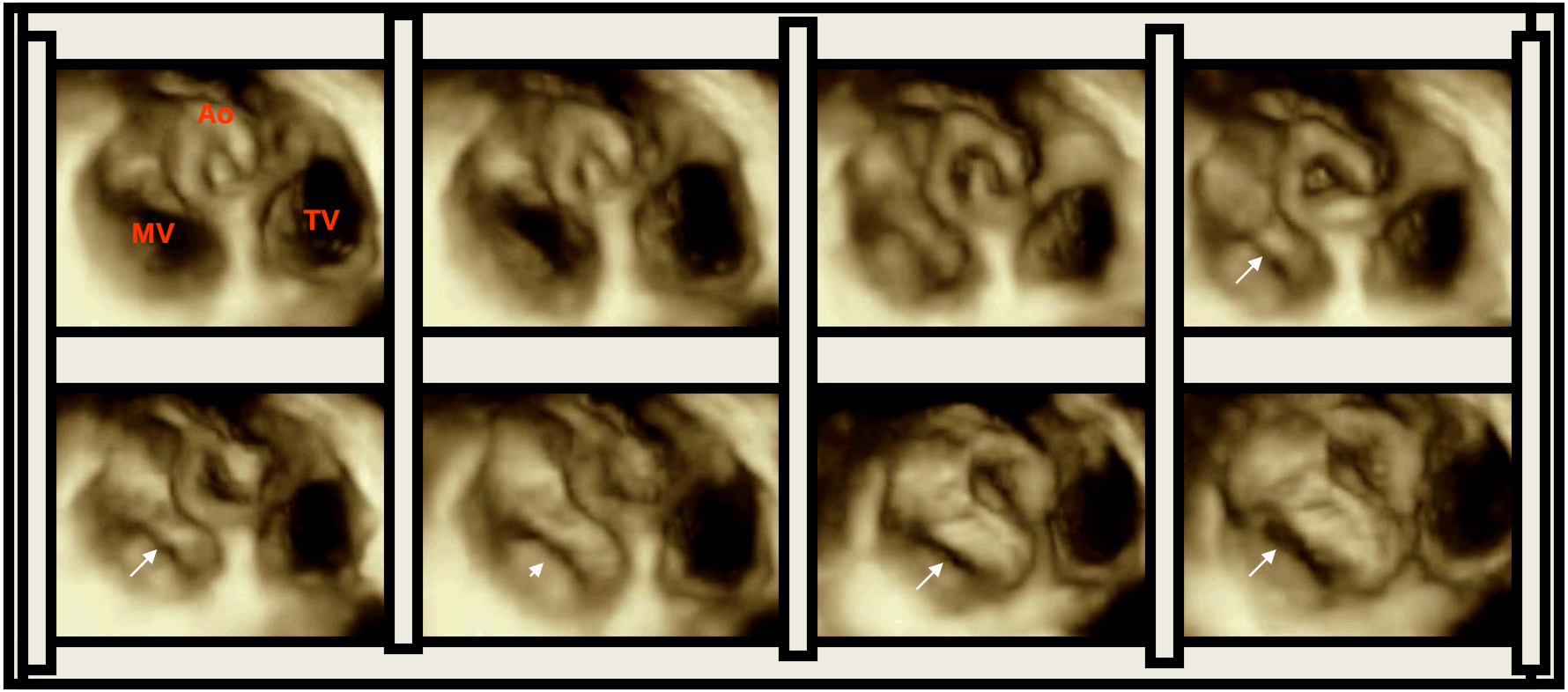
Perfect PISA hemisphere

Circular Vena Contrata

Real life






Ao
MV
TV

Regurgitant Orifices

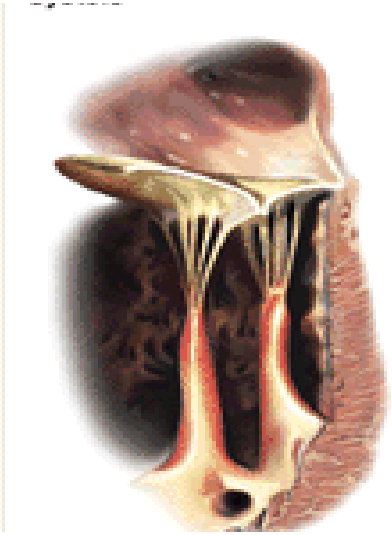
Mitral Regurgitation

SOLVD trial 1997

- **Pts with post-MI MR more likely to experience combined end point of**

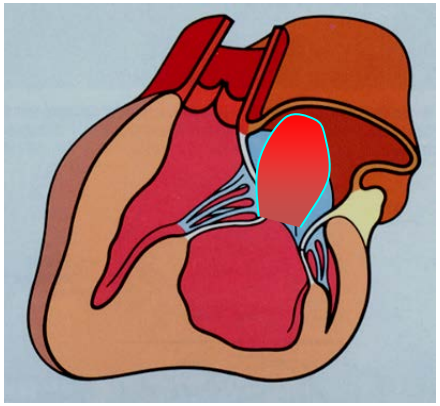
CV mortality severe HF, or recurrent MI	**47% vs. 29%** **P < .001**

- **Independent predictor of CV mortality (relative risk, 2.00; 95% CI, 1.28 to 3.04)**

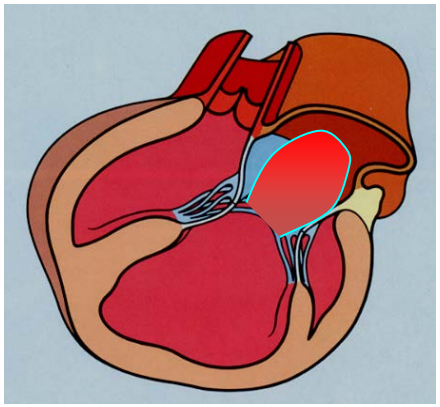


Geometric Distortion Contributing to MR

Regional LV dilation/dysfunction



Global LV dilation/dysfunction



Surgical Annuloplasty for Functional MR in CHF

First 48 patients*

Operative Mortality = 2.1%

LOS = 9 ± 4 d (5-37)

