RIGHT VENTRICULAR SIZE AND FUNCTION

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Philippine Society of Echocardiography
Quezon City, Philippines

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NO DISCLOSURE

NORMAL HEART = NORMAL FAMILY

Outline

- Need to evaluate the right ventricle
- Systematic evaluation of the right ventricle
- Right ventricular dimension
- Right ventricular systolic function
- Recommendation

GUIDELINES AND STANDARDS

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*

(J Am Soc Echocardiogr 2015;28:1-39.)

GUIDELINES AND STANDARDS

Guidelines for the Echocardiographic Assessment of the Right Heart in Adults: A Report from the American Society of Echocardiography

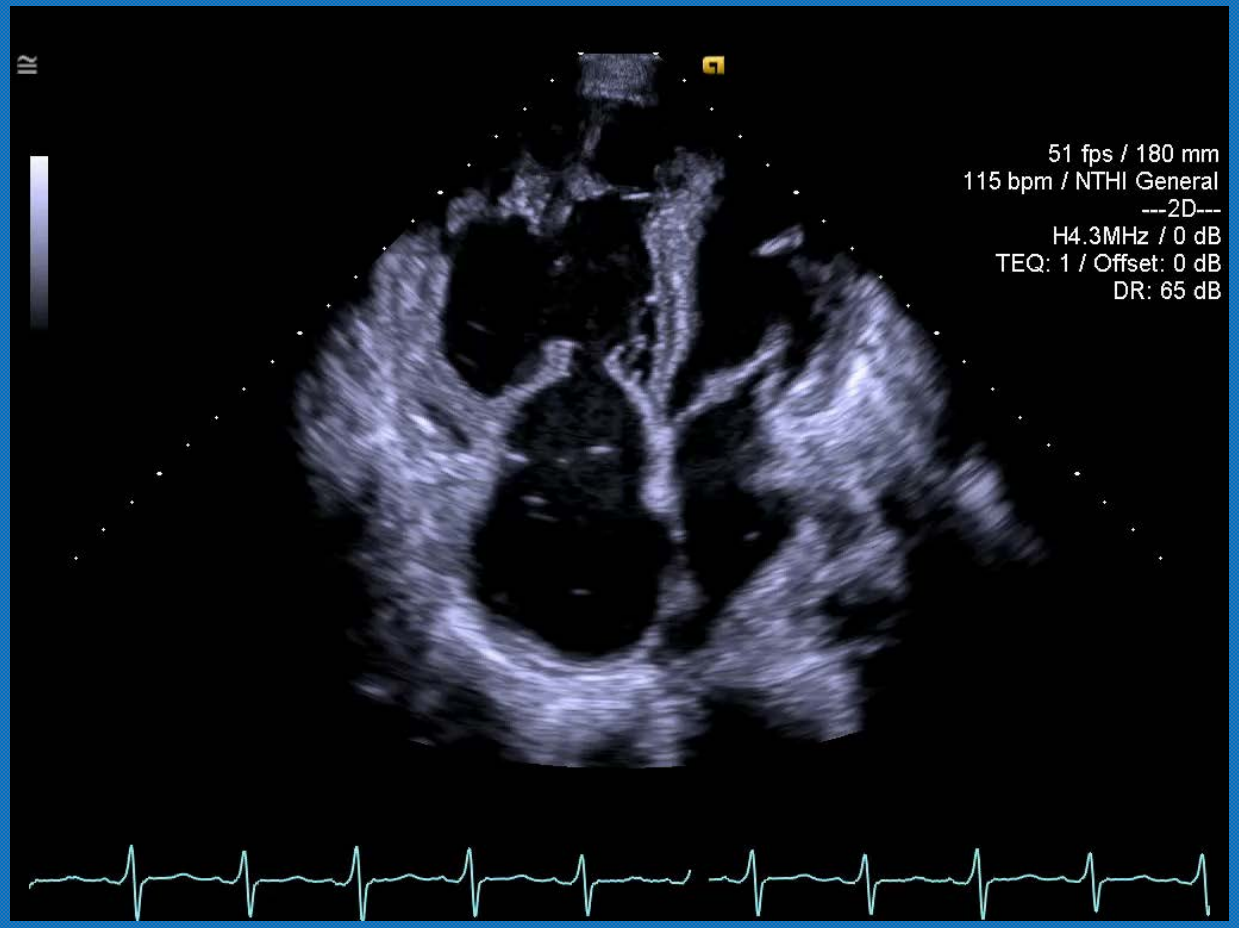
Endorsed by the European Association of Echocardiography, a registered branch of the European Society of Cardiology, and the Canadian Society of Echocardiography

Lawrence G. Rudski, MD, FASE, Chair, Wyman W. Lai, MD, MPH, FASE, Jonathan Afilalo, MD, Msc, Lanqi Hua, RDCS, FASE, Mark D. Handschumacher, BSc, Krishnaswamy Chandrasekaran, MD, FASE, Scott D. Solomon, MD, Eric K. Louie, MD, and Nelson B. Schiller, MD, *Montreal, Quebec, Canada; New York, New York; Boston, Massachusetts; Phoenix, Arizona; London, United Kingdom; San Francisco, California*

(J Am Soc Echocardiogr 2010;23:685-713.)

Case

Smoker
Easy fatigability
No orthopnea
Bipedal edema



Importance of evaluating the right ventricle

- Role in the clinical outcome of cardiopulmonary disease

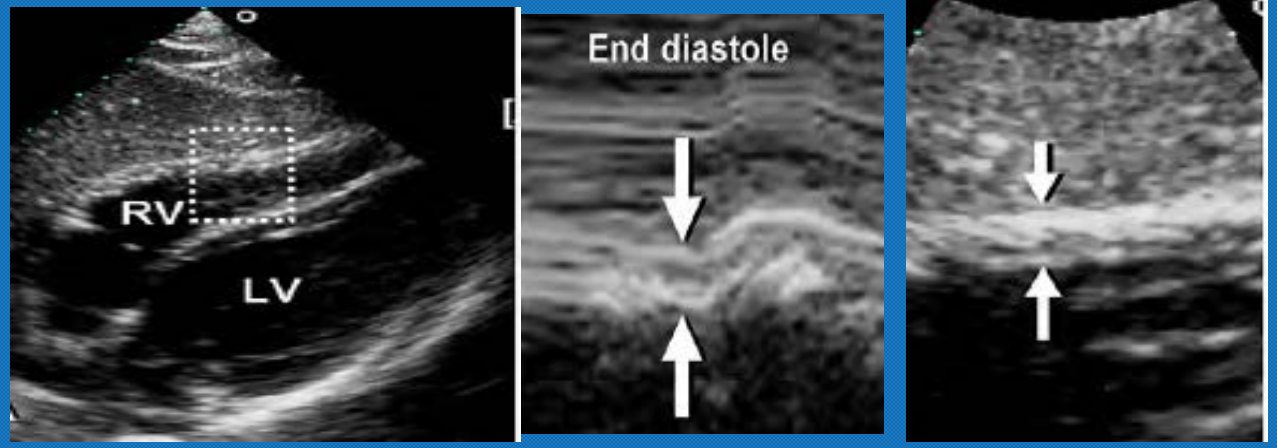
- Size and function adversely affected by
  - left ventricular dysfunction
  - primary pulmonary hypertension
  - conditions that affect the tricuspid valve leading to significant tricuspid regurgitation

Systematic Evaluation of the Right Ventricle

- **limited** due to its complex morphology
- comprehensive evaluation:
  - right ventricular dimensions
  - systolic and diastolic function, and RV systolic pressure
- use multiple echo windows:
  - apical 4-chamber, modified apical 4-chamber, left parasternal long axis (PLAX) and parasternal short-axis (PSAX), left parasternal RV inflow, and subcostal views.
- 3 D echo imaging continuously improve.

RIGHT VENTRICULAR DIMENSIONS

RIGHT VENTRICULAR WALL THICKNESS



M-MODE 2D

- End diastole
- Subcostal view
- Zoomed M-mode or (2D)
- RV wall thickness ≤5mm

Advantage:

Easy to perform

Limitations:

- Single site measurement
- overestimated by harmonic imaging and oblique M-Mode
- challenging with thickened visceral pericardium

Rudski et al. Guidelines for the echo assessment of the Right Heart in Adult . JASE 2010;23:685-713
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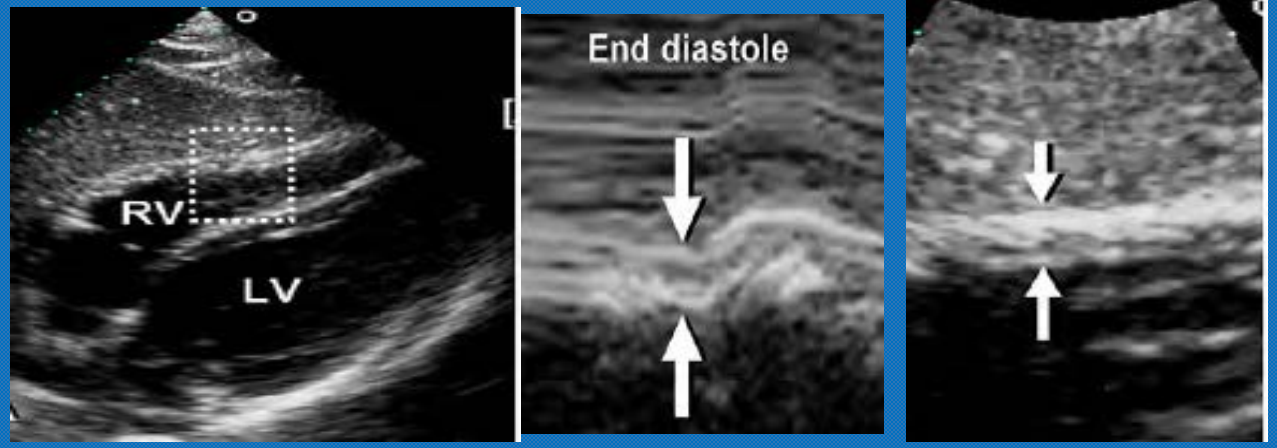

M-MODE 2D

Recommendation:

Abnormal RV wall thickness should be reported in patients suspected of having **RV and/or LV dysfunction**, using the normal cut off of **5 mm**

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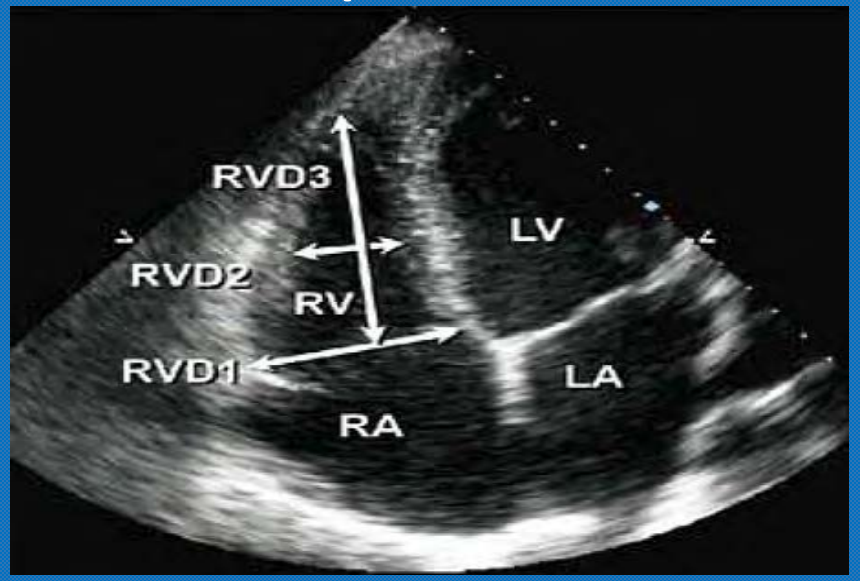
RV LINEAR DIMENSIONS

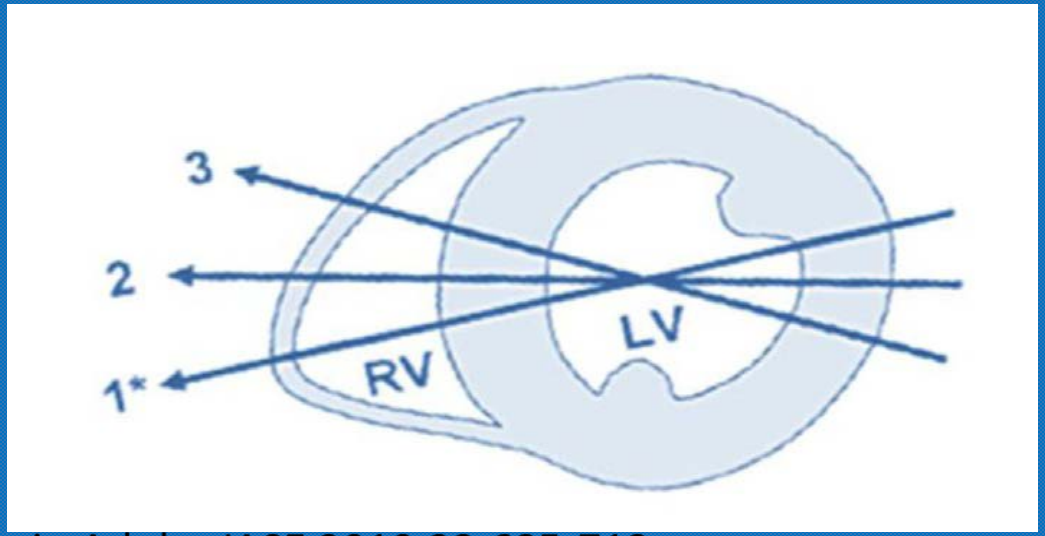
RV Focused Apical 4 chamber View



Advantages: easily obtained and a marker of RV dilatation.

