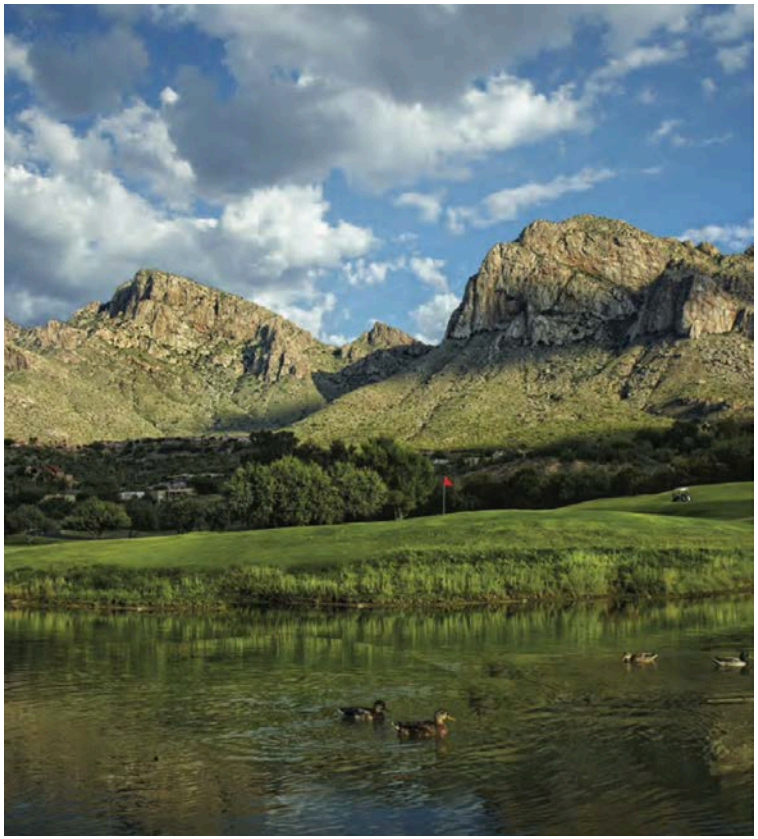


The Left Ventricle: What and How Should WE Quantify its Size and Function

State-of-the-Art ECHOCARDIOGRAPHY: ECHO SOUTHWEST 29th ANNUAL

ASE American Society of Echocardiography
Heart & Circulation Ultrasound Specialists

EACVI
EUROPEAN ASSOCIATION OF CARDIOVASCULAR IMAGING
A Registered Branch of the ESC

THE UNIVERSITY OF CHICAGO
CARDIAC IMAGING CENTER

Roberto M. Lang, MD

ASE American Society of Echocardiography

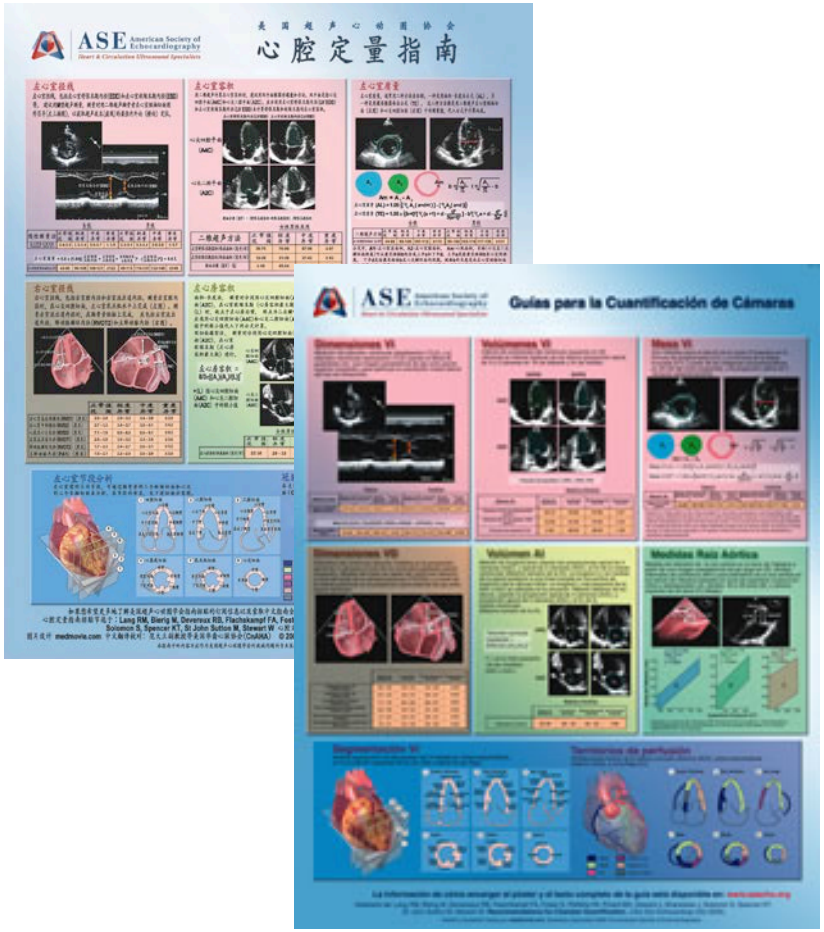
Heart & Circulation Ultrasound Specialists

Recommendations for Chamber Quantification: A Report from the American Society of Echocardiography's Guidelines and Standards Committee and the Chamber Quantification Writing Group, Developed in Conjunction with the European Association of Echocardiography, a Branch of the European Society of Cardiology

Members of the Chamber Quantification Writing Group are: Roberto M. Lang, MD, FASE, Michelle Bierig, MPH, RDCS, FASE, Richard B. Devereux, MD, Frank A. Flachskampf, MD, Elyse Foster, MD, Patricia A. Pellikka, MD, Michael H. Picard, MD, Mary J. Roman, MD, James Seward, MD, Jack S. Shanewise, MD, FASE, Scott D. Solomon, MD, Kirk T. Spencer, MD, FASE, Martin St John Sutton, MD, FASE, and William J. Stewart, MD

J AM Soc Echocardiogr 2005; 18:1440-1463

- Approximately 5500 citations



iASE in iTUNE

美国超声心动图学会（ASE）委员会建议

美国超声心动图学会指南与标准委员会
和心腔定量分析起草小组
联合欧洲心脏病学会所属超声心动图学会
共同起草的报告：

关于心腔定量分析的建议

ASE COMMITTEE RECOMMENDATIONS

Recommendations pour la Quantification des Cavités Cardiaques: Le Rapport de La Société Américaine d'Échocardiographie, La comité de Direction des Standards et le bureau de rédaction sur La quantification des Cavités Cardiaques, développé avec l'association Européenne d'Échocardiographie, une branche de La société Européenne de Cardiologie

Roberto M. Lang, MD, FASE, Michelle Bierig, MPH, RDCS, FASE, Richard B. Devereux, MD, Frank A. Flachskampf, MD, Elyse Foster, MD, Patricia A. Pellikka, MD, Michael H. Picard, MD, Mary J. Roman, MD, James Seward, MD, Jack S. Shanewise, MD, FASE, Scott D. Solomon, MD, Kirk T. Spencer, MD, FASE, Martin St John Sutton, MD, FASE, and William J. Stewart, MD

Translators : Maëva Clerte, MD, Maryse Palardy, MD, Luc Anh Duy Pham, MD, et Anahita Dabo-Trubelja, MD, avec le soutien de Lawrence Rudski, MD, FASE
Supervisé par Marielle Scherrer-Crosbie, MD, PhD, FASE

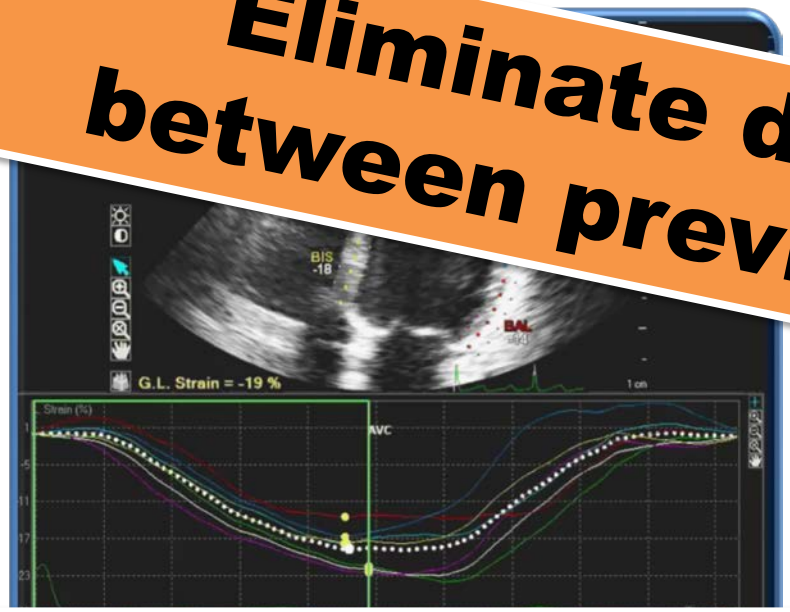
RECOMENDACIONES DEL COMITÉ DE LA ASE

Recomendaciones para la Cuantificación de las Cavidades: Informe del Comité de Guías y Estándares de la Sociedad Americana de Ecocardiografía y del Grupo Redactor de la Cuantificación de las Cavidades, desarrollado conjuntamente con la Asociación Europea de Ecocardiografía, rama de la Sociedad Europea de Cardiología

Cardiac Chamber Quantification: What is New?

Database

Eliminate discrepancies between previous guidelines



Deformation Imaging

RT3DE

Recommendations for Cardiac Chamber Quantification by Echocardiography in Adults: An Update from the American Society of Echocardiography and the European Association of Cardiovascular Imaging

Roberto M. Lang, MD, FASE, FESC, Luigi P. Badano, MD, PhD, FESC, Victor Mor-Avi, PhD, FASE, Jonathan Afilalo, MD, MSc, Anderson Armstrong, MD, MSc, Laura Ernande, MD, PhD, Frank A. Flachskampf, MD, FESC, Elyse Foster, MD, FASE, Steven A. Goldstein, MD, Tatiana Kuznetsova, MD, PhD, Patrizio Lancellotti, MD, PhD, FESC, Denisa Muraru, MD, PhD, Michael H. Picard, MD, FASE, Ernst R. Rietzschel, MD, PhD, Lawrence Rudski, MD, FASE, Kirk T. Spencer, MD, FASE, Wendy Tsang, MD, and Jens-Uwe Voigt, MD, PhD, FESC, *Chicago, Illinois; Padua, Italy; Montreal, Quebec and Toronto, Ontario, Canada; Baltimore, Maryland; Créteil, France; Uppsala, Sweden; San Francisco, California; Washington, District of Columbia; Leuven, Liège, and Ghent, Belgium; Boston, Massachusetts*

Eur Heart J Cardiovasc Imaging. 2015 Mar;16(3):233-71. J Am Soc Echocardiogr 2015;28:1-39