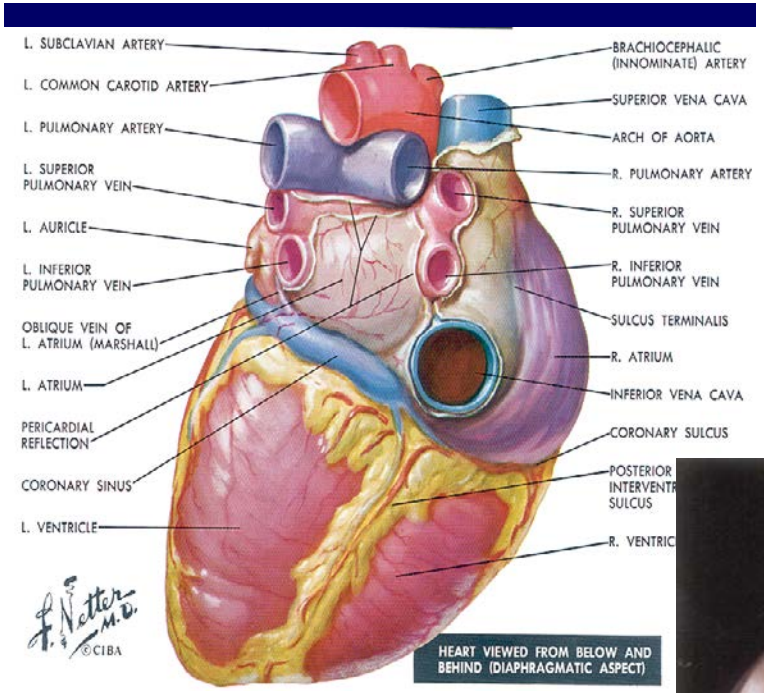
Expanded series - 92 patients*

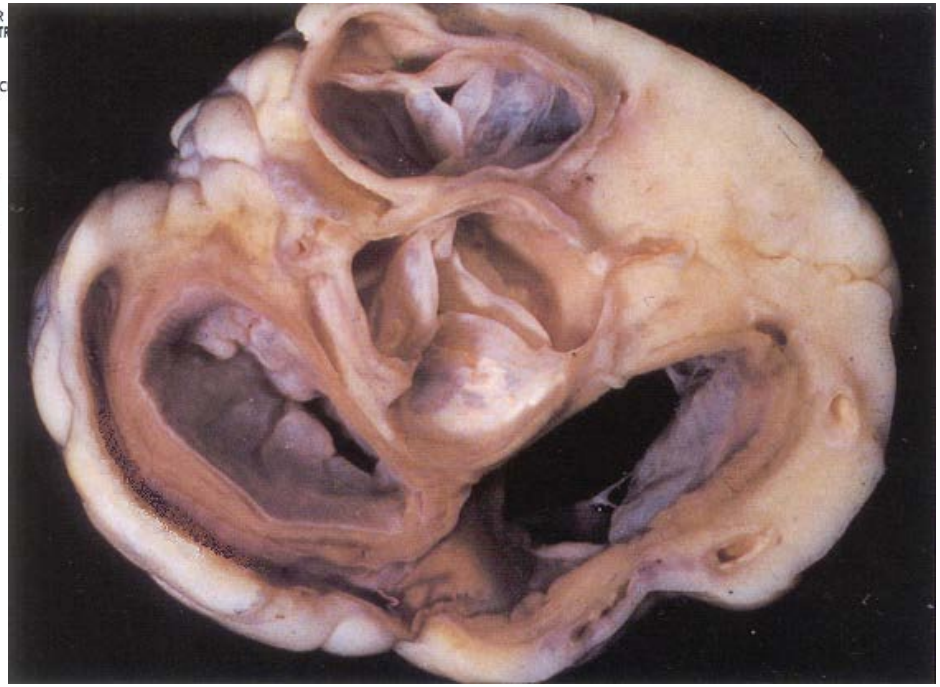