Limitation: highly dependent on probe rotation which can result in an underestimation of RV width.

- End diastole
- diameter > 41 mm (base) and > 35 mm (mid level)=RV dilatation
- > 83 mm (longitudinal) = RV enlargement



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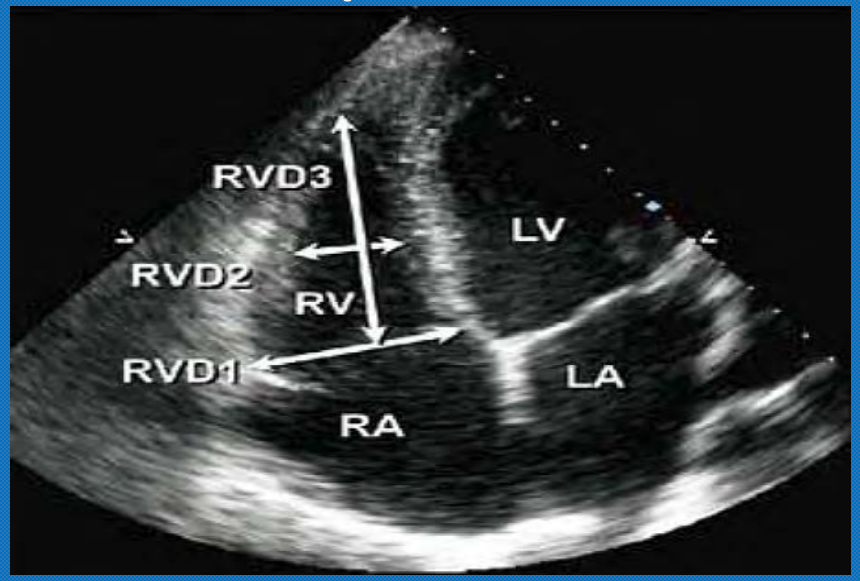

Recommendations:

- **right-sided heart disease or PH** should have measurements of **RV basal, mid cavity, and longitudinal dimensions** on a **4-chamber right ventricle-focused view**.
- report the right ventricle as dilated despite measuring within the normal range, on the basis of a right ventricle appearing significantly larger than the left ventricle.

Rudski et al. Guidelines for the echo assessment of the Right Heart in Adult . JASE 2010;23:685-713

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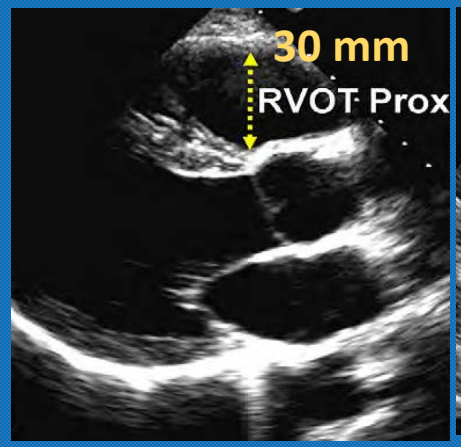
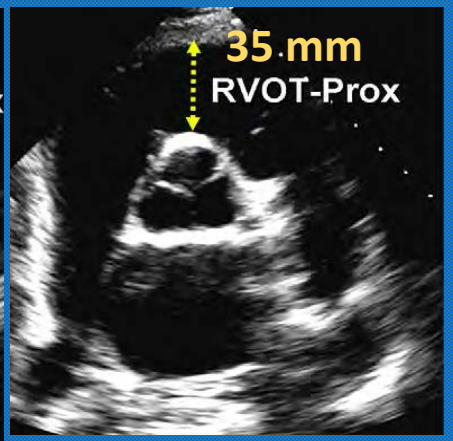
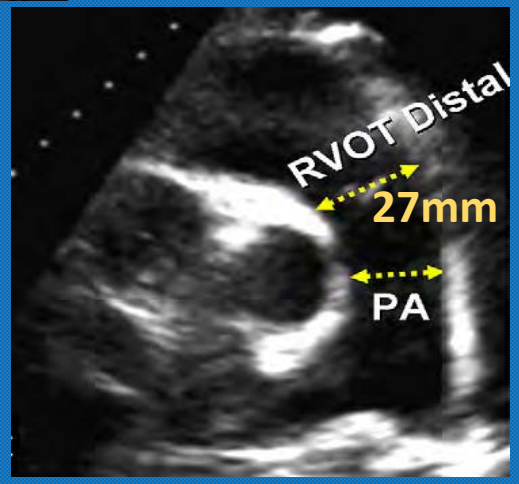
RIGTH VENTRICULAR OUTFLOW TRACT

Proximal RVOT





Distal RVOT



End-diastole
RVOT proximal
- PLAX: RV wall to IVS-aortic junction
- PSAX: RV wall to Aortic valve

RVOT distal
- PSAX: just proximal to pulmonic valve

Advantages: easily obtained from the left PSAX window.
Limitation: Limited normative data, window for measurement not yet standardized, wall is often suboptimal.

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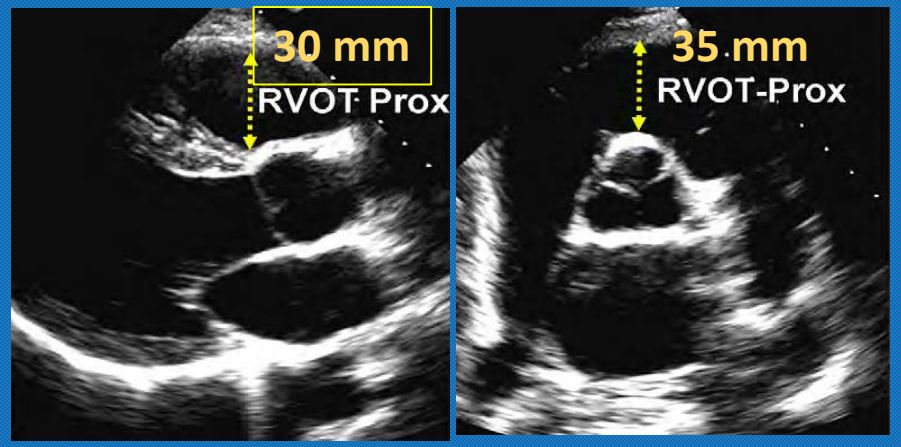
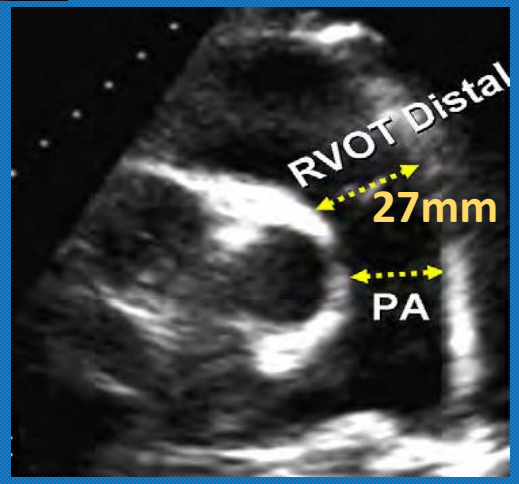


Distal RVOT



Recommendations:

- In congenital heart disease or arrhythmia potentially involving the RVOT, proximal and distal diameters of the RVOT should be measured from the PSAX or PLAX views.
- upper reference limit for the
  - PSAX distal RVOT diameter is 27 mm
  - PLAX proximal RVOT is 30mm
  - PSAX proximal RVOT is 35mm

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RIGHT VENTRICULAR SYSTOLIC FUNCTION

QUANTITATIVE PARAMETERS (Global/Regional)

With clinical utility and value based on studies are

- right ventricular index of myocardial performance (RIMP)
- tricuspid annular plane systolic excursion (TAPSE)
- 2D fractional area change (FAC)
- tricuspid annulus systolic velocity (*S'*)

Need more data to demonstrate clinical utility:

- dP/dT
- 2D RV ejection fraction
- 3D RV ejection fraction
- RV longitudinal strain and strain rate

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RIGHT VENTRICULAR SYSTOLIC FUNCTION

Global Function

- Pulsed Doppler RIMP
- Tissue Doppler RIMP

Global Systolic Function

- Fractional Area Change (RVFAC)
- 3D RVEF

Longitudinal Systolic Function

- TAPSE
- Pulse Tissue Doppler S' wave (Tricuspid annulus systolic velocity)
- Global Longitudinal Strain (GLS)

Recommendations for Cardiac Chamber Quantification by Echo in Adults: update from ASE/EACI. JASE 2015;28:1-39

RV SYSTOLIC FUNCTION: Right Ventricular Index of Myocardial Performance (RIMP),or Myocardial Performance Index (MPI)

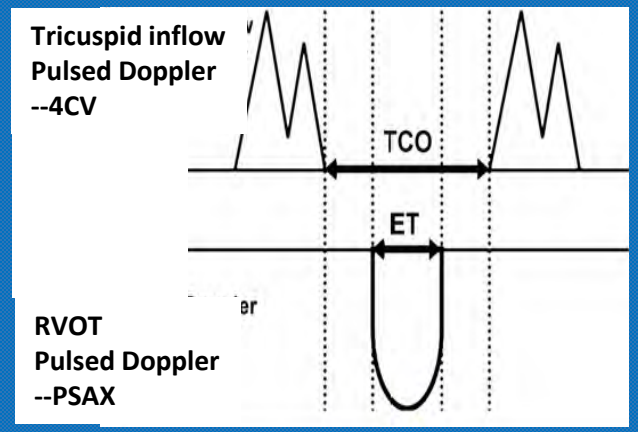
MPI is defined as the ratio of isovolumic time divided by ET, or [(IVRT + IVCT)/ET]

MPI = (TCO - ET)/ET

TCO =**T**ricuspid valve **C**losing to **O**pening time

ET =Right Ventricular **Ejection Time**

PULSED DOPPLER METHOD



PULSED TISSUE DOPPLER METHOD

Advantages:

>Less affected by heart rate (both methods)

>single beat recording, no need for R-R interval matching (*Pulse Tissue Doppler Method)*

Limitations:

>Unreliable when RA pressure is elevated (both)

>R-R interval matching of 2 separate recordings (Pulse Doppler Method)

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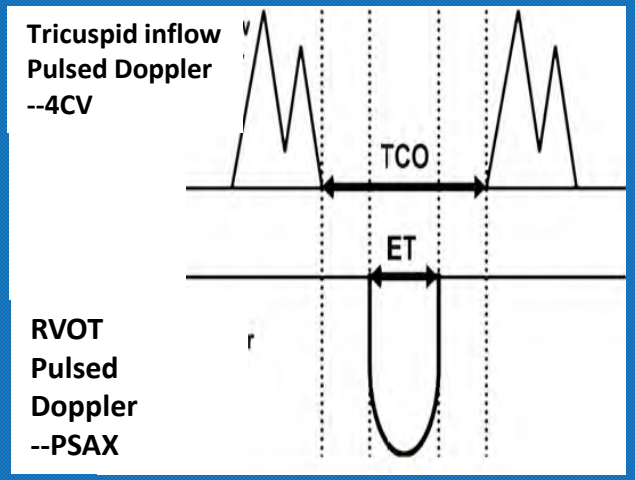

PULSED TISSUE DOPPLER METHOD

Recommendations:

- used for initial and serial measurements of RV function in complement with other quantitative and nonquantitative measures.
- **upper** reference limit for the right-sided MPI is 0.43 using the pulsed Doppler method and 0.54 using the pulsed tissue Doppler method.
- It should not be used as the sole quantitative method for evaluation of RV function and should not be used with irregular heart rates.