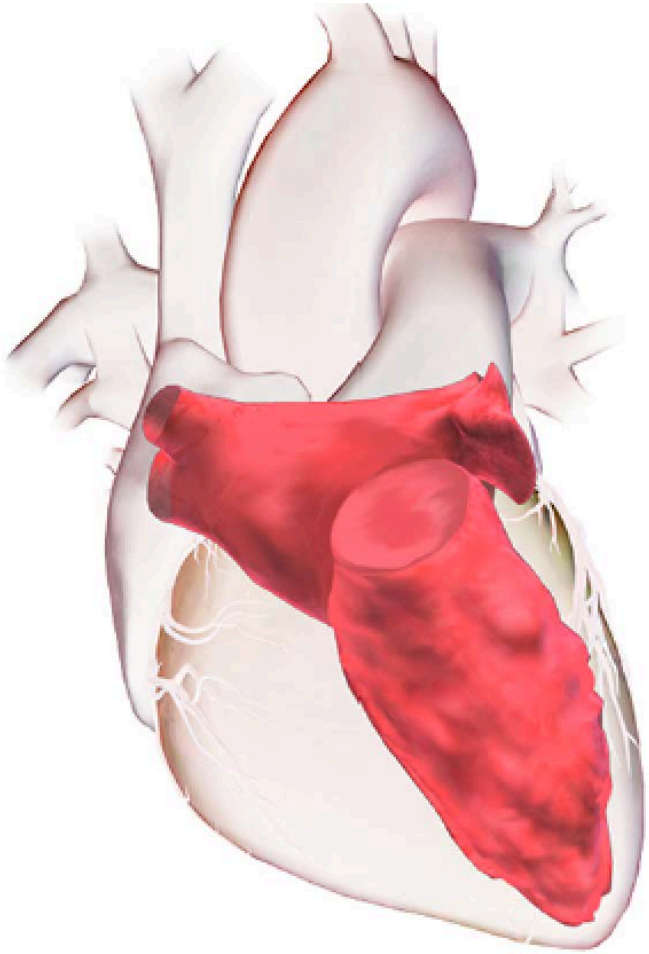
Partition Values for Severity of Abnormalities

- **Cutoffs based on SD**
  - **Data readily exist**
  - **Echo parameters are not normally distributed**
  - **Asymmetric distribution**
- **Cutoffs based on percentile values (95^{th})**
- **Cutoffs based on outcomes or prognosis**
- **Cutoffs based on consensus**
- **LV EF, LA, LA size and LV mass**

Normal Reference Values for 2DE

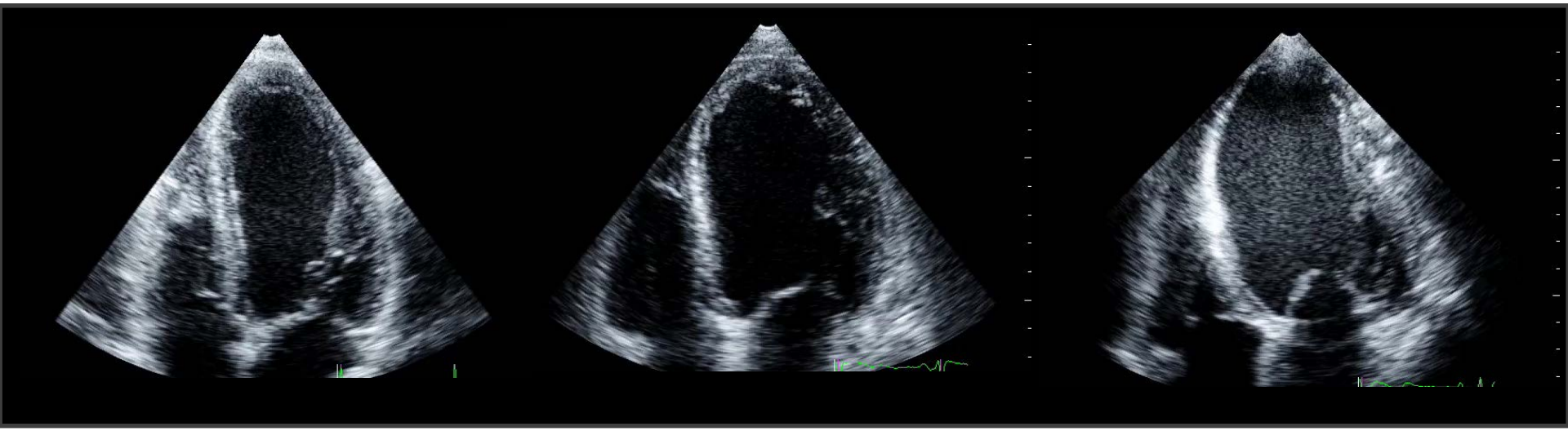
- **Seven data *bases (Asklepios, Flemengho, Cardia5, Cardia 25, Padua 3D Echo Normal, Norre Study)***
- **No contrast studies**
- **Age, gender, ethnicity, height and weight**
- **Nl BP, no diabetes, nl BMI, creatinine, glomerular filtration rate, cholesterol, LDL and triglicerides**

Left Ventricle and Left Atrium



Eye ball

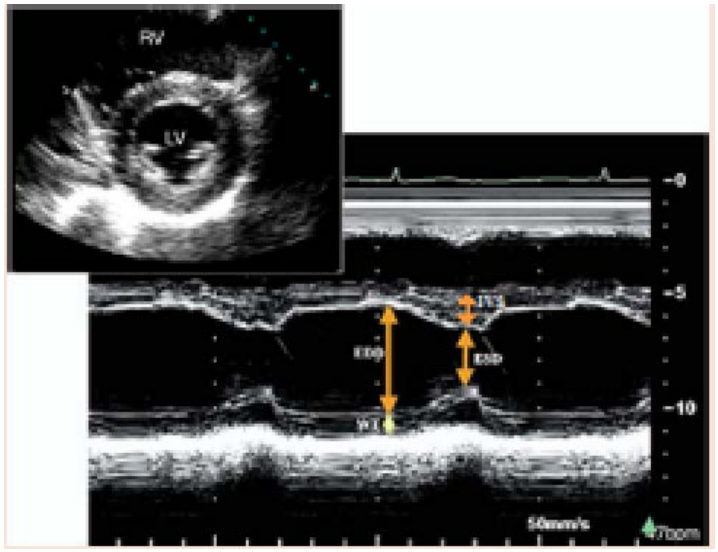
How do we Assess LV Function ?

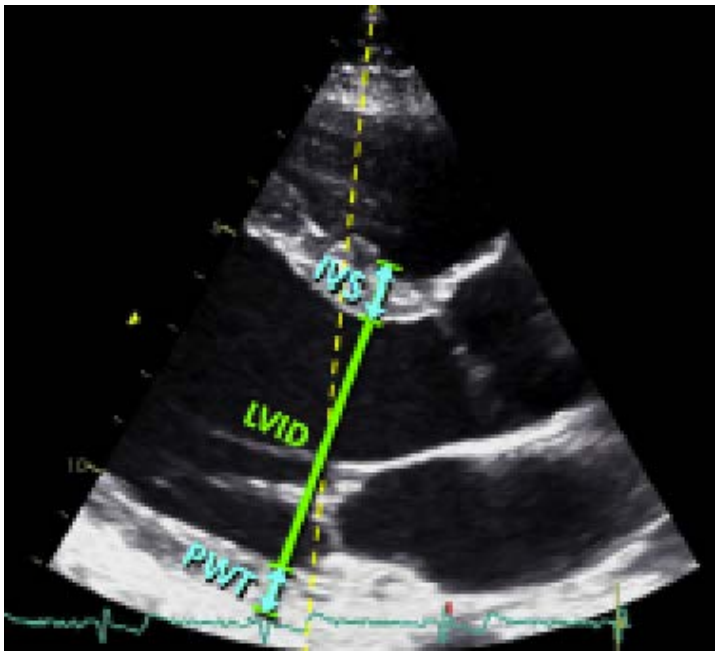


Qualitative Assessment

- **Subjective**
- **Experience dependent**
- **Lack of standardization**
- **Large inter- and intra-observer variability**

Left Ventricular Linear Measurement

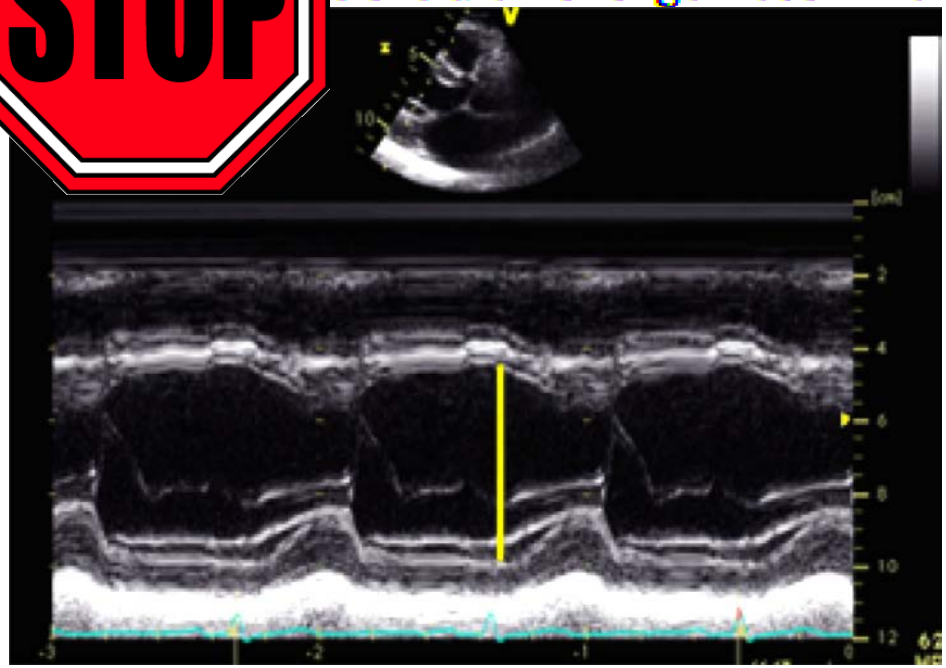




1.1. Linear Measurements. It is recommended that linear internal measurements of the left ventricle and its walls be performed in the parasternal long-axis view. Values should be carefully obtained perpendicular to the LV long axis and measured at or immediately below the level of the mitral valve leaflet tips. In this regard, the electronic calipers should be positioned on the interface between the myocardial wall and cavity and the interface between the wall and the pericardium. Internal dimensions can be obtained with a two-dimensional (2D) echocardiography (2DE)–guided M-mode approach, although linear measurements obtained from 2D echocardiographic images are preferred to avoid oblique sections of the ventricle (Table 1).

Left Ventricular Volumetric Measurement

1.2. Volumetric Measurements. LV volumes are measured using 2DE or 3DE. Volume calculations derived from linear measurements may be inaccurate, because they rely on the assumption of a fixed geometric LV shape such as a prolate ellipsoid, which does not apply in a variety of cardiac pathologies. Accordingly, the Teichholz and Quinones methods for calculating LV volumes from LV linear dimensions are no longer recommended for clinical use.