30 d Operative Mortality = 5.4%

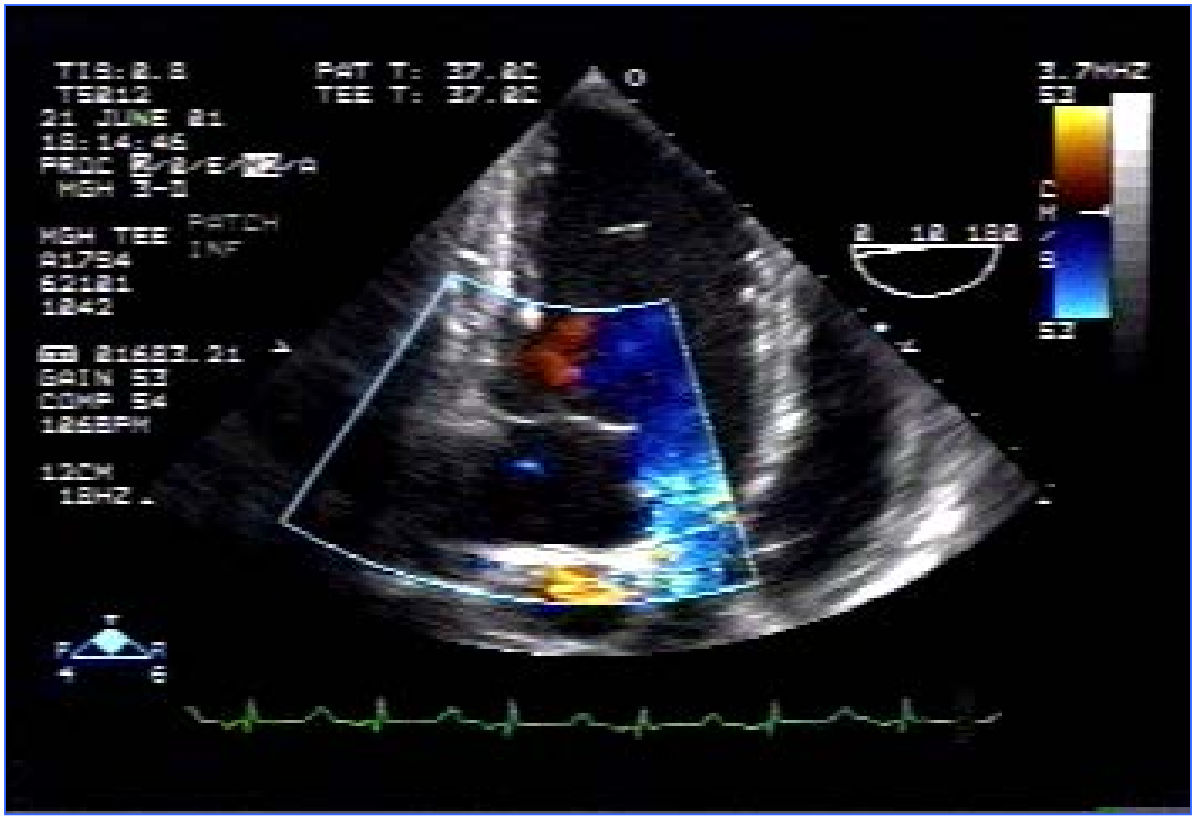
Sicker pts, Less experienced Surgeon

Operative Mortality = ?