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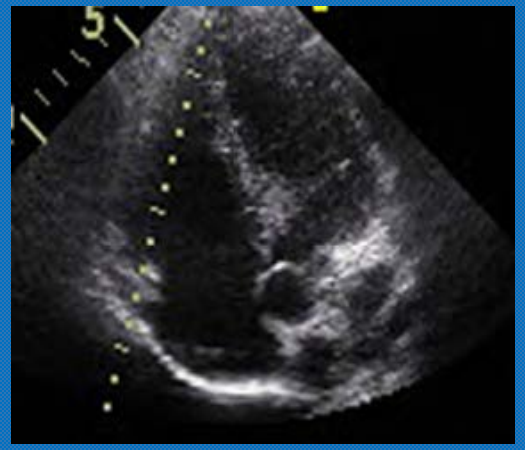
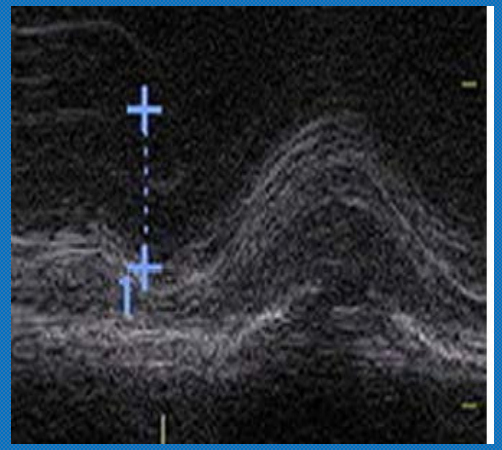
Rudski et al. Guidelines for the echo assessment of the Right Heart in Adult . JASE 2010;23:685-713

RV SYSTOLIC FUNCTION: Tricuspid Annular Plane Systolic Excursion (TAPSE)





- RV focused View
- M-mode the tricuspid lateral annulus.
- Excursion from end-diastole to peak systole
- Abnormal <17 mm

Advantages:

- Established prognostic value
- Validated against radionuclide EF

Limitations:

- Angle dependency
- Partial representation of RV Global Function

Recommendations for Cardiac Chamber Quantification by Echo in Adults: update from ASE/EACI. JASE 2015;28:1-39
Kaul S,. Am Heart J 1984;107: 526-31.
Lopez-Candales A, et al. Postgrad Med J 2008;84:40-5.
Miller D, Farah MG, Liner A, Fox K, Schluchter M, Hoit BD. J Am Soc Echocardiogr 2004;17:443-7.

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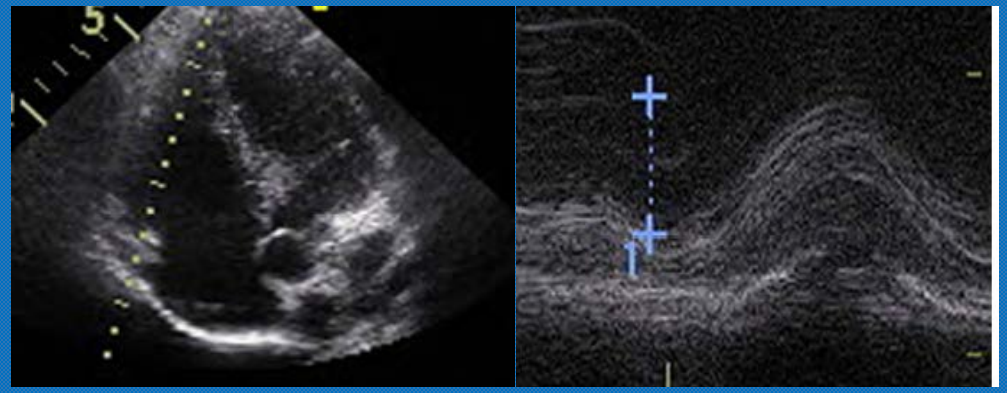
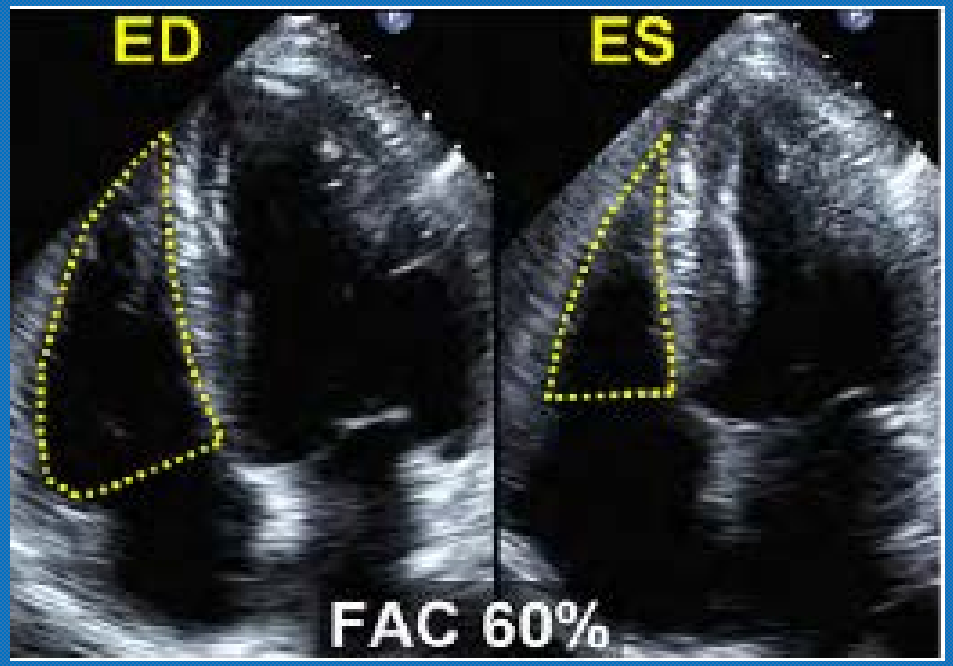


Recommendation:

- TAPSE should be used routinely as a simple method of estimating RV function, with a lower reference value for impaired RV systolic function of 17 mm.

Recommendations for Cardiac Chamber Quantification by Echo in Adults: update from ASE/EACI. JASE 2015;28:1-39
Rudski et al. Guidelines for the echo assessment of the Right Heart in Adult . JASE 2010;23:685-713

RV SYSTOLIC FUNCTION: 2D RV Fractional Area Change (RVFAC)



- RV focused apical 4 C view
- RV area end diastole and end systole
- RV FAC (%) = 100 x (EDA - ESA)/EDA
- Abnormal <35%

Advantages

- Established prognostic value
- Reflects both longitudinal and radial RV contraction
- Correlates with RVEF by CMR

Limitations

- Neglects contribution of RV outflow tract to overall systolic function

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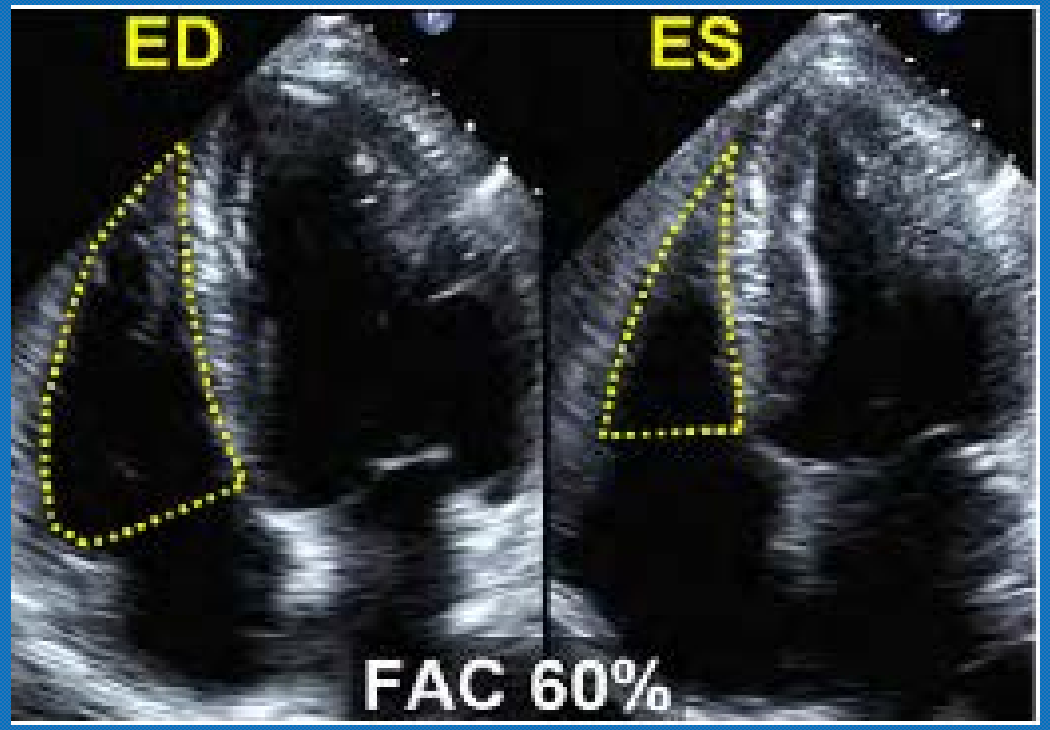

Recommendations:

- one of the recommended methods of quantitatively estimating RV function, with a lower reference value for normal RV systolic function of 35%.

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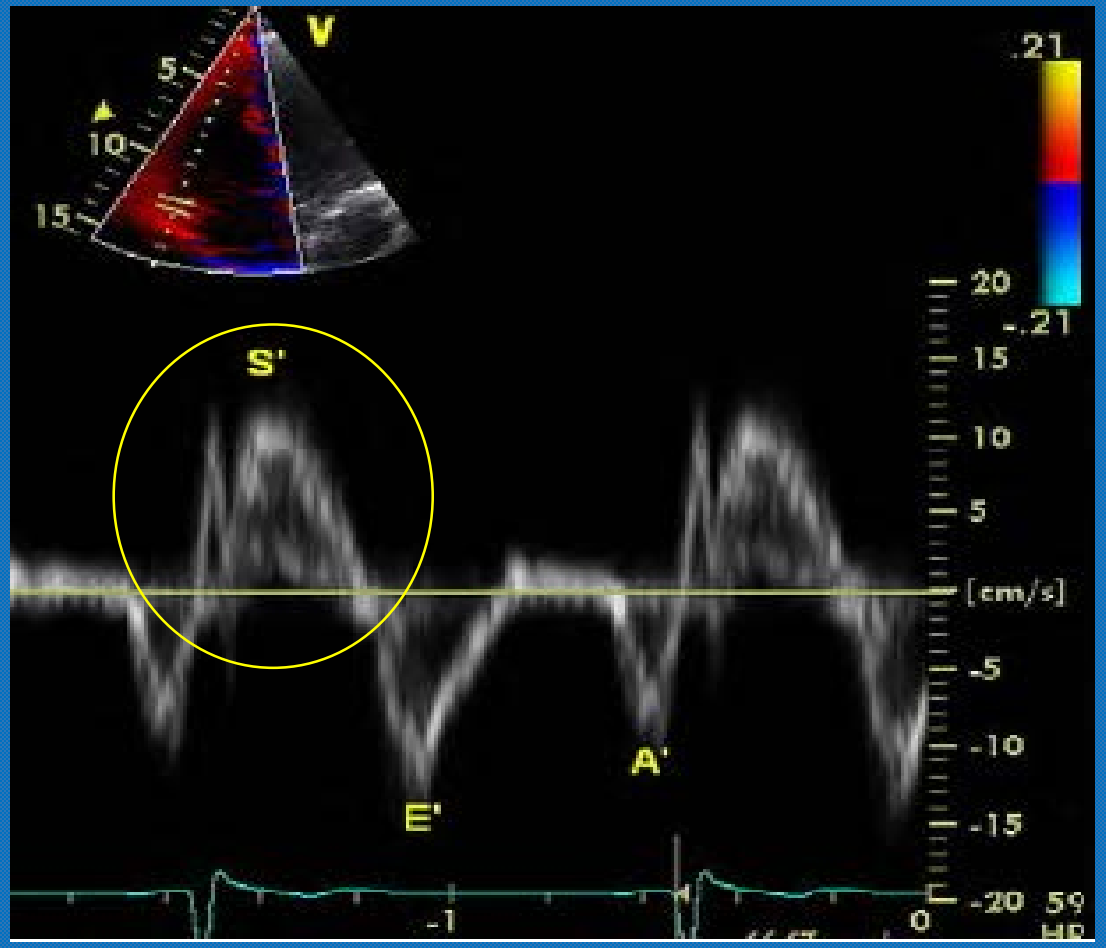
RV SYSTOLIC FUNCTION: Tricuspid Annulus Systolic Velocity (S')



- Pulse wave DTI of the lateral tricuspid annulus
- Apical 4C view with parallel alignment of Doppler beam with RV free wall longitudinal excursion
- Systolic Velocity <u>≤9.5 cm/sec</u> is abnormal