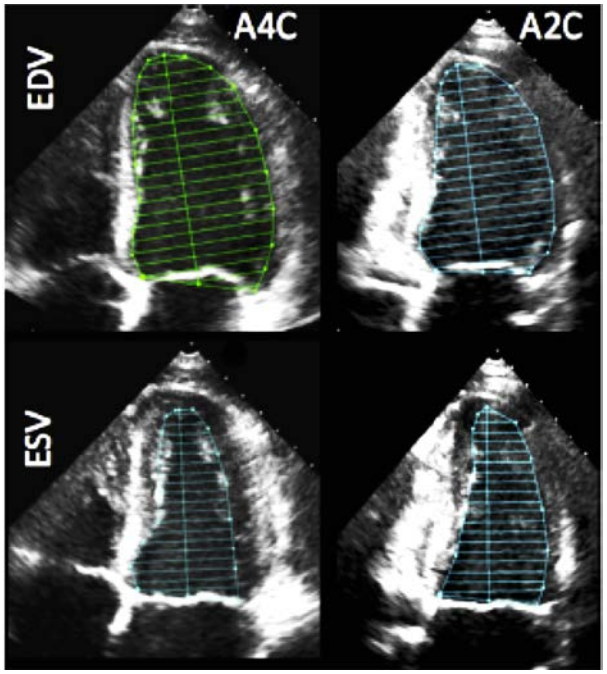


TEICHHOLZ Formula

$$V = \frac{7 \times D^3}{2.4 + D}$$

Am J Cardiol 1976;37:7–11

Left Ventricular Volumetric Measurement

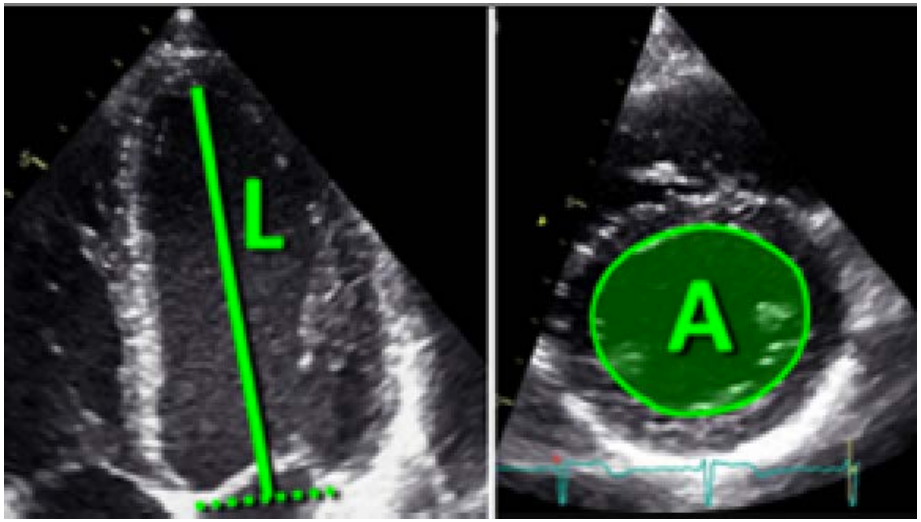


1

Biplane Disk Summation

- Corrects for shape distortions
- Less geometrical assumptions compared with linear dimensions

- Apex frequently foreshortened
- Endocardial dropout
- Blind to shape distortions not visualized in the apical two- and four-chamber planes



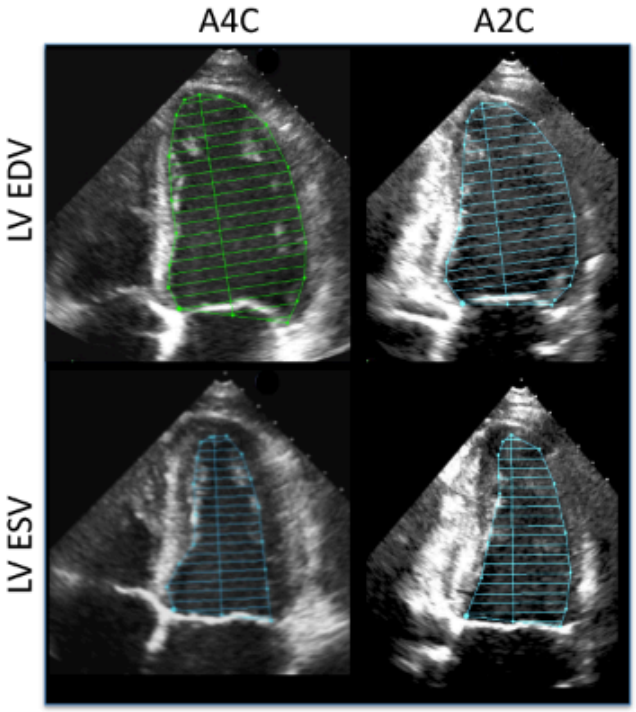
Area Length Method

- Partial correction for shape distortion

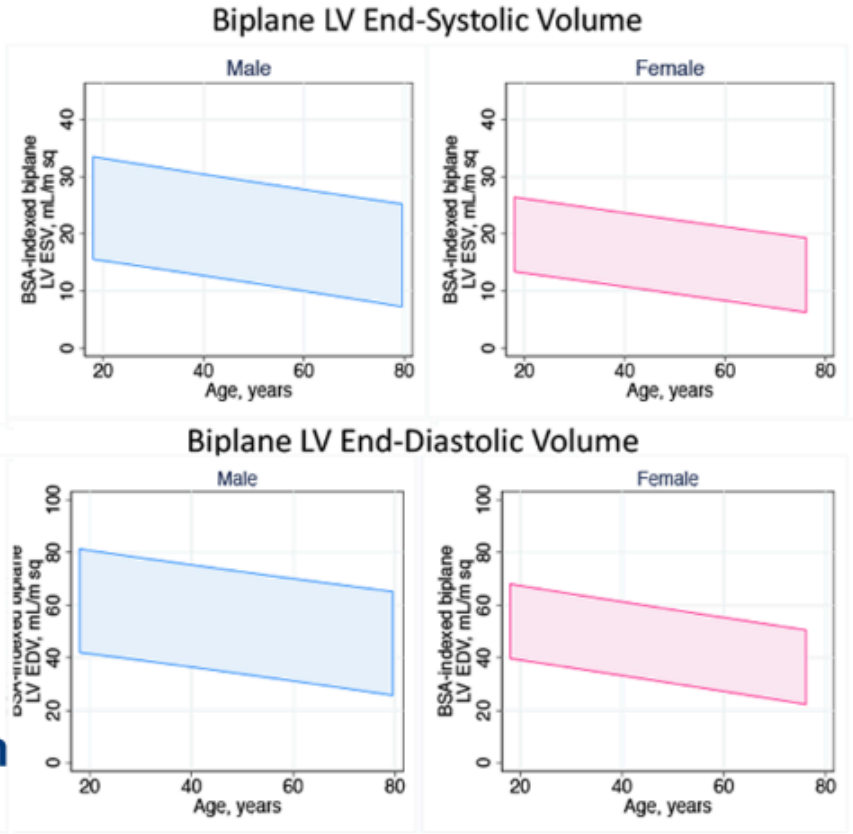
2

- Apex frequently foreshortened
- Heavily based on geometrical assumptions
- Limited published data on normal population

LV Volumes by 2D



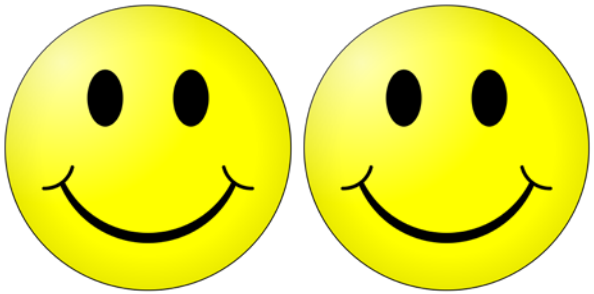
Biplane disc's summation



Parameters LV volumes normalized by BSA	Male Mean ± SD	Male 2SD Range	Female Mean ± SD	Female 2SD Range
LV end-diastolic volume, mL/m²	54 ± 10	34 - 74	45 ± 8	29 - 61
LV end-systolic volume, mL/m²	21 ± 5	11 - 31	16 ± 4	8 - 24

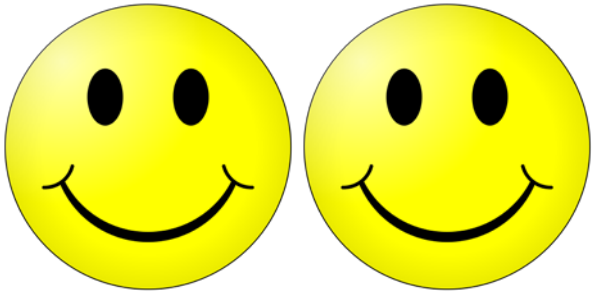
2-D measurements for LV volume calculations using the biplane method of discs, in the apical four-chamber (A4C) and apical two-chamber (A2C) views at end diastole (LV EDD) and at end-systole (LV ESD).

Left Ventricular Ejection Fraction



	Normal	Mild	Moderate	Severe
2015	>52	51-41	40-30	<30
2005	>55	54-45	44-30	<30

LV Ejection Fraction



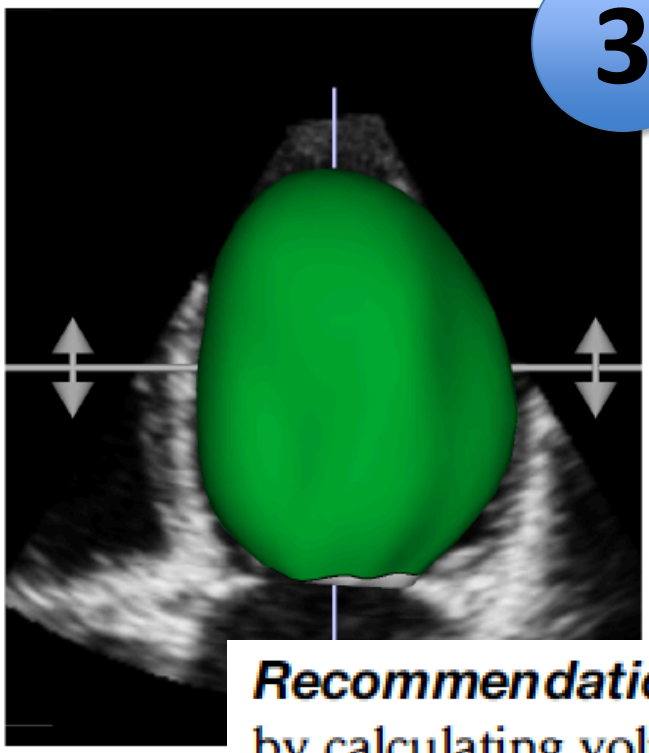
Male

	Normal	Mildly	Moderately	Severely
LVEF	52-72	41-51	30-40	<30

Female

	Normal	Mildly	Moderately	Severely
LVEF	54-74	41-53	30-40	<30

LV Volumes by 3D



Upper limits of normal:

EDV:

79 ml/m² for men

71 ml/m² for women

ESV:

32 ml/m² for men

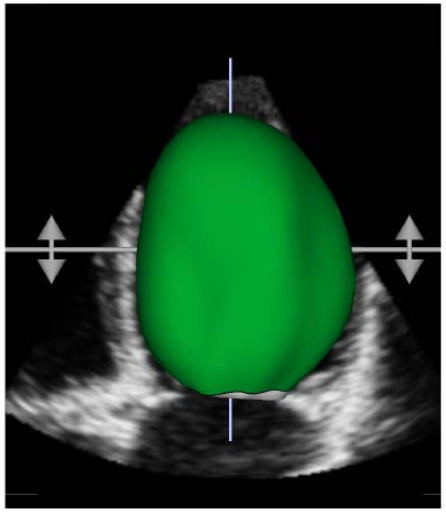
28 ml/m² for women

Recommendation. LV size should be routinely assessed on 2DE by calculating volumes using the biplane method of disks summation technique. In laboratories with experience in 3DE, 3D measurement and reporting of LV volumes is recommended when feasible depending on image quality. When reporting LV linear dimensions, the recommended method is 2D-guided measurements. LV size and volume measurements should be reported indexed to BSA. For general reference, 2D echocardio-

Which of the following is not an advantage of 3D echo for the calculations of LV Volumes

1. **Avoids image foreshortening**
2. **No geometric assumptions**
3. **More accurate and reproducible**
4. **High temporal resolution**