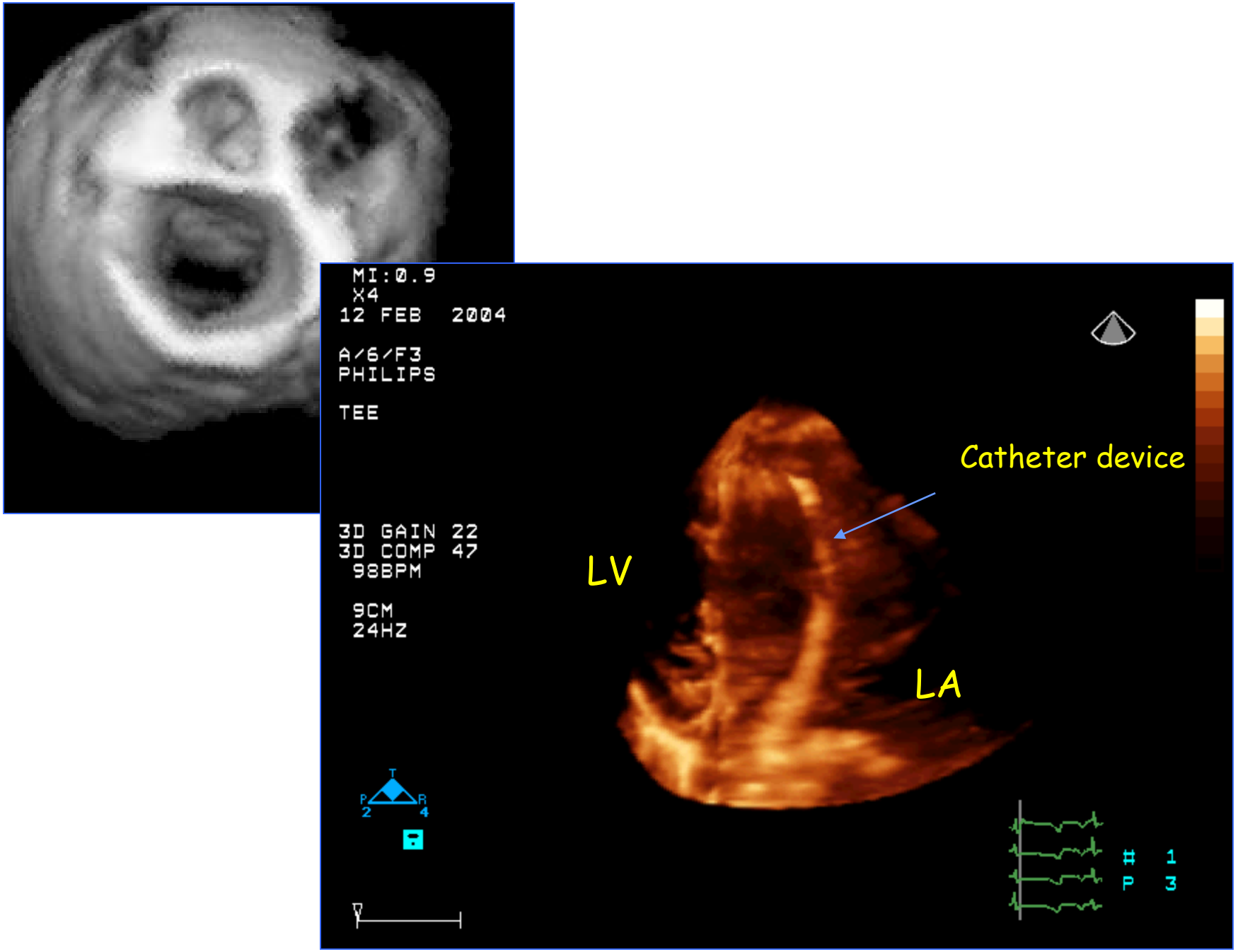
Bolling S et al


L. SUBCLAVIAN ARTERY
L. COMMON CAROTID ARTERY
L. PULMONARY ARTERY
L. SUPERIOR PULMONARY VEIN
L. AURICLE
L. INFERIOR PULMONARY VEIN
OBLIQUE VEIN OF L. ATRIUM (MARSHALL)
L. ATRIUM
PERICARDIAL REFLECTION
CORONARY SINUS
L. VENTRICLE
BRACHIOCEPHALIC (INNOMINATE) ARTERY
SUPERIOR VENA CAVA
ARCH OF AORTA
R. PULMONARY ARTERY
R. SUPERIOR PULMONARY VEIN
R. INFERIOR PULMONARY VEIN
SULCUS TERMINALIS
R. ATRIUM
INFERIOR VENA CAVA
CORONARY SULCUS
POSTERIOR INTERVENTR SULCUS
R. VENTRIC
F. Netter M.D.
©CIBA