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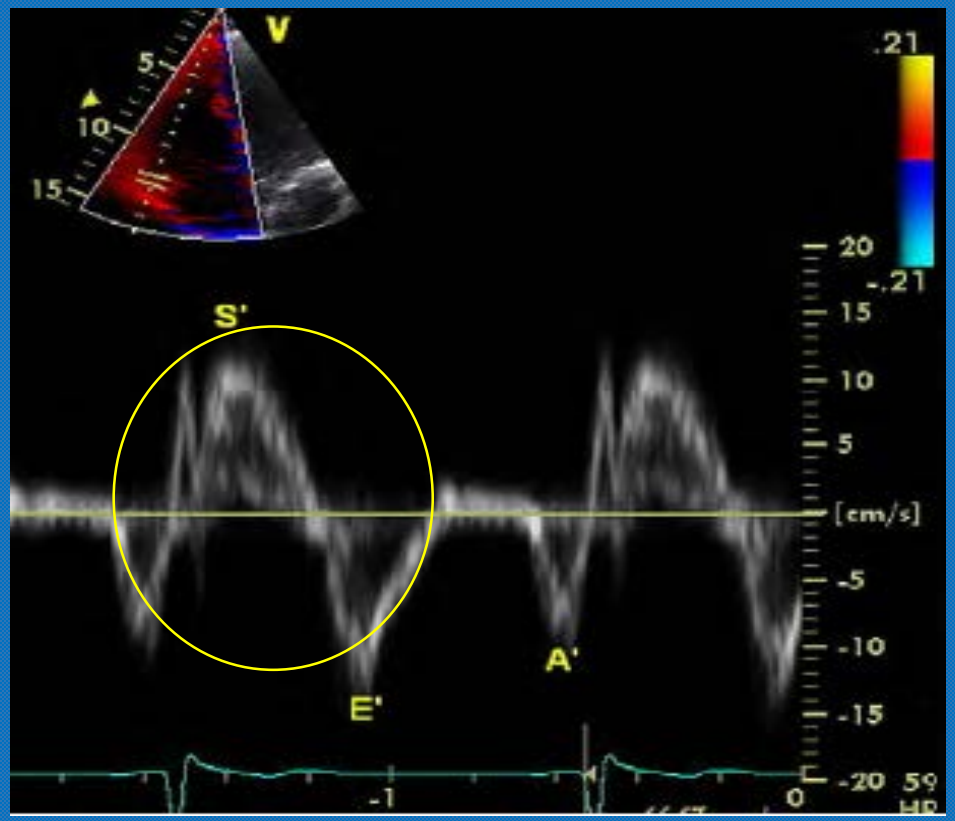

Advantages

- easily measured, reliable and reproducible.
- correlates well with other measures of global RV systolic function.
- Validated against radionuclide EF
- Established prognostic value

Limitations

- Angle dependent
- Not fully representative of RV global function after thoracotomy, pulmonary thromboendarterectomy or heart transplantation

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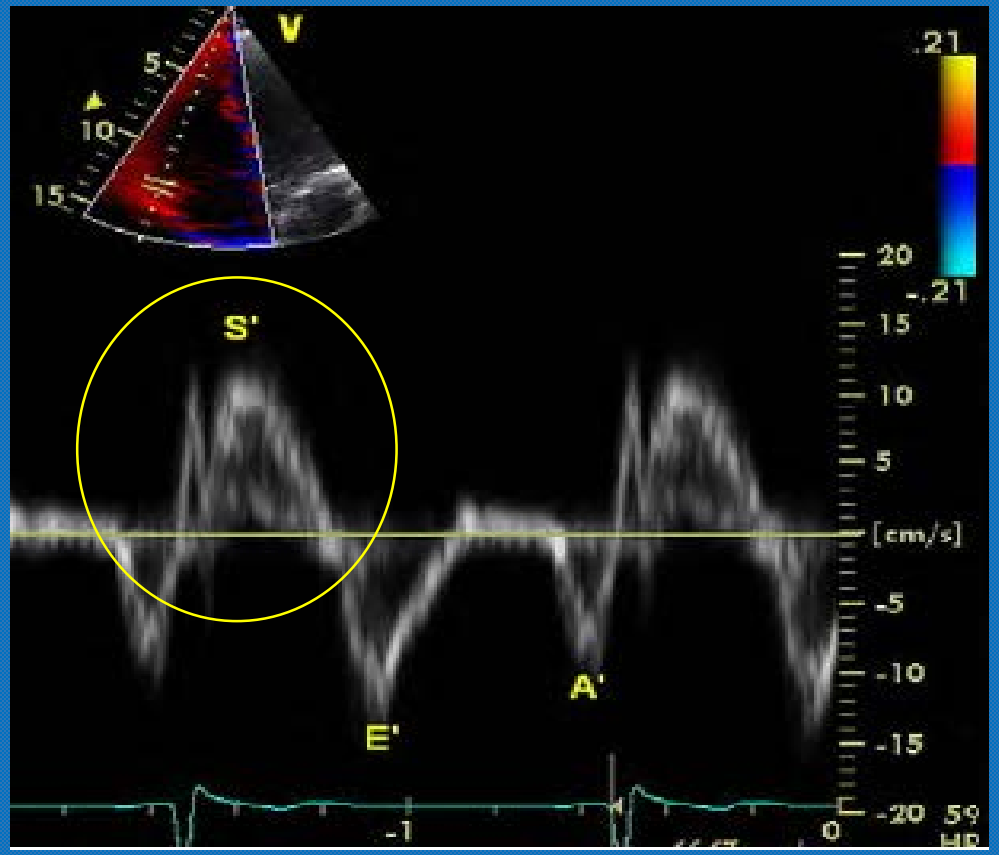
RV SYSTOLIC FUNCTION: Tricuspid Annulus Systolic Velocity (S')



Recommendation:

- should be used in the assessment of RV function.
- S' < 9.5 cm/s should raise the suspicion for abnormal RV function

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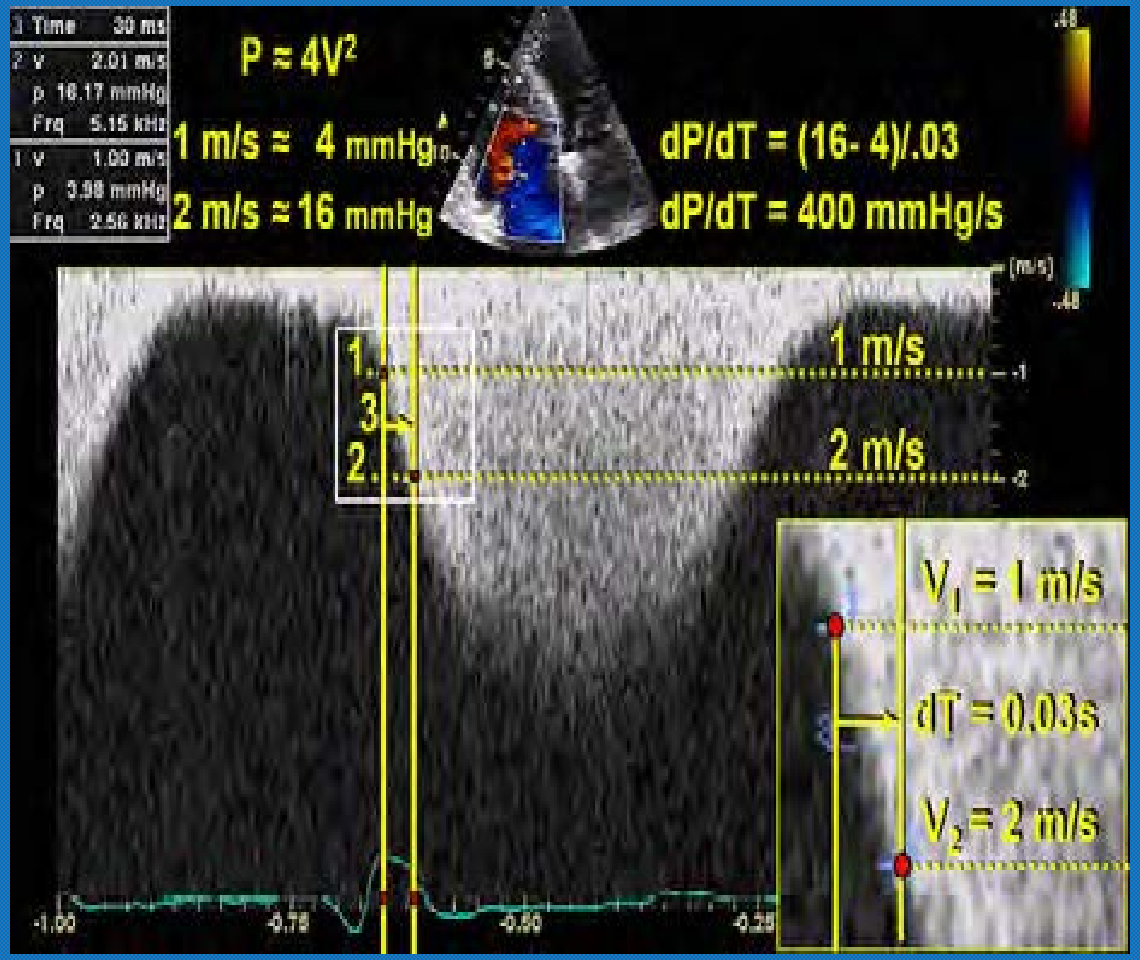
RV SYSTOLIC FUNCTION: RV dP/dT



- Ascending limb of the TR continuous-wave Doppler signal
- Mark 1 and 2 m/sec (4 and 16 mmHg)
- dP = 12 mmHg
- dT =time required for the TR jet to increase in velocity from 1 to 2 m/s.

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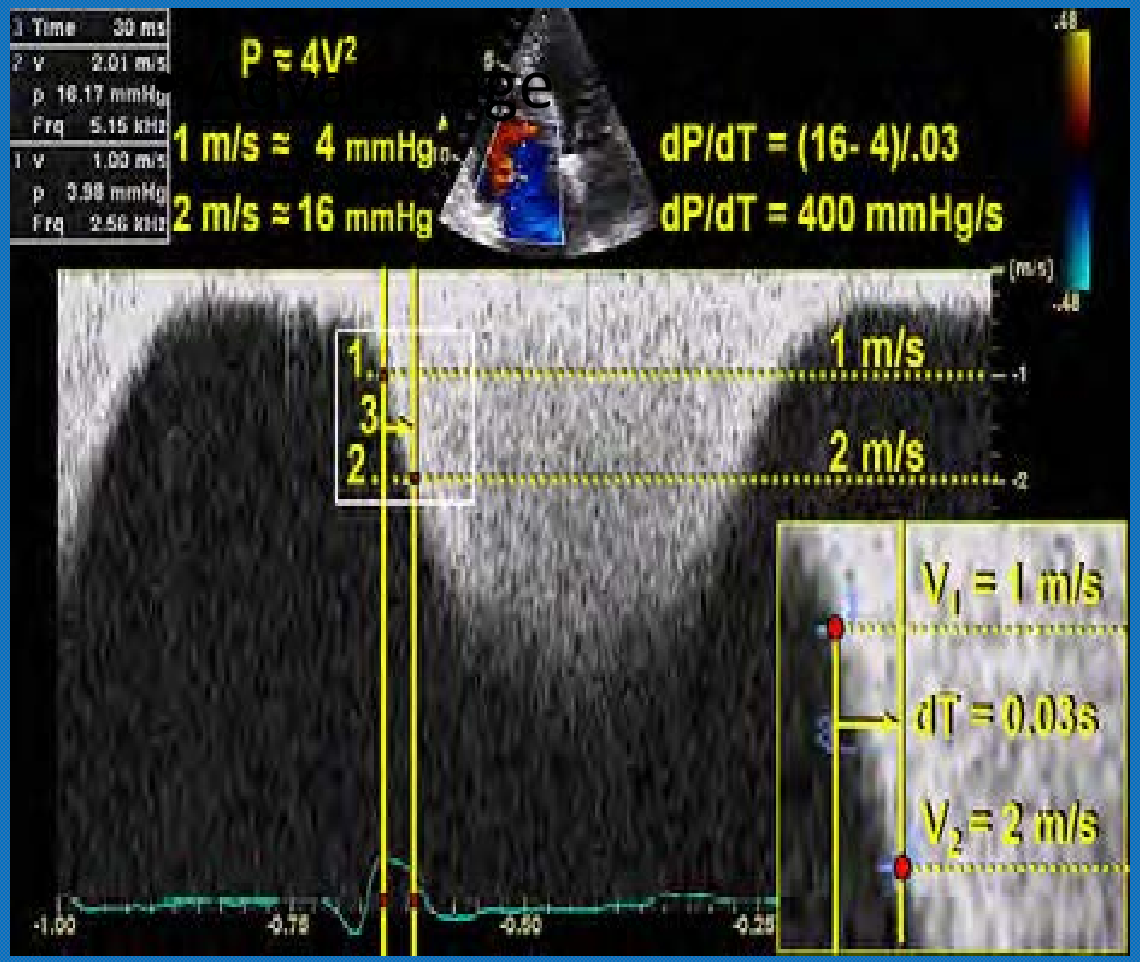
RV SYSTOLIC FUNCTION: RV dP/dT



Advantage:

- simple technique with sound physiologic basis

Limitations:

- Lack of data in normal subjects
- Load dependent

Recommendations:

- RV dP/dt < 400 mm Hg/s is likely abnormal
- cannot be recommended for routine use
- can be considered in subjects with suspected RV dysfunction.