LV Volumes: 3DE



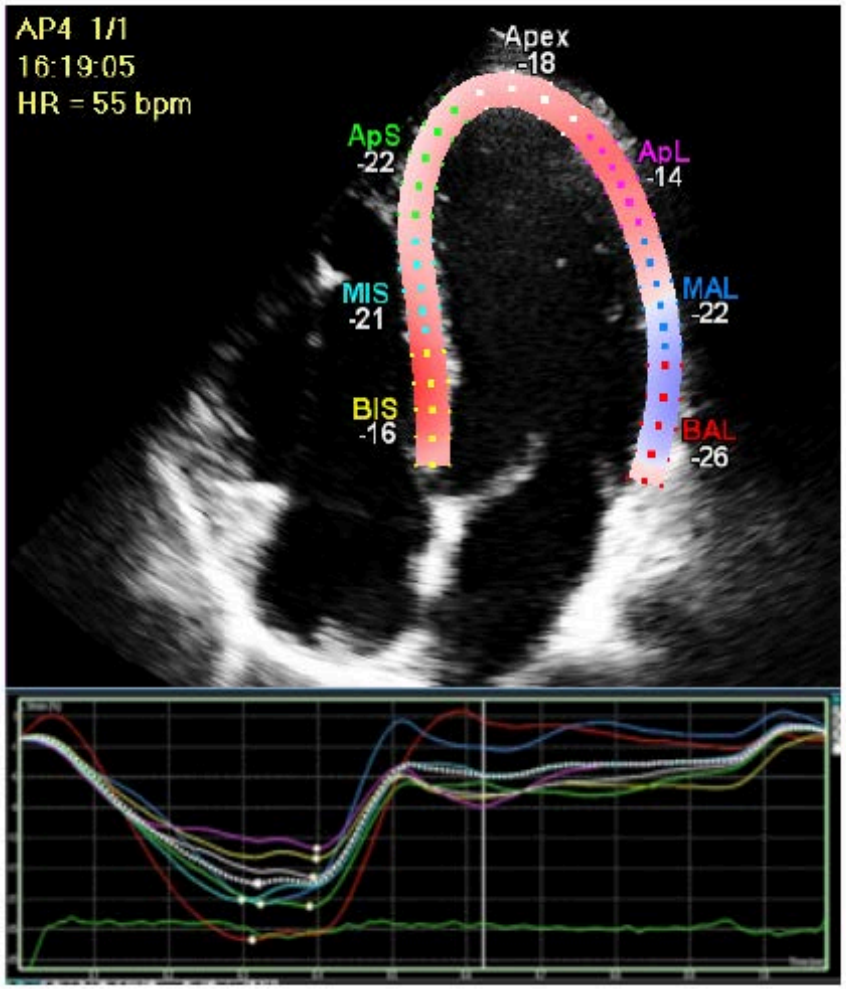
✓ Advantages

- Avoid image foreshortening
- No geometric assumptions
- More accurate and reproducible

✗ Disadvantages

- Low temporal resolution
- Less data on normals

LV Global Longitudinal Strain



Peak GLS in the range of -20% can be expected in a healthy person

- **Low Flow AS**
- **Cardio-oncology**
- **Valvular Regurgitation**

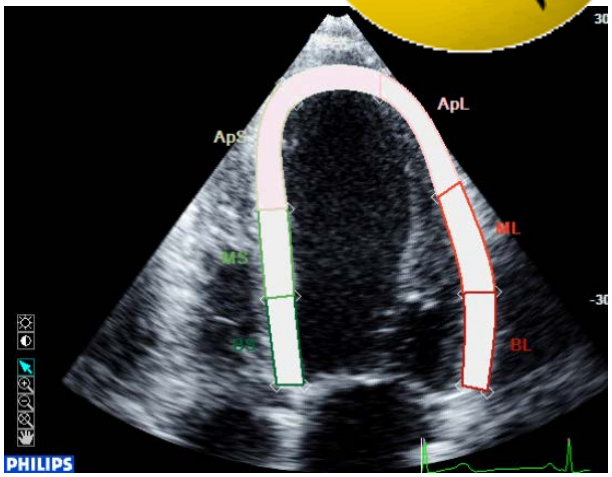
LV Global Longitudinal Strain

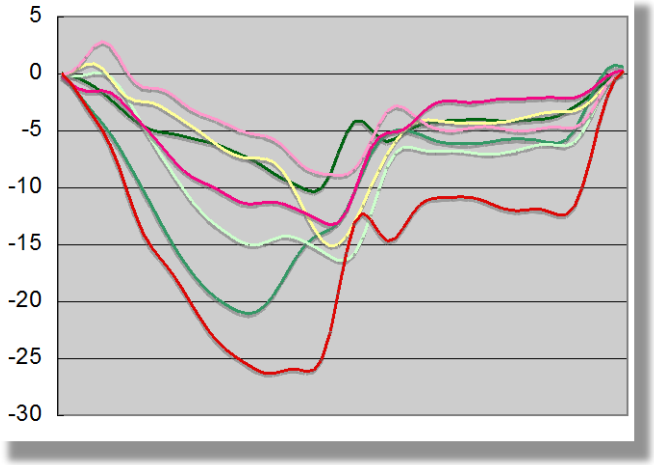
ultrasound imaging industry.[24,26] Because of intervendor and intersoftware variability and age and load dependency, serial assessment of GLS in individual patients should be performed using the same vendor's equipment and the same software.

The preponderance of currently available data is for midwall GLS. There are concurrent definitions as a basis for GLS calculation using endocardial, midwall, or average deformation.[24] This committee refrains from recommendations in this regard and refers to the ongoing joint standardization initiative of the ASE, EACVI, and the ultrasound imaging industry.[24,26] Because of intervendor and

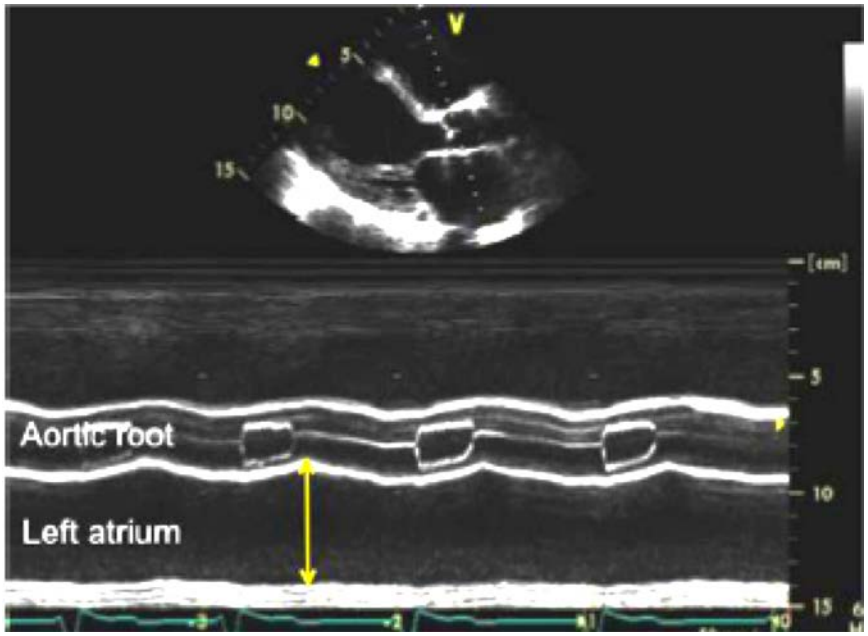
LV Segmentation: Regional Deformation

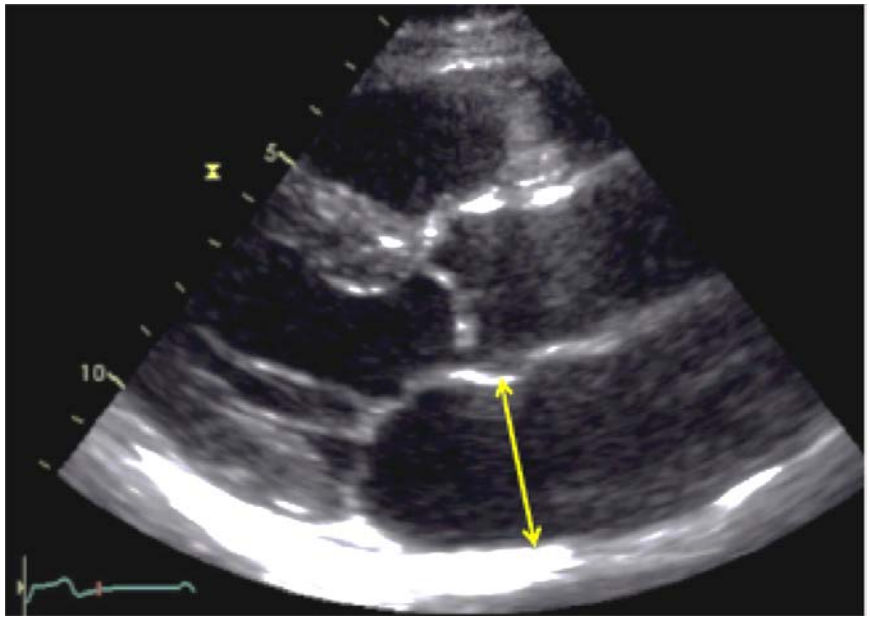
- Quantitative assessment of the magnitude of regional LV deformation is not recommended
  - lack of reference values
  - suboptimal reproducibility
  - considerable inter-vendor measurement variability