HEART VIEWED FROM BELOW AND BEHIND (DIAPHRAGMATIC ASPECT)

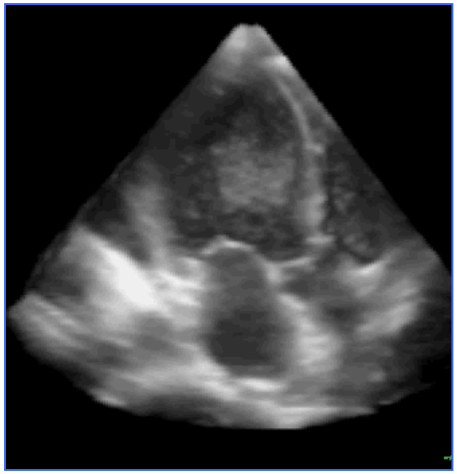


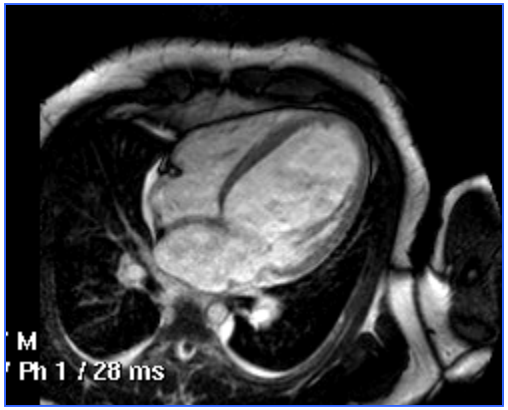


Hung et al


MI:0.9
X4
12 FEB 2004
A/6/F3
PHILIPS
TEE
3D GAIN 22
3D COMP 47
98BPM
9CM
24HZ
Catheter device
LV
LA
T
P
R
2
4
1
P 3

3D Imaging in Heart Failure





3D Echo vs. CMR

Widely available

Easy to use in any setting

3D Imaging in Heart Failure

- Better appraisal of functional morphology
- More accurate study of remodeling
- Aid to innovative therapeutic procedures
- Good investigative tool to study the heart

Thank you !