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RV SYSTOLIC FUNCTION: 2D RV Ejection Fraction

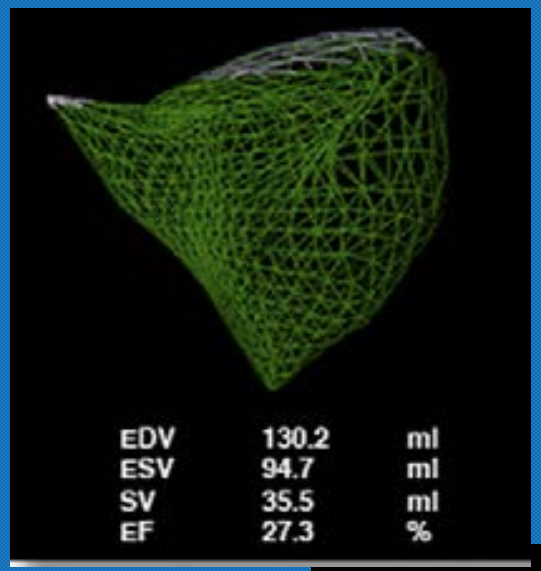
- Geometric assumptions
- area-length methods-
  - based on modified pyramidal or ellipsoidal models
- disk summation method
  - determine a RV ‘‘body’’ volume, using predominantly the apical 4-chamber view.

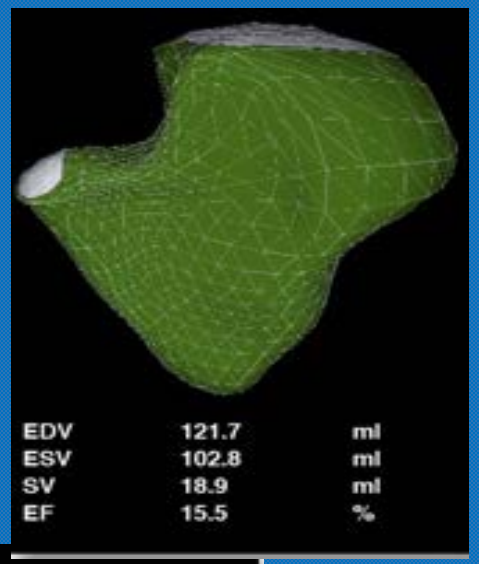
- (EDV-ESV)/EDV
- lower reference limit RV EF is 44%.

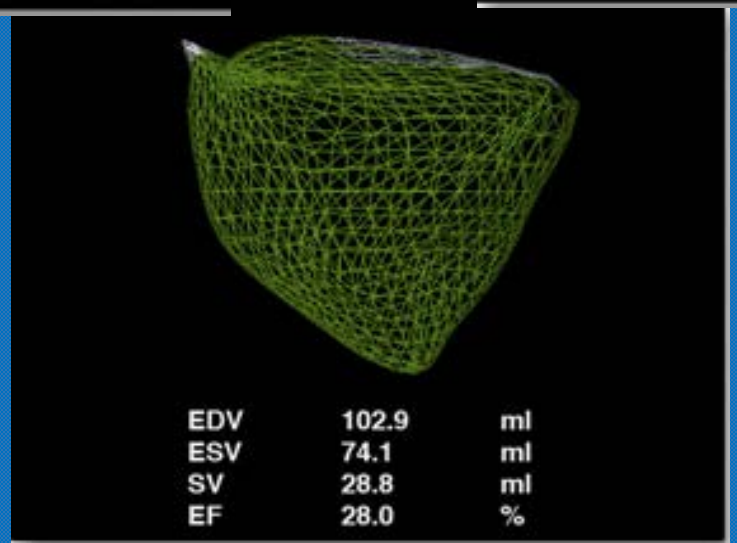
Recommendations:

- derived estimation of RV EF is not recommended, because of the heterogeneity of methods and the numerous geometric assumptions.

RV SYSTOLIC FUNCTION: 3D RV Ejection Fraction







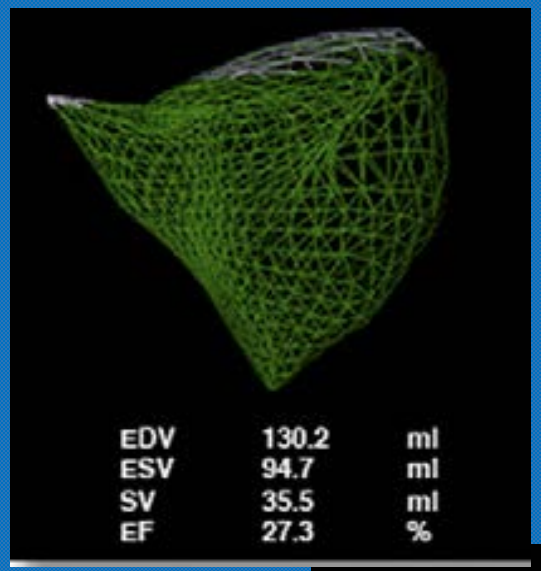
Advantages:

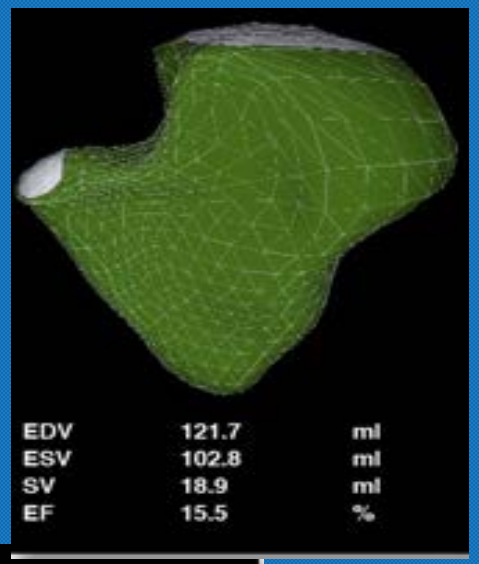
- No geometric assumptions
- Includes RV outflow tract contribution to overall function
- Correlates with RV EF by CMR

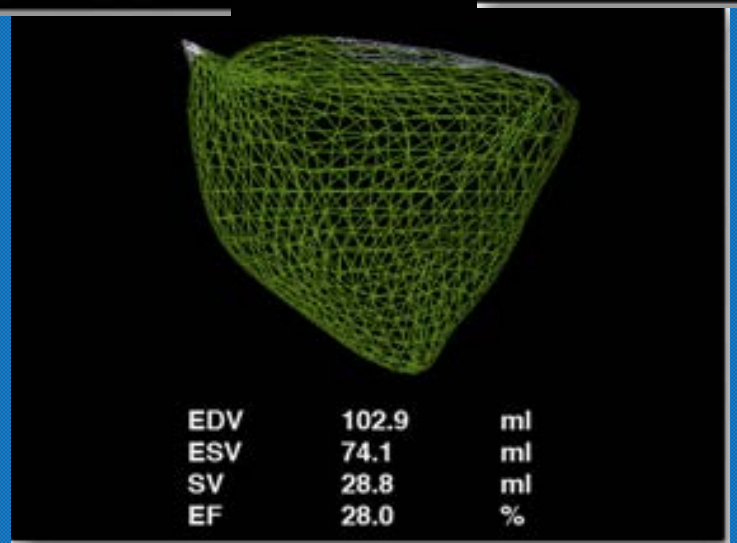
Limitations:

- Depends on adequate image quality
- Requires offline analysis and experience
- Prognostic value not established

RV SYSTOLIC FUNCTION: 3D RV Ejection Fraction







Recommendations:

- 3D echocardiography RV EF may be reported.
- lower reference limit of 45%
- reserve 3D methods for serial volume and EF determinations.

RV SYSTOLIC FUNCTION: RV Strain and Strain Rate

- Strain = percentage change in myocardial deformation
- Strain rate = rate of deformation of myocardium over time.
- Strain rate has been closely correlated with myocardial contractility in vitro and in vivo

- DTI-derived Strain
- Speckle tracking Echo (STE) derived strain – angle independent

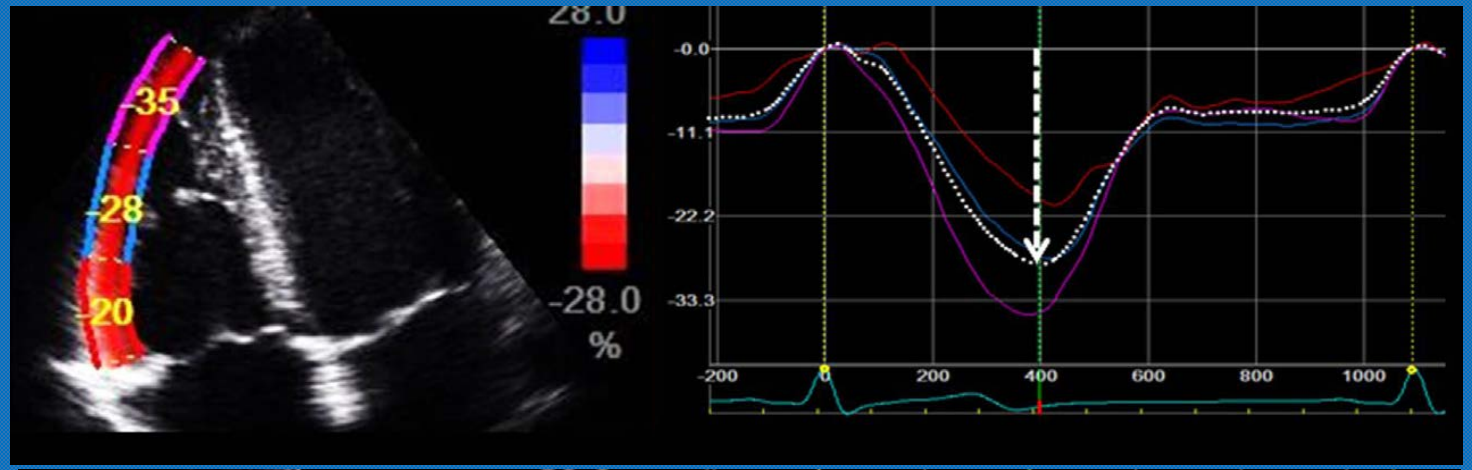
- Global Longitudinal Strain

Jamal F, Bergerot C, Argaud L, Loufouat J, Ovize M. Longitudinal strain quantitates regional right ventricular contractile function. Am J Physiol Heart Circ Physiol 2003;285:H2842-7.

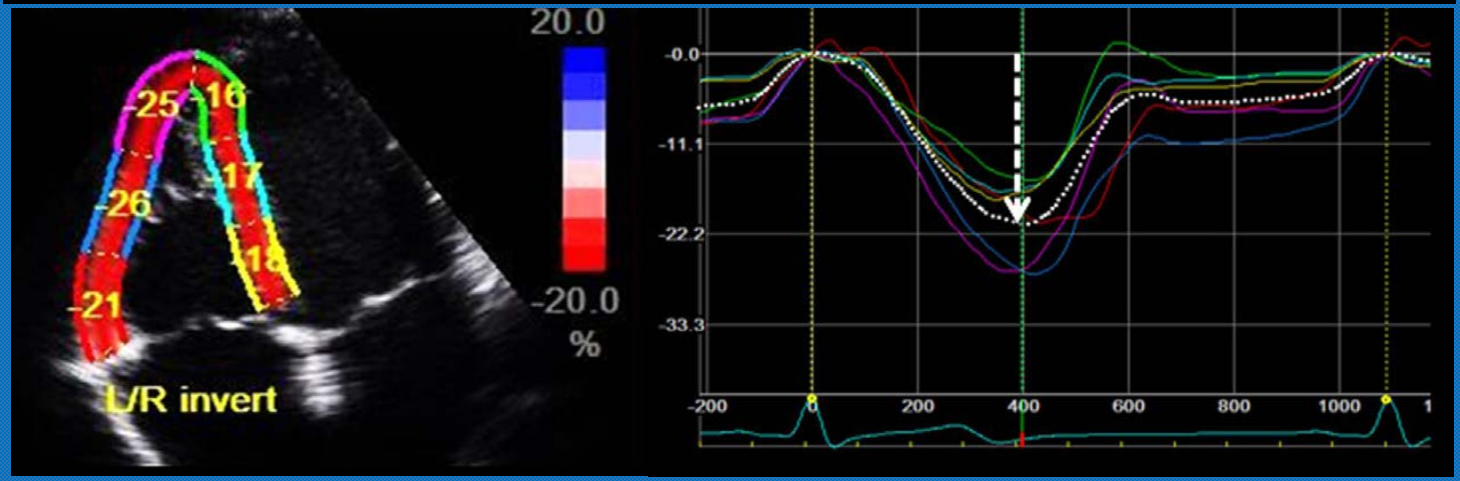
RV Systolic Function:
Right Ventricular Global Longitudinal Strain

Speckle tracking Echocardiography

Average strain
RV Free wall segments



Average strain
RV Free wall and septal segments



RV SYSTOLIC FUNCTION: RV Global Longitudinal Strain and - 2d Speckle Tracking

Advantages:

- relatively angle independent
- possesses an improved signal-to-noise ratio.
- provide regional function estimates, as well as a more ‘‘global’’ function.