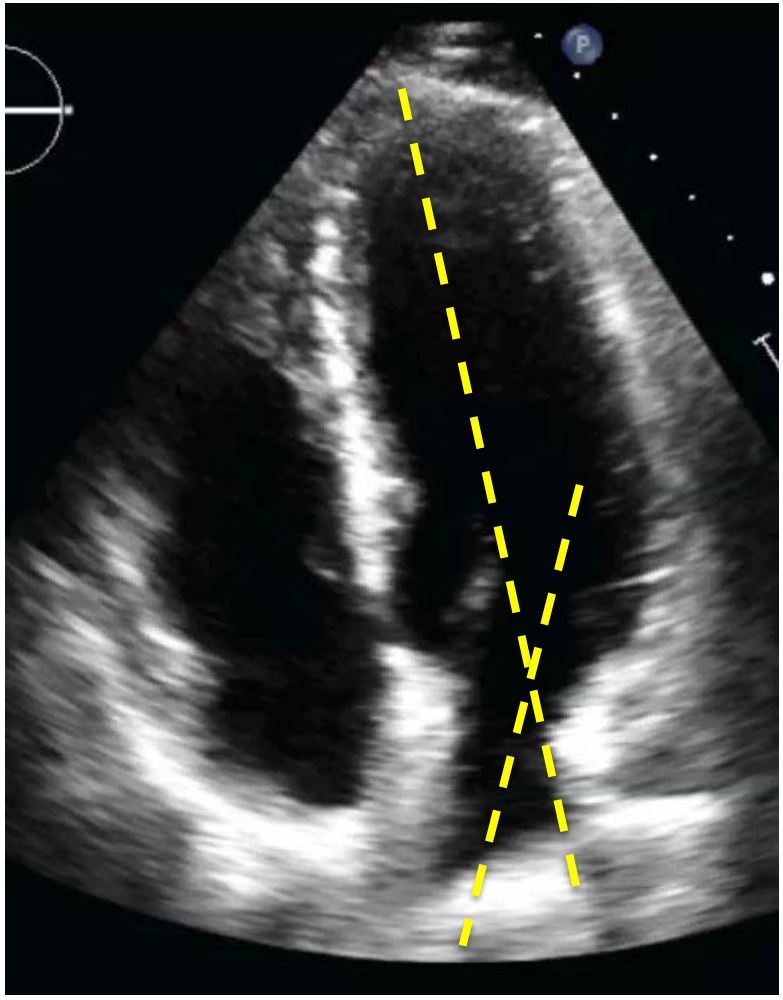


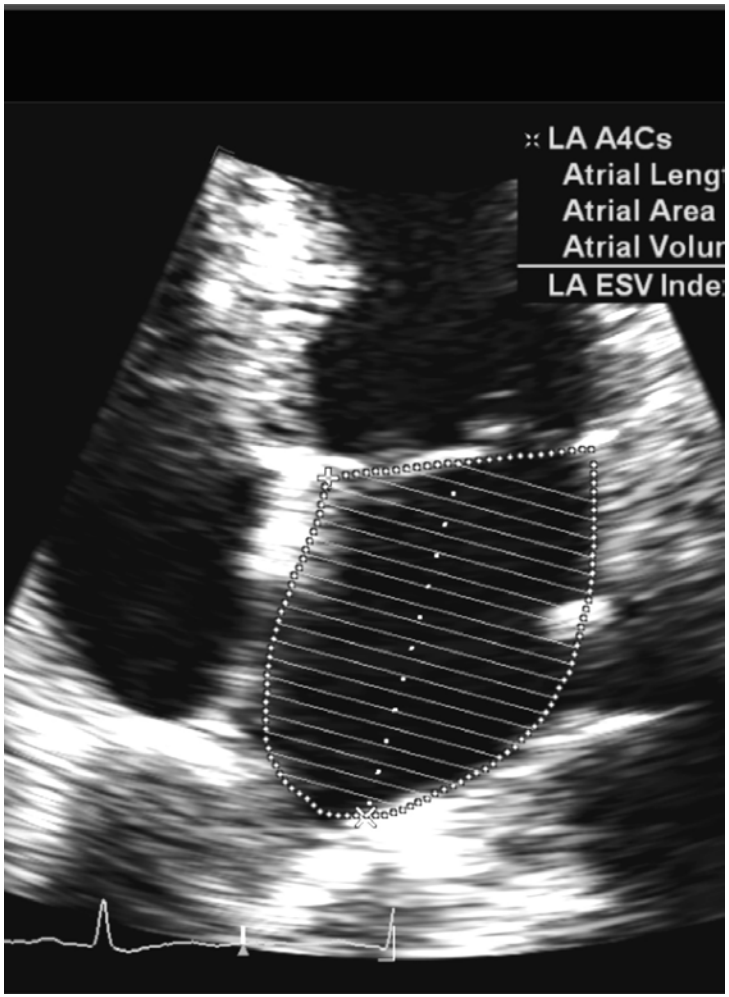
LA Linear Dimension



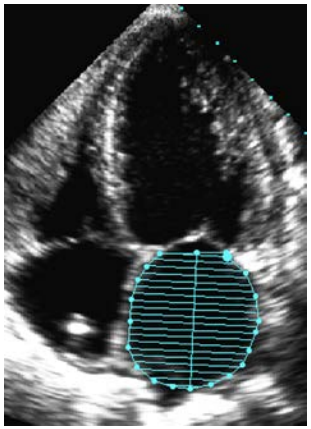


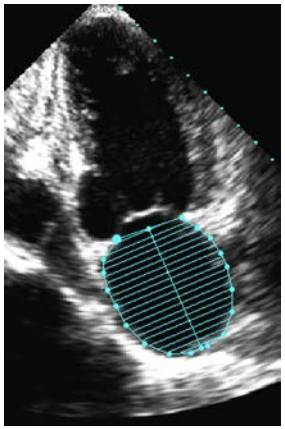
LA Volume



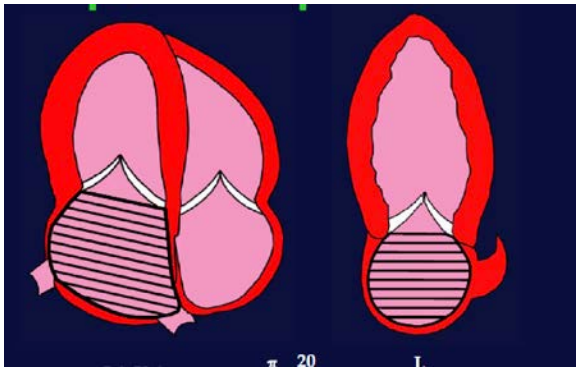


LA Volume





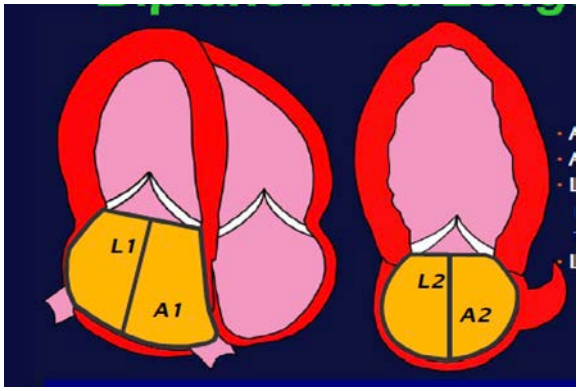
Biplane Simpson's Rule

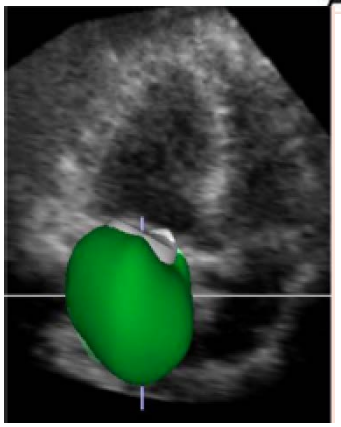


A4C

A2C

Biplane Area-Length





3D Echo

The normal values of LA volume for the 2015 guidelines are?

1. 16-28 ml/BSA
2. 29-33 ml/BSA
3. 16-34 ml/BSA
4. 42-48 ml/BSA

LA Volume

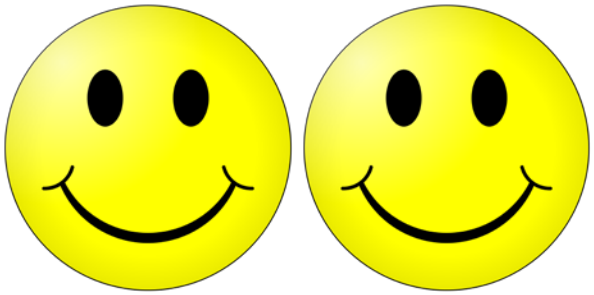
	Normal	Mildly	Moderately	Severely
LA Vol/BSA	16-28	29-33	34-39	>40

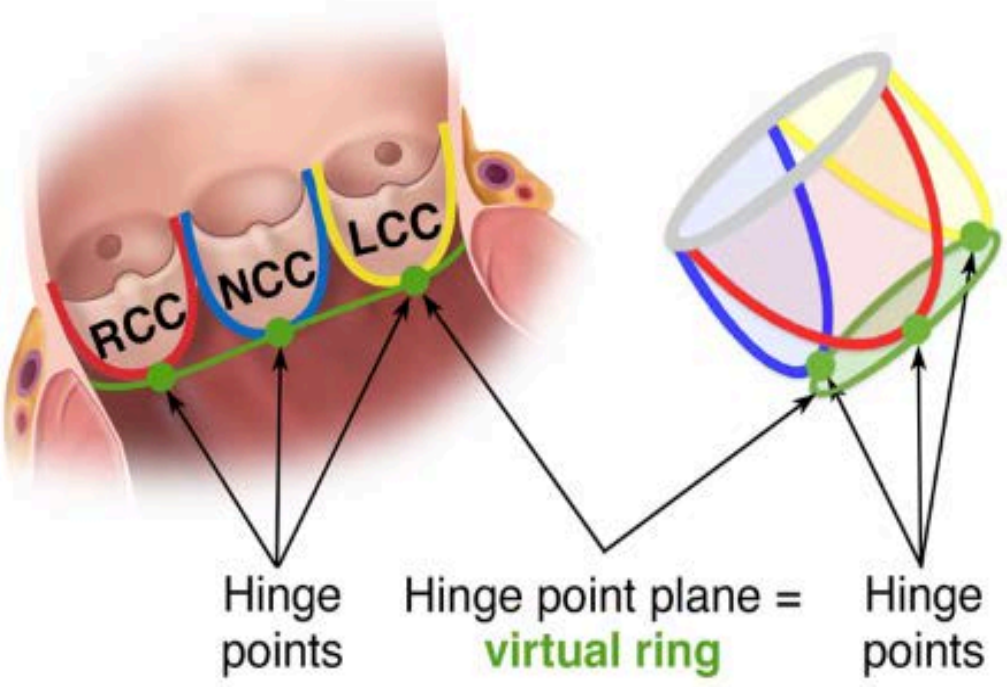
Lang RM et al; J Am Soc Echocardiogr 2005; 18:1440-1463

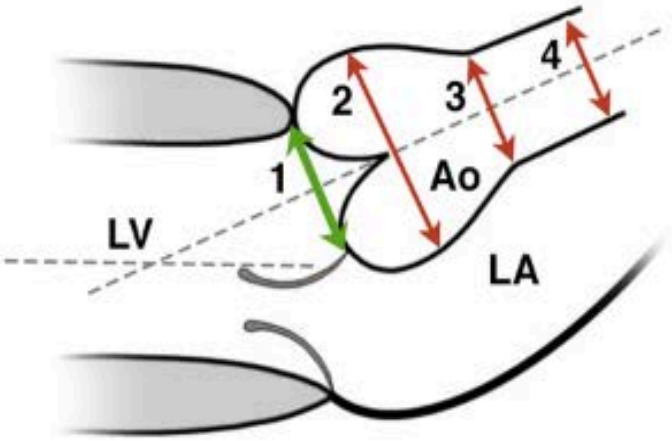
	Normal	Mildly	Moderately	Severely
LA Vol/BSA	16-34	35-41	42-48	>48