Disadvantages:

- lack of normative data and need additional validation.
- different algorithms in different platforms may result in different normal ranges.

RV SYSTOLIC FUNCTION: RV Strain and Strain Rate

Recommendations:

- Because of the lack of reproducibility and the paucity of data, this technique is not recommended for routine clinical use.
- No reference limits can be recommended, because of the large degree of variability.

Rudski et al. Guidelines for the echo assessment of the Right Heart in Adult . JASE 2010;23:685-713

Recommendation for the evaluation of RV systolic function

- Visual assessment of RV systolic function gives an initial qualitative evaluation of RV systolic function but remains insufficient
- Simple and reproducible methods of assessing RV systolic function should be incorporated into the routine echocardiographic assessment. (FAC, TAPSE, pulsed tissue Doppler S', and MPI).
- Combining more than one measure of RV function, such as S' and MPI, may more reliably distinguish normal from abnormal function.

Rudski et al. Guidelines for the echo assessment of the Right Heart in Adult . JASE 2010;23:685-713

Miller D, Farah MG, Liner A, Fox K et al. J Am Soc Echocardiogr 2004;17:443-7.

Recommendation for the evaluation of RV systolic function

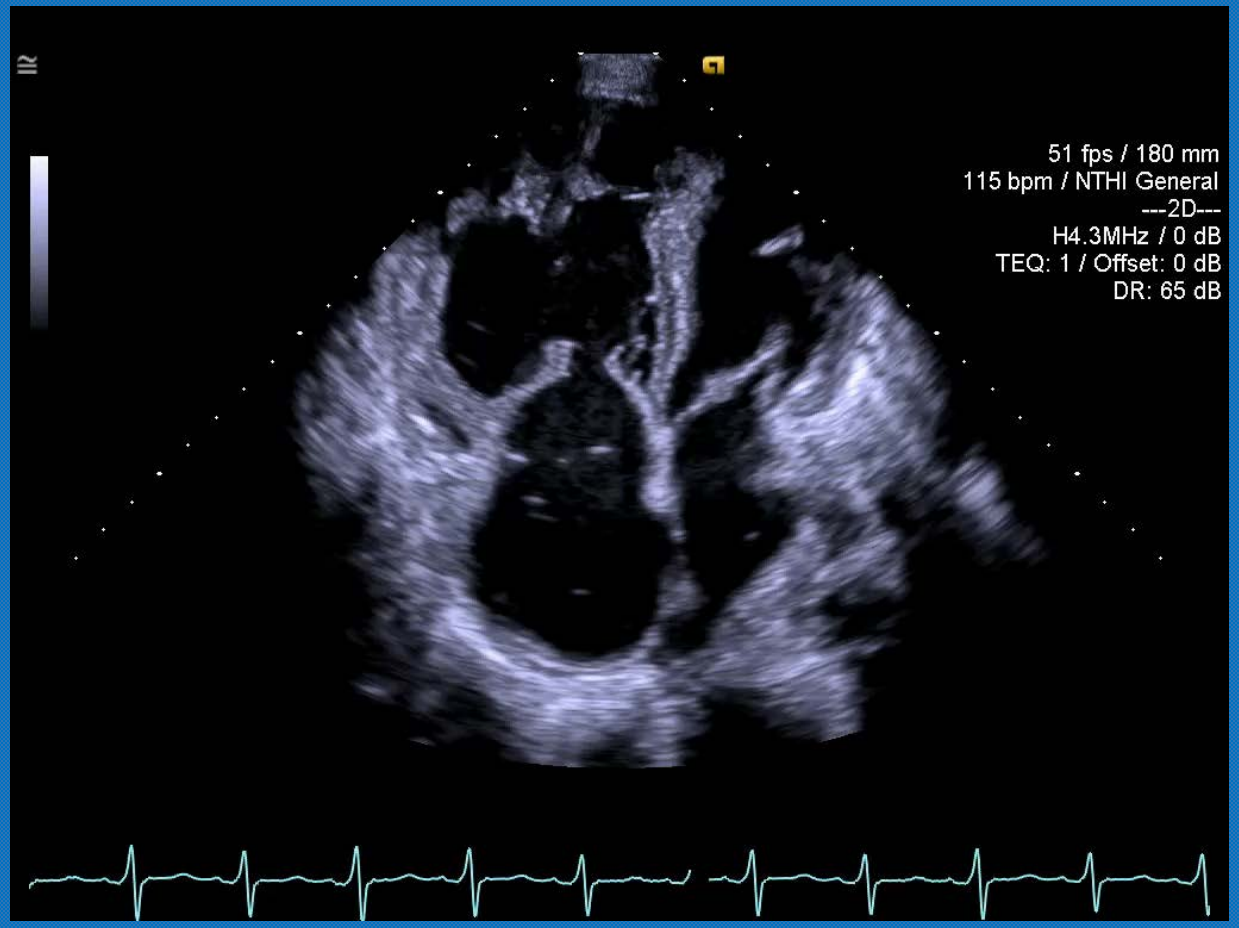
- At least one of the above quantitative measures be incorporated into the routine echocardiographic examination and report
  - when RV dysfunction is suspected
  - when the clinical indication for the study relates to a condition that may affect the right ventricle.
- Techniques such as strain, and strain rate are not currently recommended as routine and are best reserved for specific clinical and research applications.

Rudski et al. Guidelines for the echo assessment of the Right Heart in Adult . JASE 2010;23:685-713

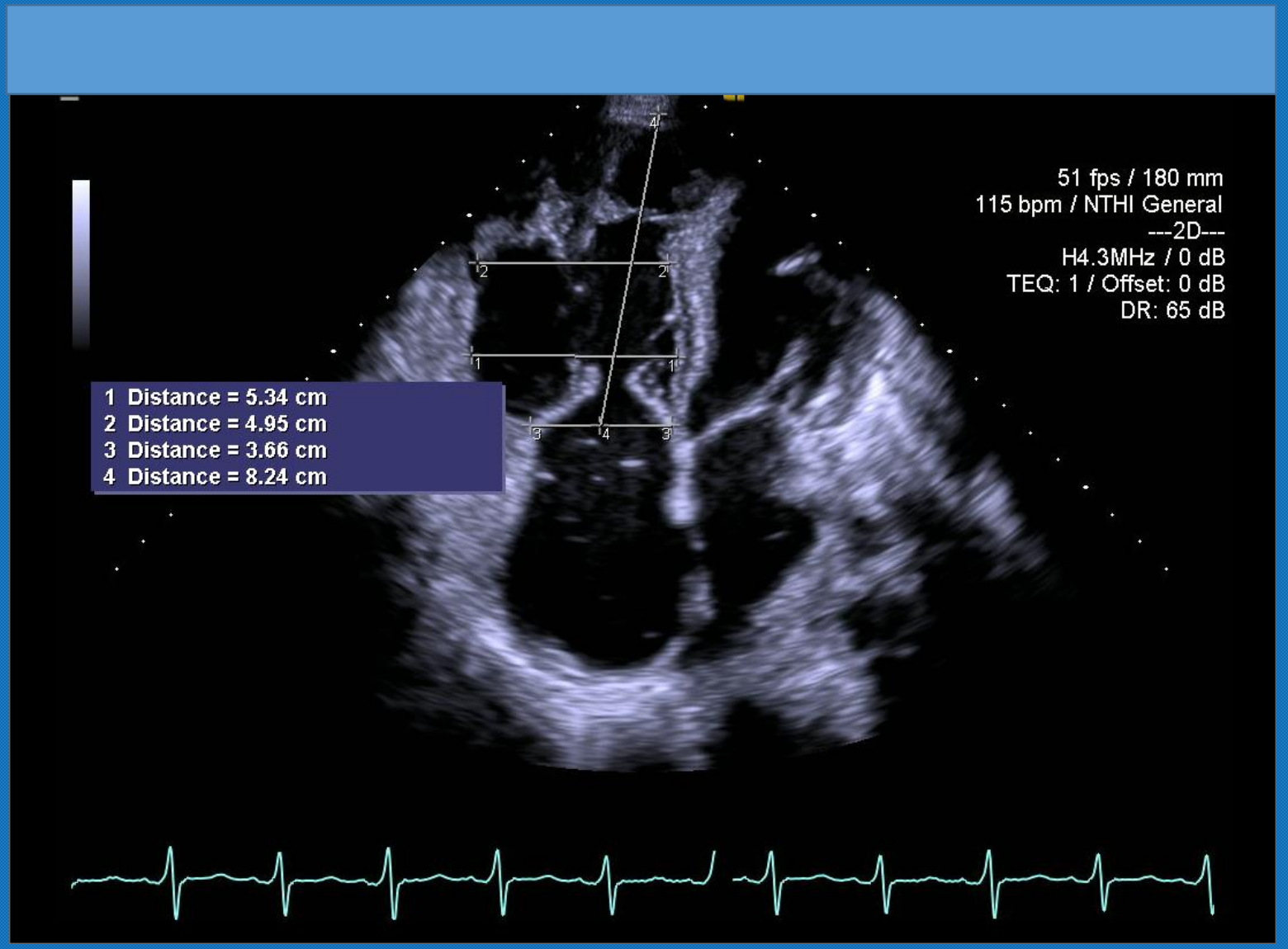
Miller D, Farah MG, Liner A, Fox K et al. J Am Soc Echocardiogr 2004;17:443-7.

Case

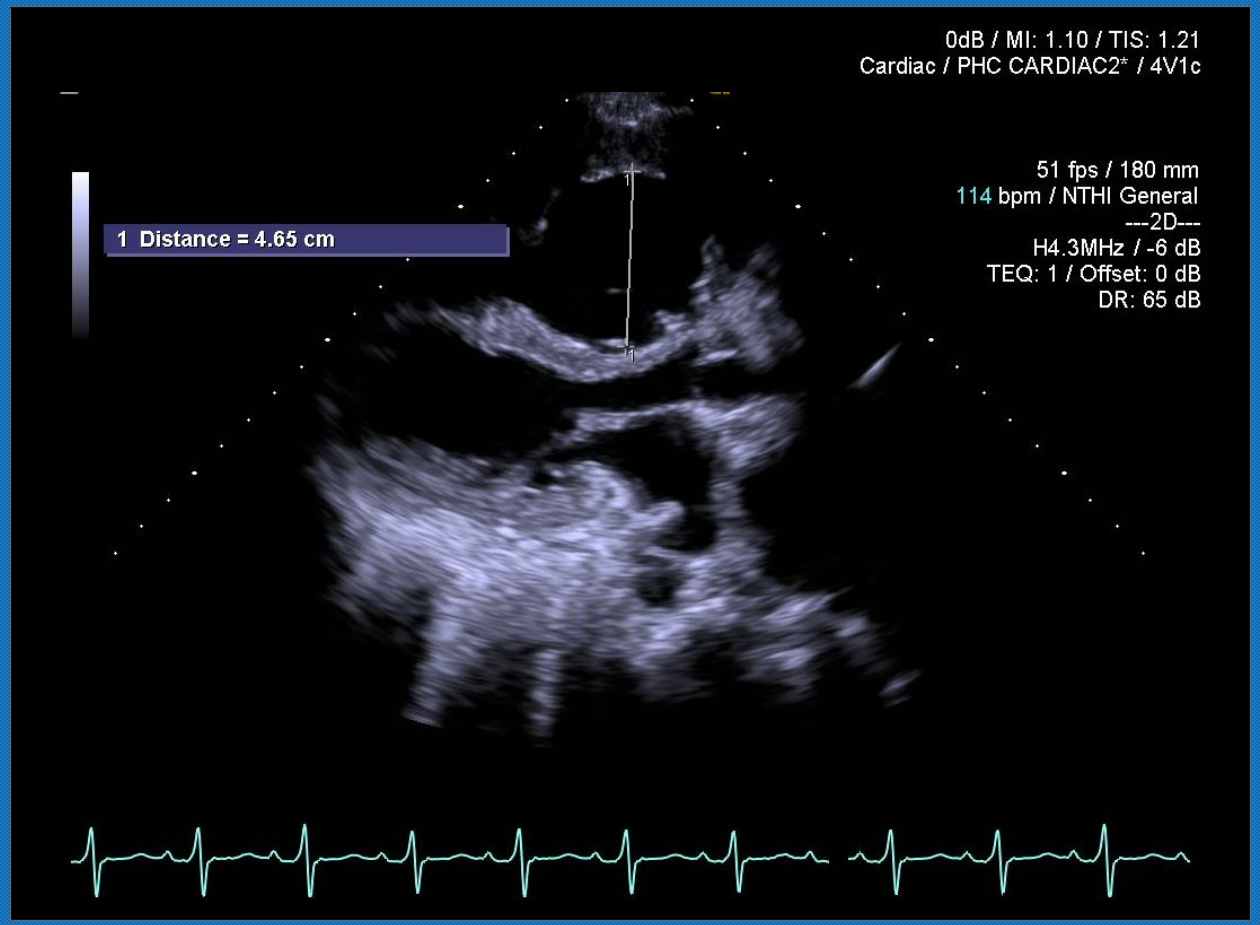
Smoker
Easy fatigability
No orthopnea
Bipedal edema