Lang RM et al; J Am Soc Echocardiogr 2015; 28:1-39

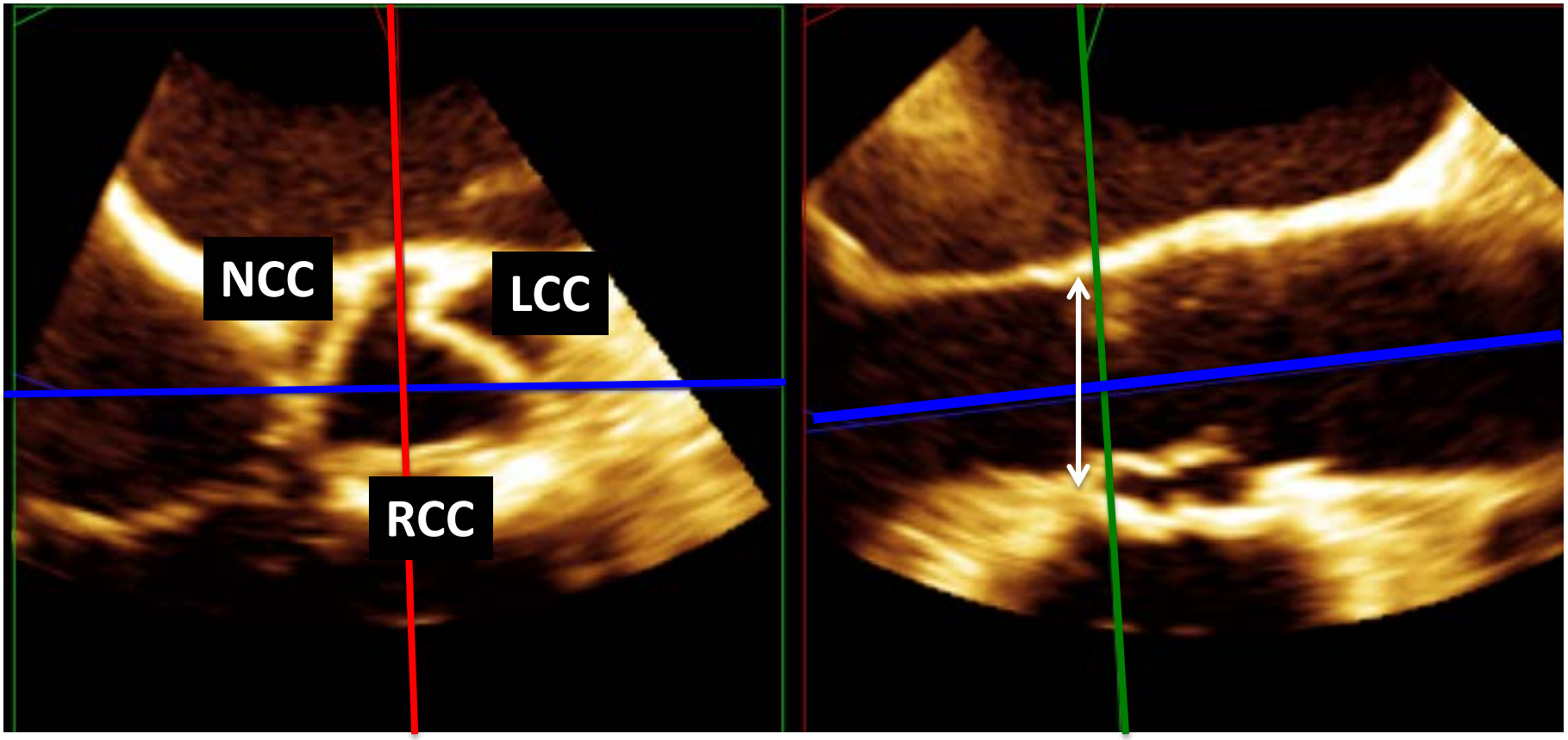
Aorta




RCC
NCC
LCC
Hinge points
Hinge point plane = virtual ring
Hinge points


1
2
3
4
Ao
LV
LA

Aortic Annulus Measurements

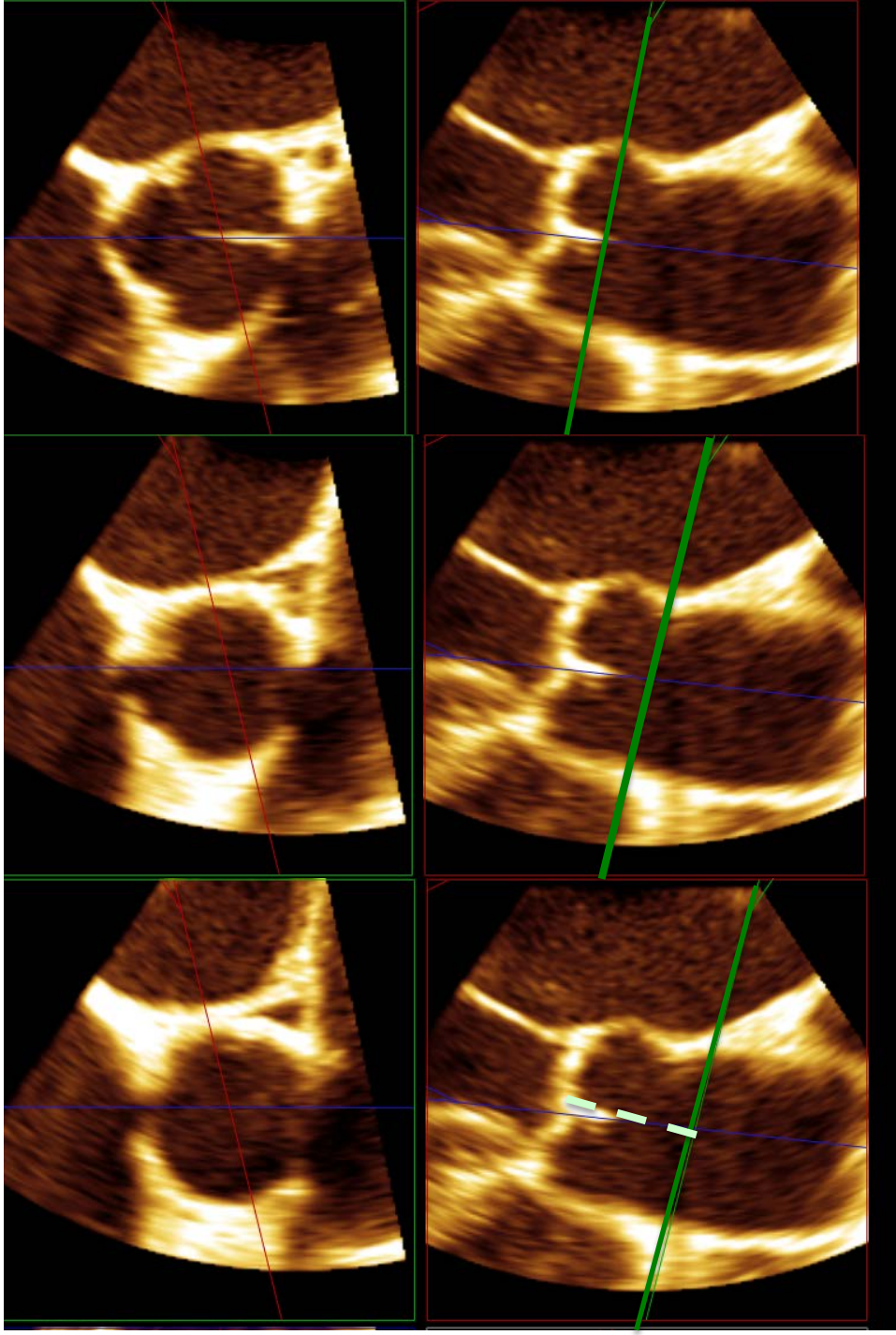


When: mid-systole: slightly larger and rounder

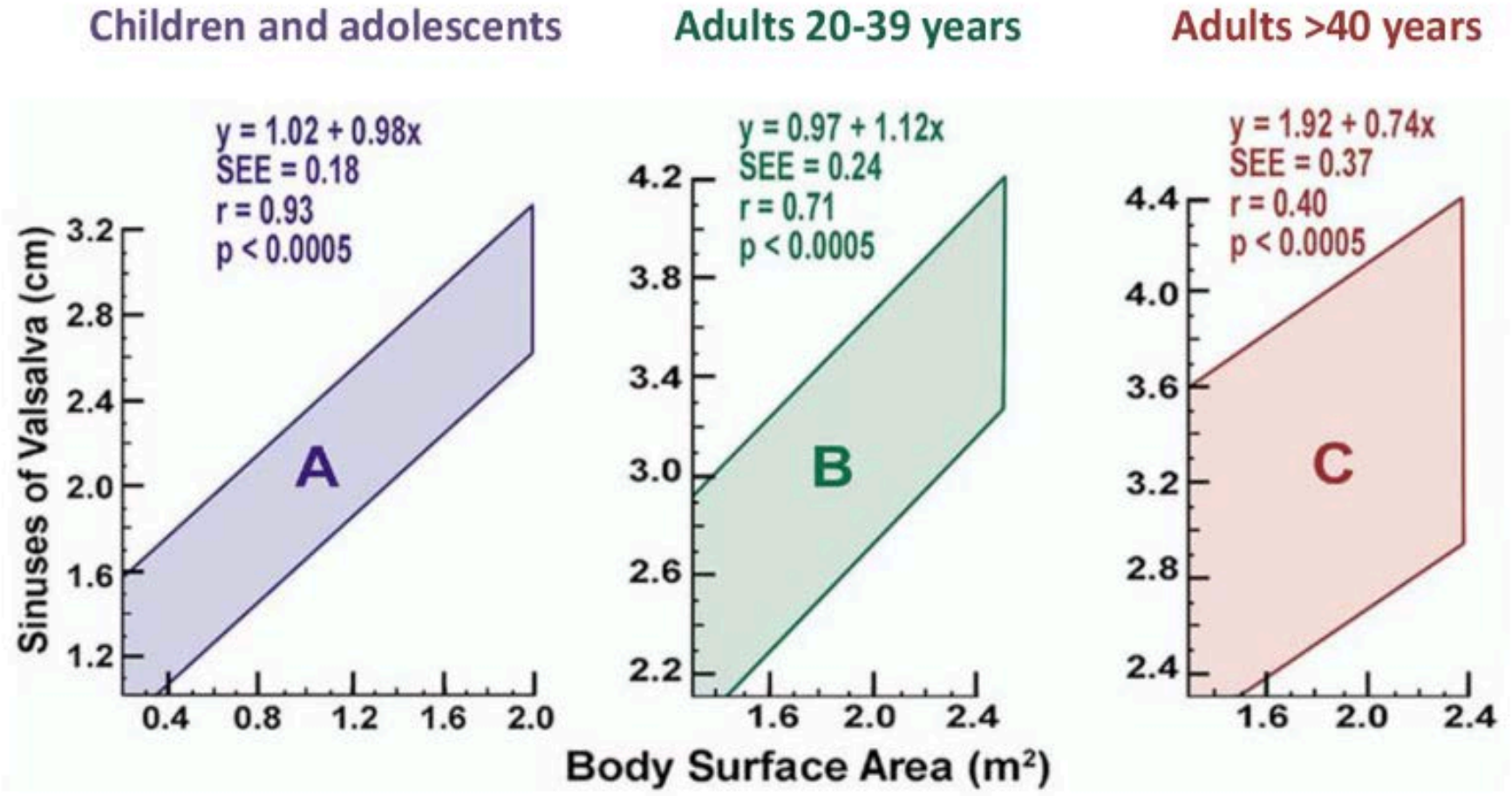
Where: mid right coronary cusp and the edge of the commissures between the LCC and NCC from inner edge to inner edge

- Sinuses of Valsalva (End-diastole)
- Sino-tubular junction (End-diastole)
- Maximal diameter of the proximal Asc Ao (End-diastole)

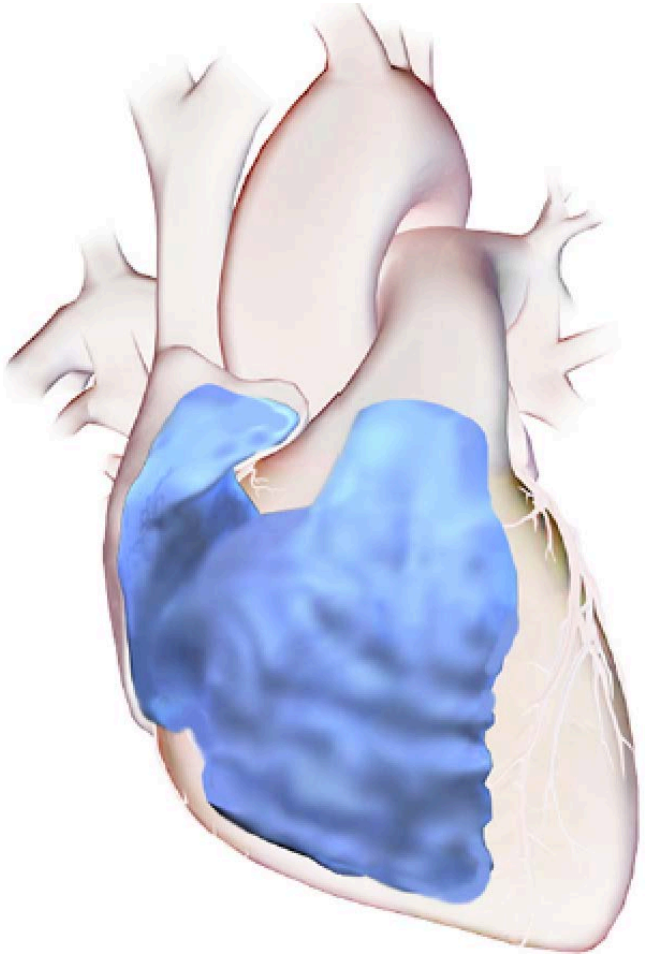
Leading edge to leading edge



Aortic Root Measurements (Sinus of Valsalva)



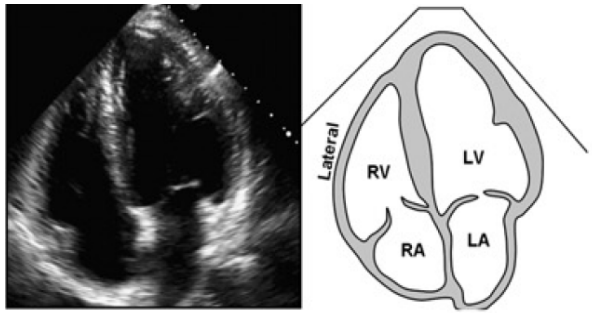
RV Ventricle and Right Atrium



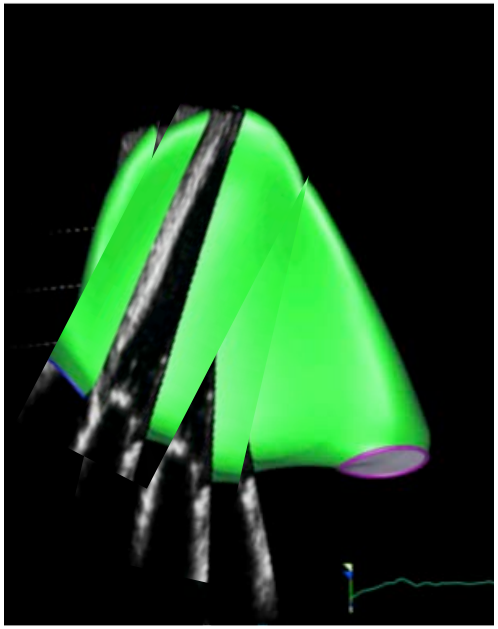
3DE For Assessing the Right Ventricle

What We Actually Measure by 2D Echo …

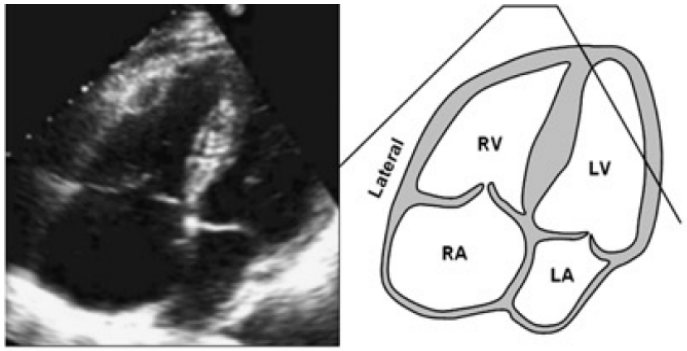
Apical 4-chamber



Variable RV/RA size, shape and function



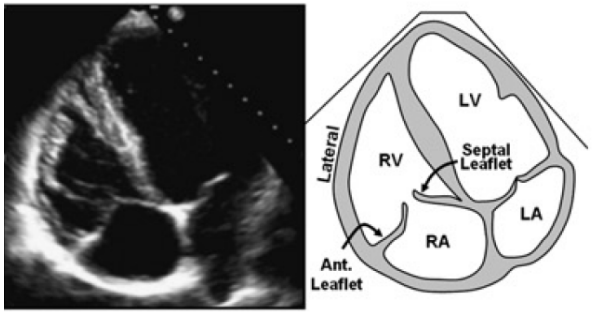
Lateral RV wall, RV maximal longitudinal distance



RV Modified Apical 4-chamber

RV Focused Apical 4-Chamber

Larger RV minor dimension in the basal segment



RV focused apical 4-chamber

Lang RM, Badano LP et al Eur Heart J Cardiovasc Imaging 2015

RV Linear Dimensions

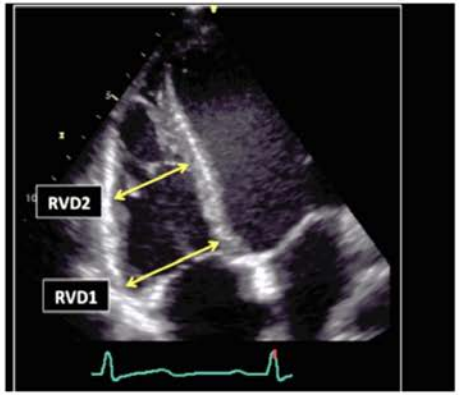
27±4mm

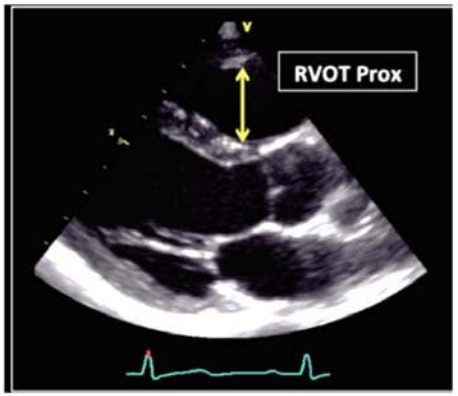
33±4mm

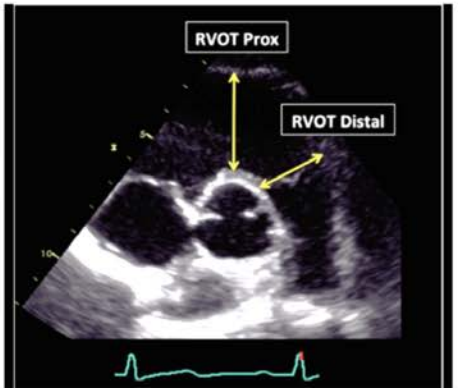
25±2mm

28±3.5mm

22±2.5mm







Inflow

Basal RV linear dimension (RVD1) = maximal transversal dimension in the basal one third of RV inflow at end-diastole in the RV-focused view

Mid-cavity RV linear dimension (RVD2) = transversal RV diameter in the middle third of RV inflow, approximately halfway between the maximal basal diameter and the apex, at the level of papillary muscles at end-diastole.

Outflow

Proximal RV outflow diameter (RVOT Prox) = linear dimension measured from the anterior RV wall to the inter-ventricular septal-aortic junction (in parasternal long-axis view) or to the aortic valve (in parasternal short-axis) at end-diastole

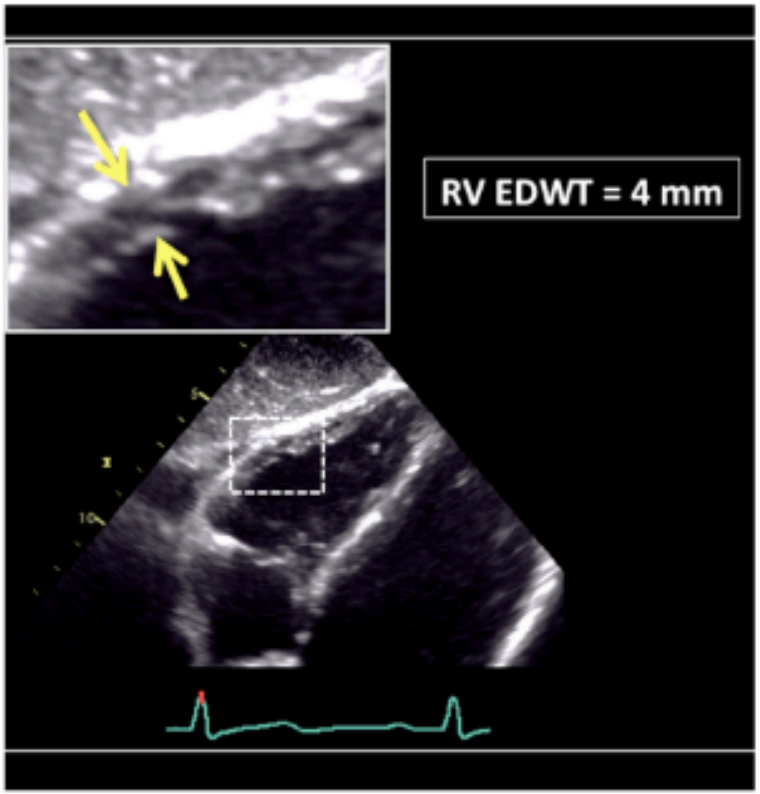
Distal RV outflow diameter (RVOT Distal) = linear transversal dimension measured just proximal to the pulmonary valve at end-diastole

RV Wall Thickness

Linear measurement of RV free wall thickness (either by M-mode or 2D echocardiography) performed at end-diastole, below the tricuspid annulus at a distance approximating the length of anterior tricuspid leaflet, when it is fully open and parallel to the RV free wall.

Trabeculae, papillary muscles and epicardial fat should be excluded

Zoomed imaging with focus on the RV mid-wall and respiratory maneuvers may improve endocardial border definition



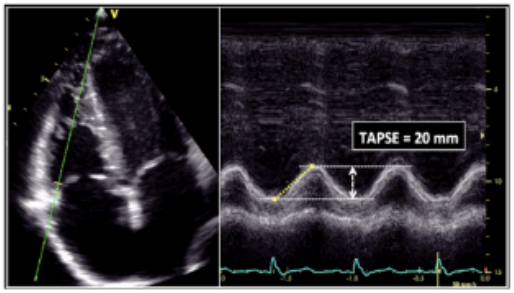
3±1

RV Longitudinal Systolic Function

TAPSE

Tricuspid annular longitudinal excursion by M-mode (mm), measured between end-diastole and peak systole

Proper alignment of M-mode cursor with the direction of RV longitudinal excursion should be achieved from the apical approach.

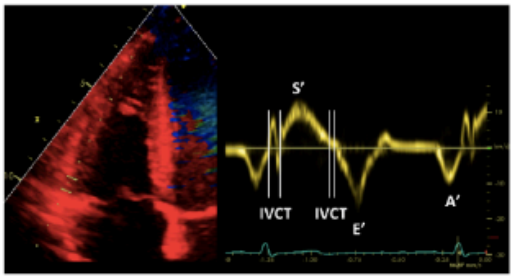


24±3.5, mm

<17, mm

Pulsed Tissue Doppler S Wave

Peak systolic velocity of tricuspid annulus by pulsed-wave DTI (cm/s), obtained from the apical approach, in the view that achieves parallel alignment of Doppler beam with RV free wall longitudinal excursion