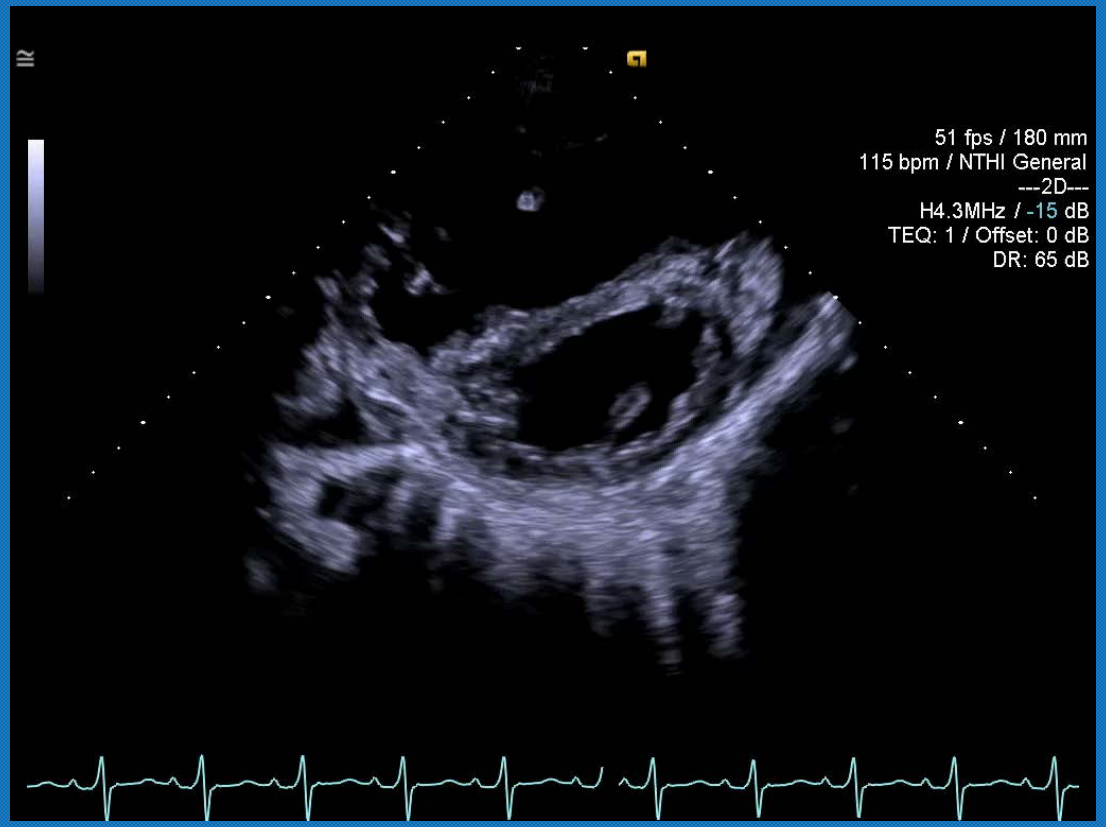


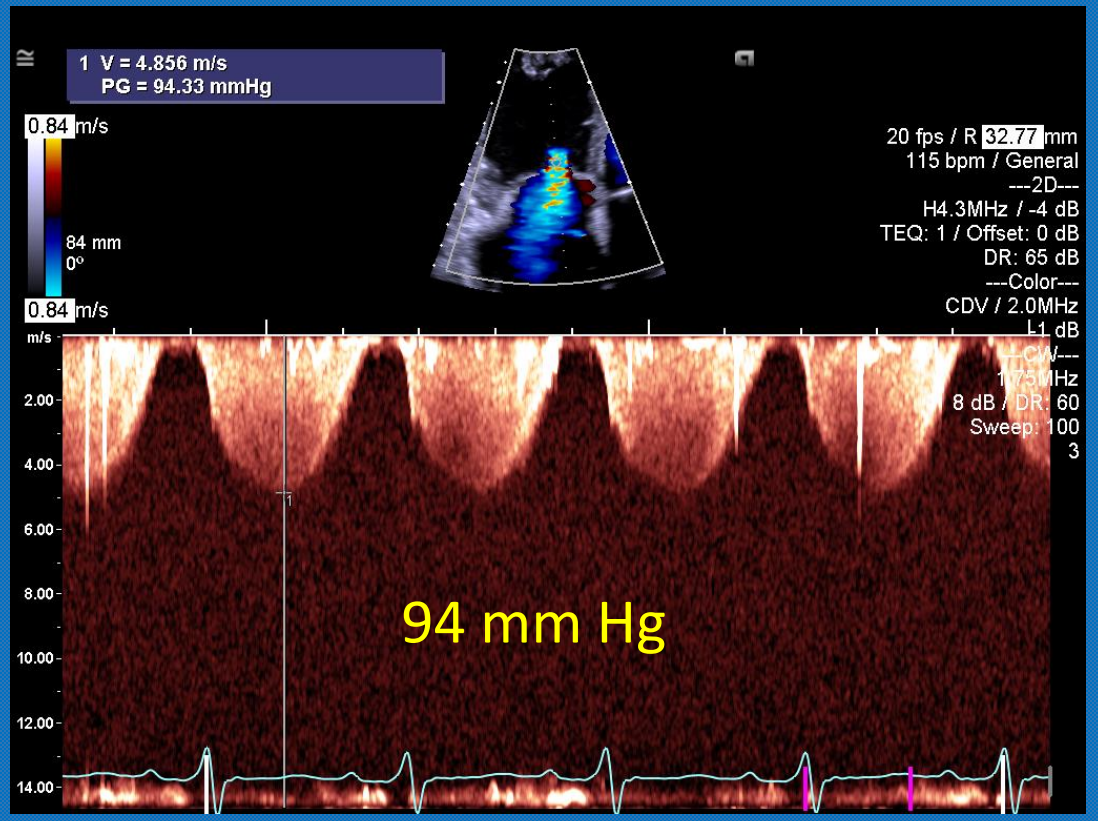
RV Linear Dimensions



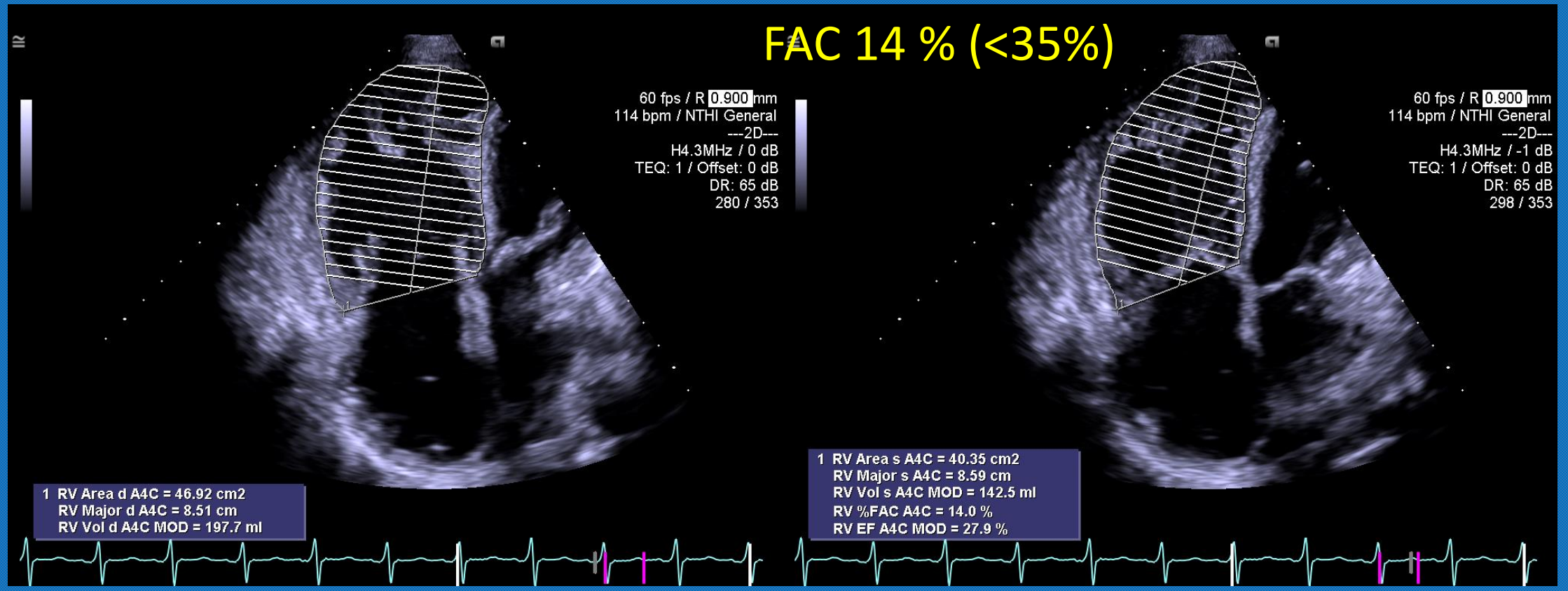
RV LINEAR DIMENSIONS



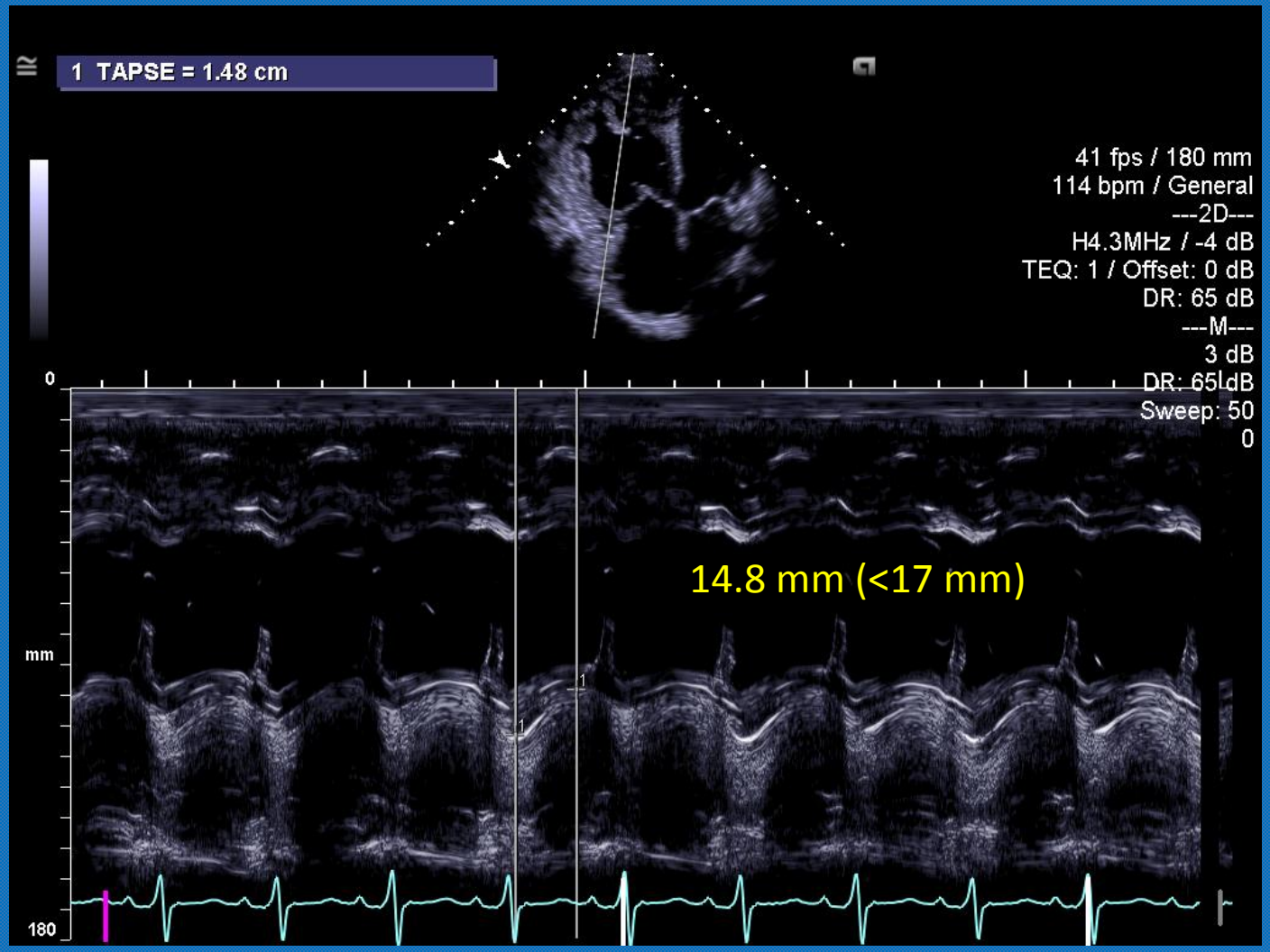

51 fps / 180 mm
115 bpm / NTHI General
---2D---
H4.3MHz / -15 dB
TEQ: 1 / Offset: 0 dB
DR: 65 dB