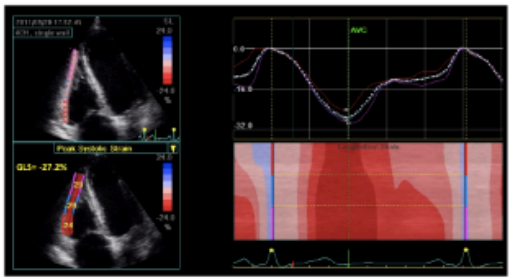


14.1±2.3, cm/s

<9.5, cm/s

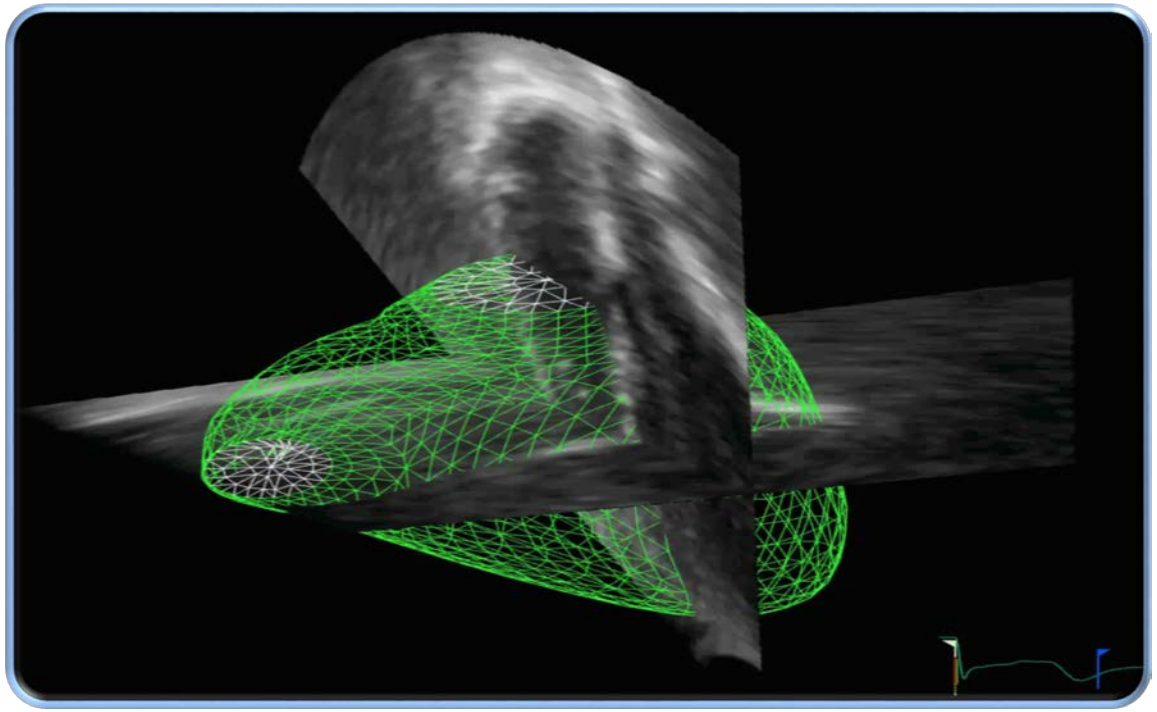
Global Longitudinal RV Free-Wall Strain

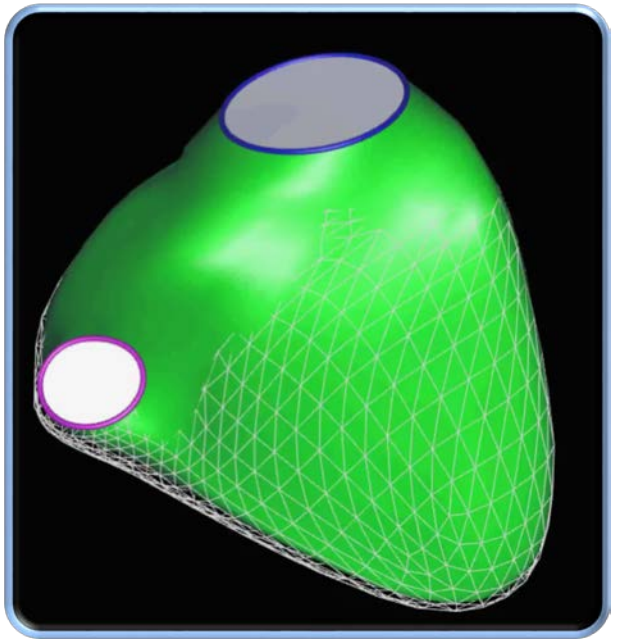
Peak value of 2D longitudinal speckle tracking derived strain, averaged over the 3 segments of the RV free wall in RV-focused apical 4-chamber view (%)

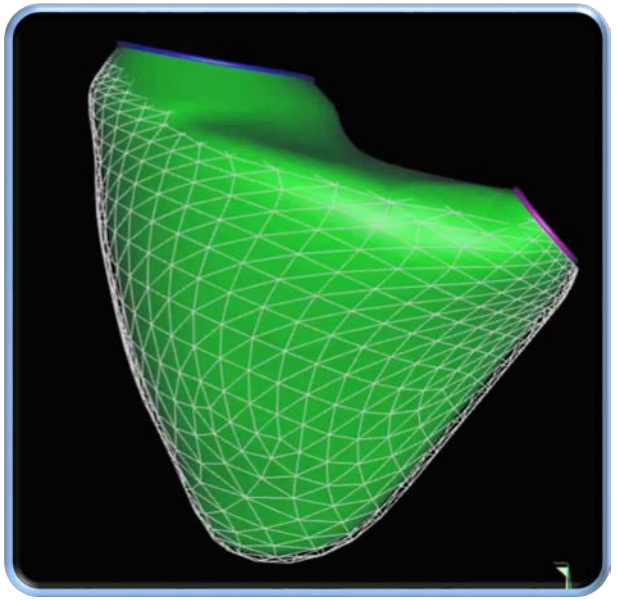


-29±4.5, %

>-20, %

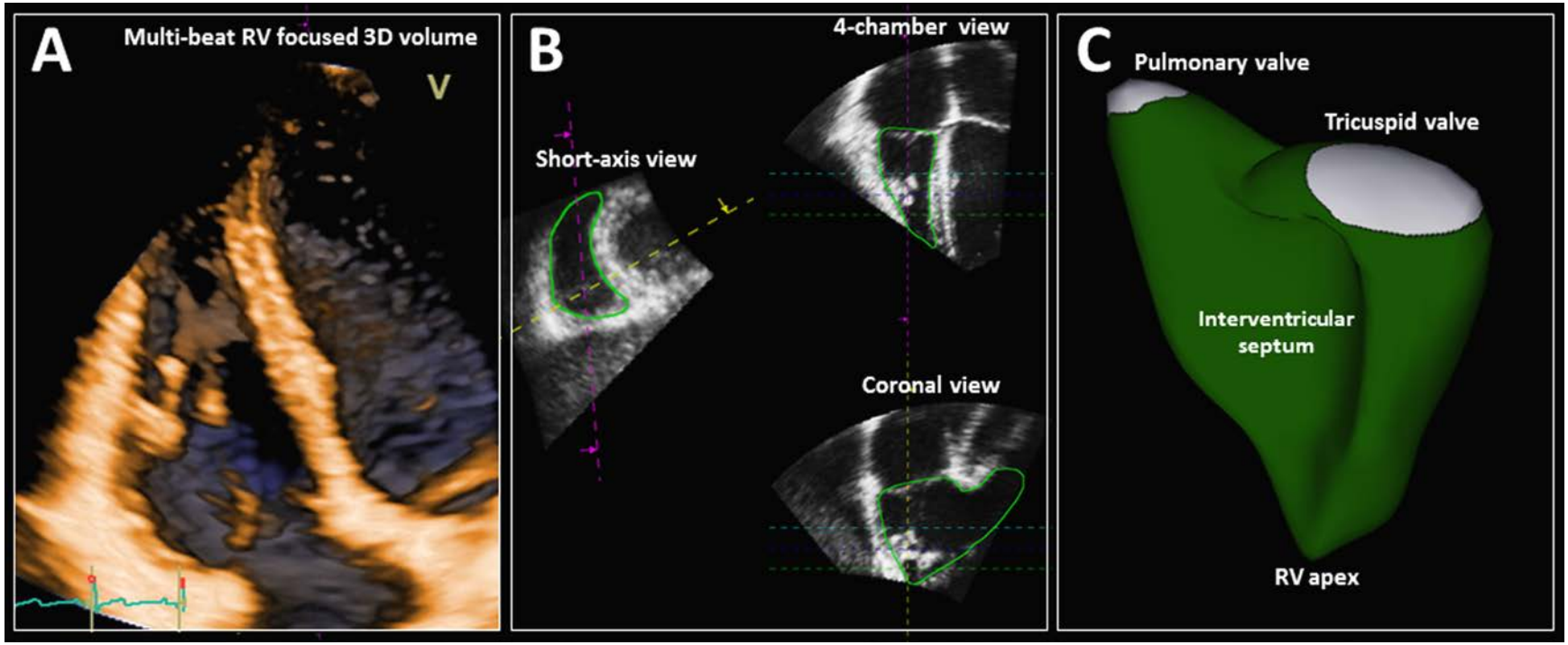






RV Volumes from 3D Echocardiography

RV Volumes and EF



RV EDV/BSA, Men	61.3±13	35-87
RV EDV/BSA, Women	53±10.5	32-74

RV EF % 58±6.5

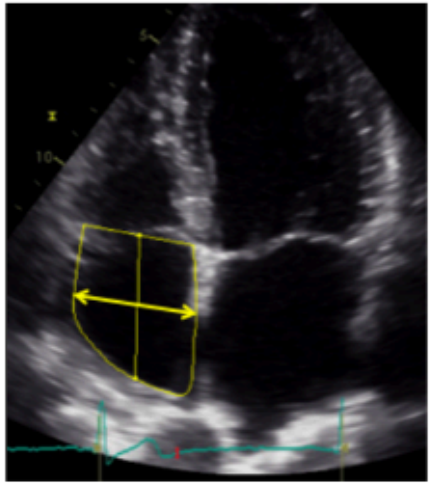
RV ESV/BSA, Men	27±8.5	10-44
RV ESV/BSA, Women	22±7	8-36

<45

RA Size

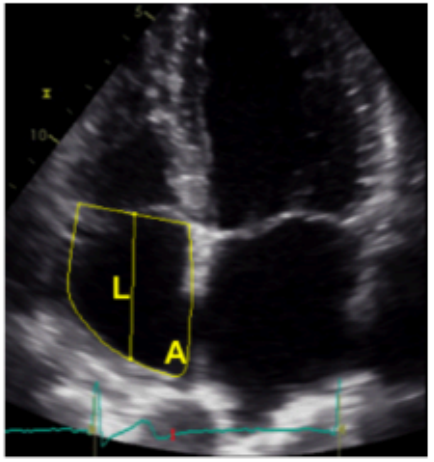
RA Linear Dimensions

The minor axis of the right atrium should be measured in the apical 4-chamber view as the distance between the lateral right atrial wall and inter-atrial septum, at the mid-atrial level defined by half of right atrial long axis



RA Volume

2D volumetric measurements are usually based on tracings of the blood-tissue interface on the apical 4-chamber view. At the tricuspid valve level, the contour is closed by connecting the two opposite sections of the tricuspid ring with a straight line. Volumes can be computed by using either the single plane area-length or the discs summation technique.



	Women	Men
RA minor axis dimension (cm/m²)	1.9 ± 0.3	1.9 ± 0.3
RA major axis dimension (cm/m²)	2.5 ± 0.3	2.4 ± 0.3
2DE right atrial volume (ml/m²)	21 ± 6	25 ± 7

IVC

- **Measure in subcostal view 1-2cm from RA junction**
- **Collapsibility index and estimated RAP**
  - **< 1.7 cm & 50% collapse ~RAP 0-5 mm Hg**
  - **>1.7cm & >50% collapse ~RAP 6-10 mm Hg**
  - **>1.7cm & <50% collapse ~RAP 10-15 mm Hg**
  - **>1.7cm with no collapse ~RAP 15+ mm Hg**

  - **IVC <1.2 with complete collapse- dry**

Summary

1. Reference ranges for left ventricular volumes and ejection fraction as well as LA volumes have changed in the recent guidelines due to the use of large echo databases.
2. Left ventricular wall motion scoring has changed to a 4-grade system.
3. Three-dimensional echocardiography is recommended for measurement of left and right ventricular volumes if possible.

Summary

4. If global longitudinal strain is being used to follow patients, it should be using the same vendors machine and analysis package.

Lang et al. Recommendations for Cardiac Chamber Quantification by Echocardiography in Adults: An Update from the American Society of Echocardiography and the European Association of Cardiovascular Imaging. J Am. Soc. Echocardiogr. 2015;28:1-39.

http://asecho.org/wordpress/wp-content/uploads/2015/01/ChamberQuantification2015.pdf

Thanks for your attention

ASE American Society of Echocardiography

Heart & Circulation Ultrasound Specialists

Recommendations for Chamber Quantification: A Report from the American Society of Echocardiography's Guidelines and Standards Committee and the Chamber Quantification Writing Group, Developed in Conjunction with the European Association of Echocardiography, a Branch of the European Society of Cardiology

Members of the Chamber Quantification Writing Group are: Roberto M. Lang, MD, FASE, Michelle Bierig, MPH, RDCS, FASE, Richard B. Devereux, MD, Frank A. Flachskampf, MD, Elyse Foster, MD, Patricia A. Pellikka, MD, Michael H. Picard, MD, Mary J. Roman, MD, James Seward, MD, Jack S. Shanewise, MD, FASE, Scott D. Solomon, MD, Kirk T. Spencer, MD, FASE, Martin St John Sutton, MD, FASE, and William J. Stewart, MD

J AM Soc Echocardiogr 2005; 18:1440-1463