1 V = 4.856 m/s
PG = 94.33 mmHg
0.84 m/s
84 mm
0°
0.84 m/s
20 fps / R 32.77 mm
115 bpm / General
---2D---
H4.3MHz / -4 dB
TEQ: 1 / Offset: 0 dB
DR: 65 dB
---Color---
CDV / 2.0MHz
L1 dB
---CW---
1.75MHz
8 dB / DR: 60
Sweep: 100
3
m/s
2.00
4.00
6.00
8.00
10.00
12.00
14.00
94 mm Hg

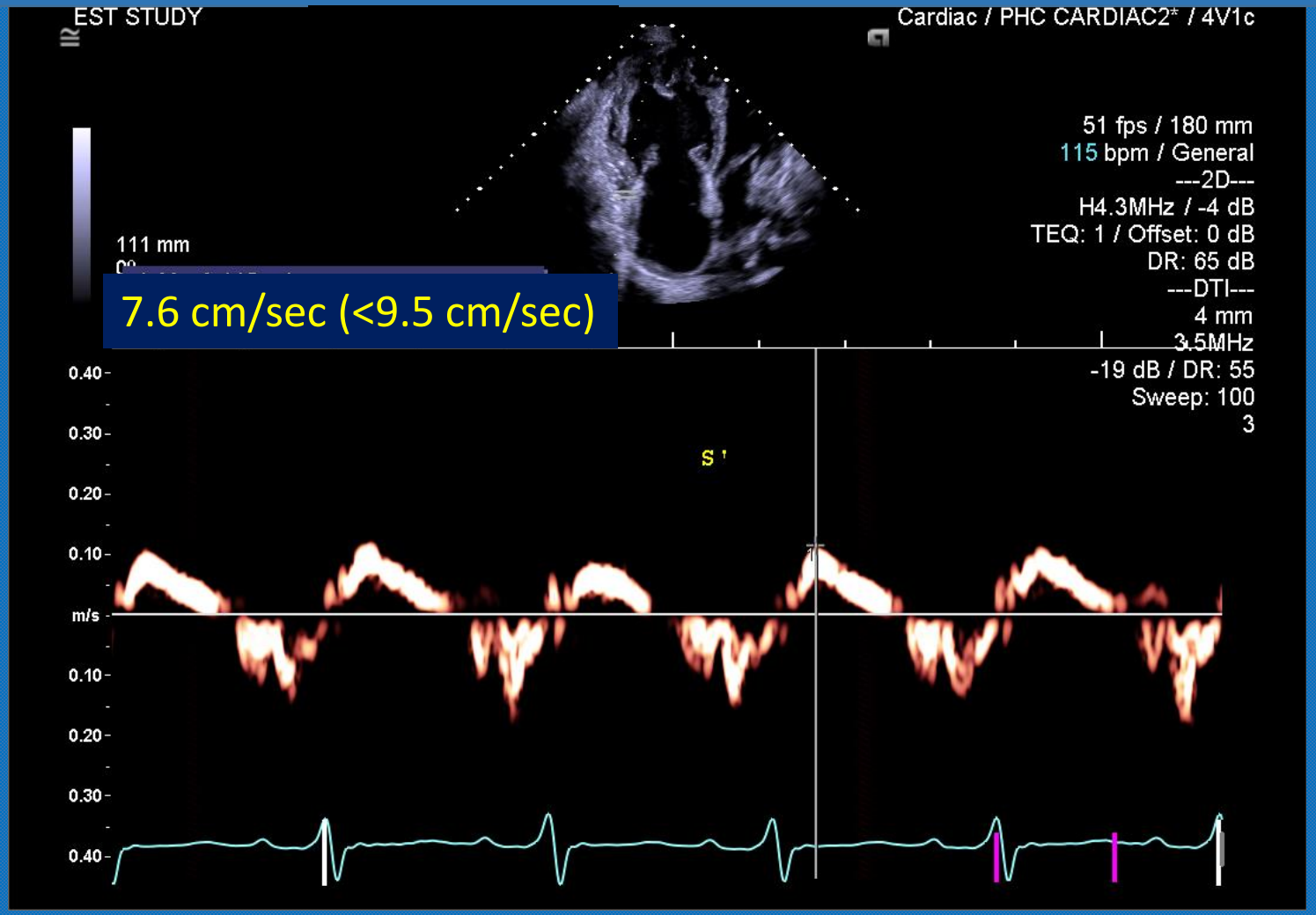
RV FRACTIONAL AREA CHANGE



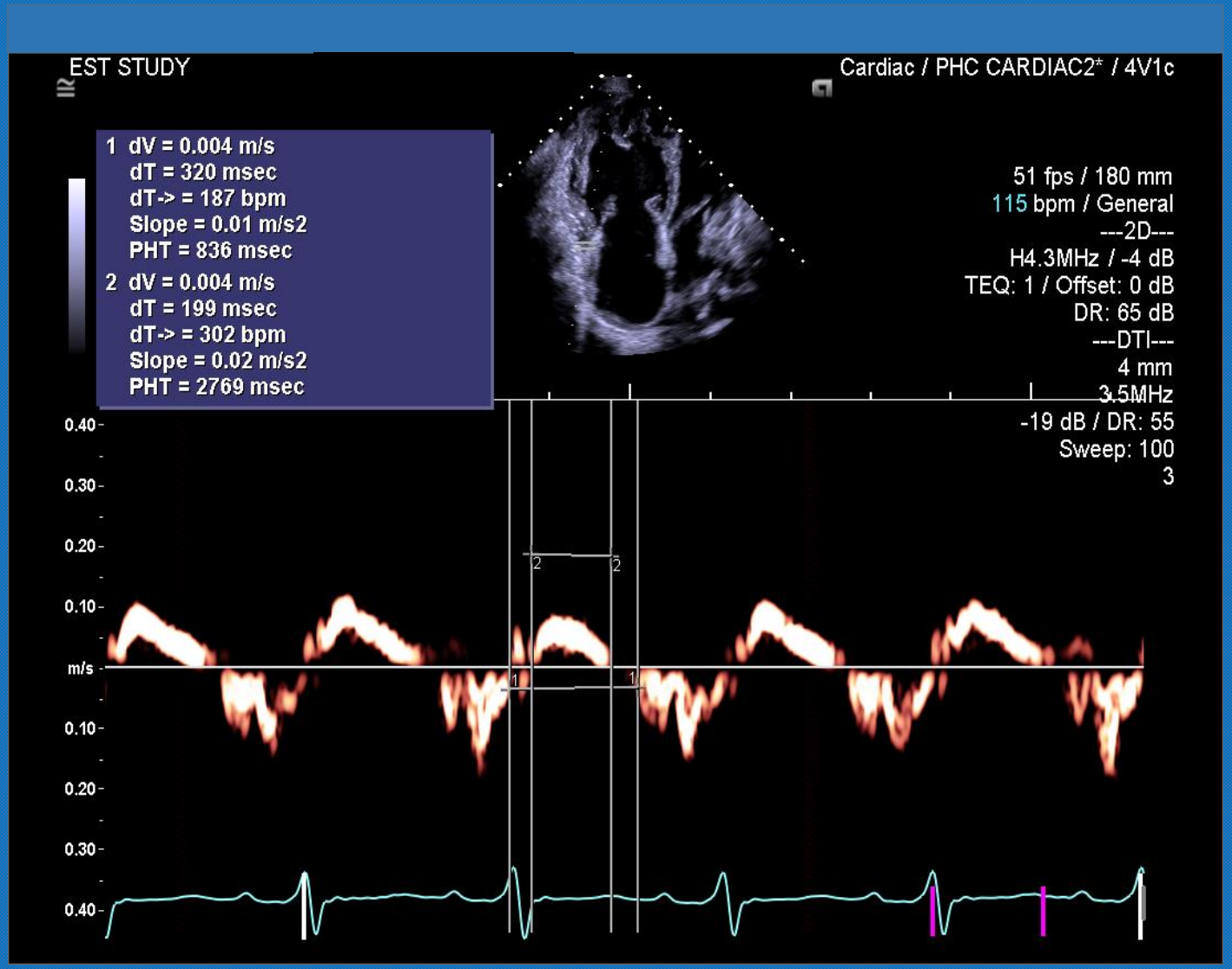
TAPSE


1 TAPSE = 1.48 cm
41 fps / 180 mm
114 bpm / General
---2D---
H4.3MHz / -4 dB
TEQ: 1 / Offset: 0 dB
DR: 65 dB
---M---
3 dB
DR: 65dB
Sweep: 50
0
0
mm
180
14.8 mm (<17 mm)

Tricuspid Annulus Systolic Velocity (S')



RIMP (Pulse Tissue Doppler Method)

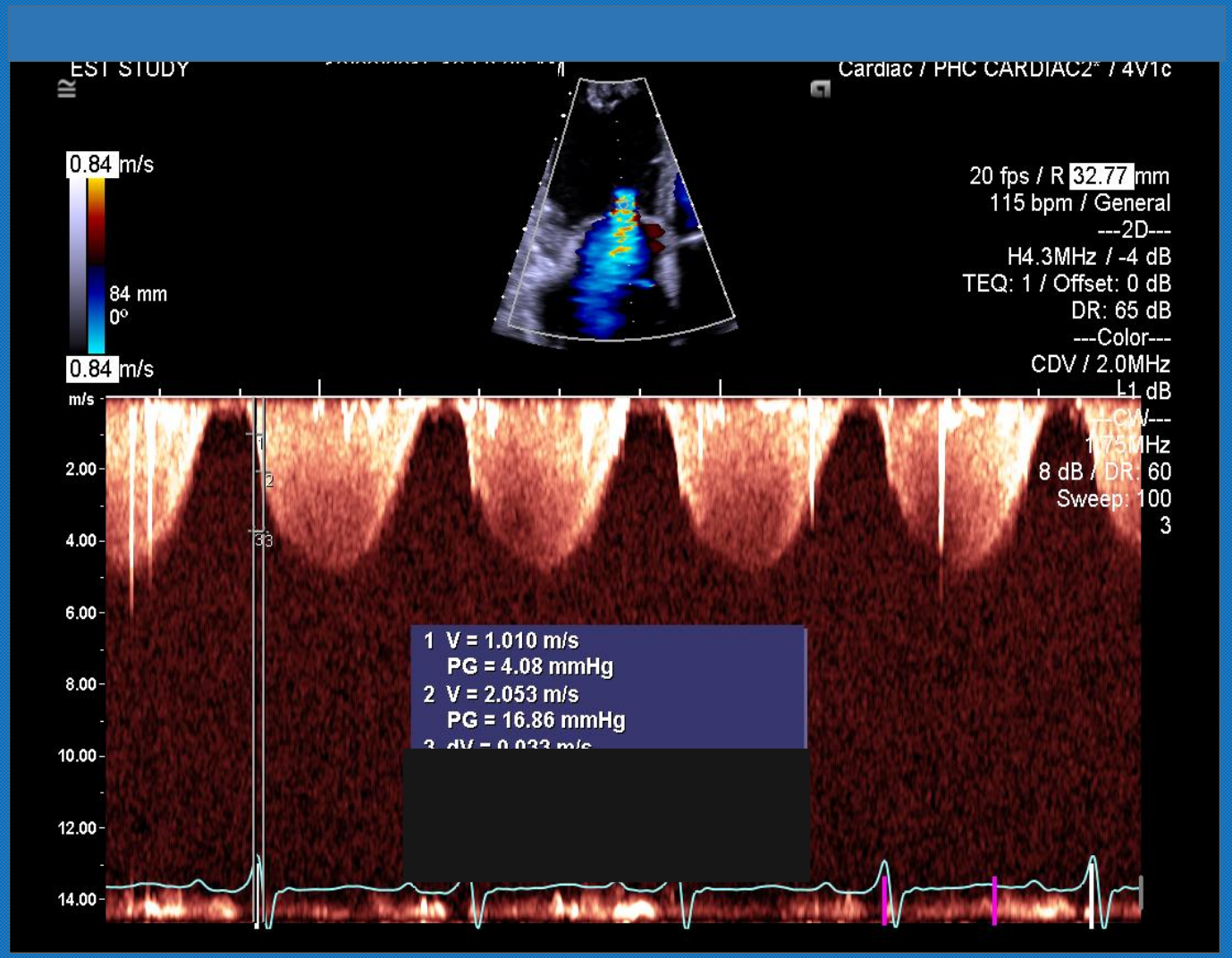


(TCO – ET) / ET

=(320msec – 199msec)/199msec

=0.60 *(>0.54)*

RV dP/dT

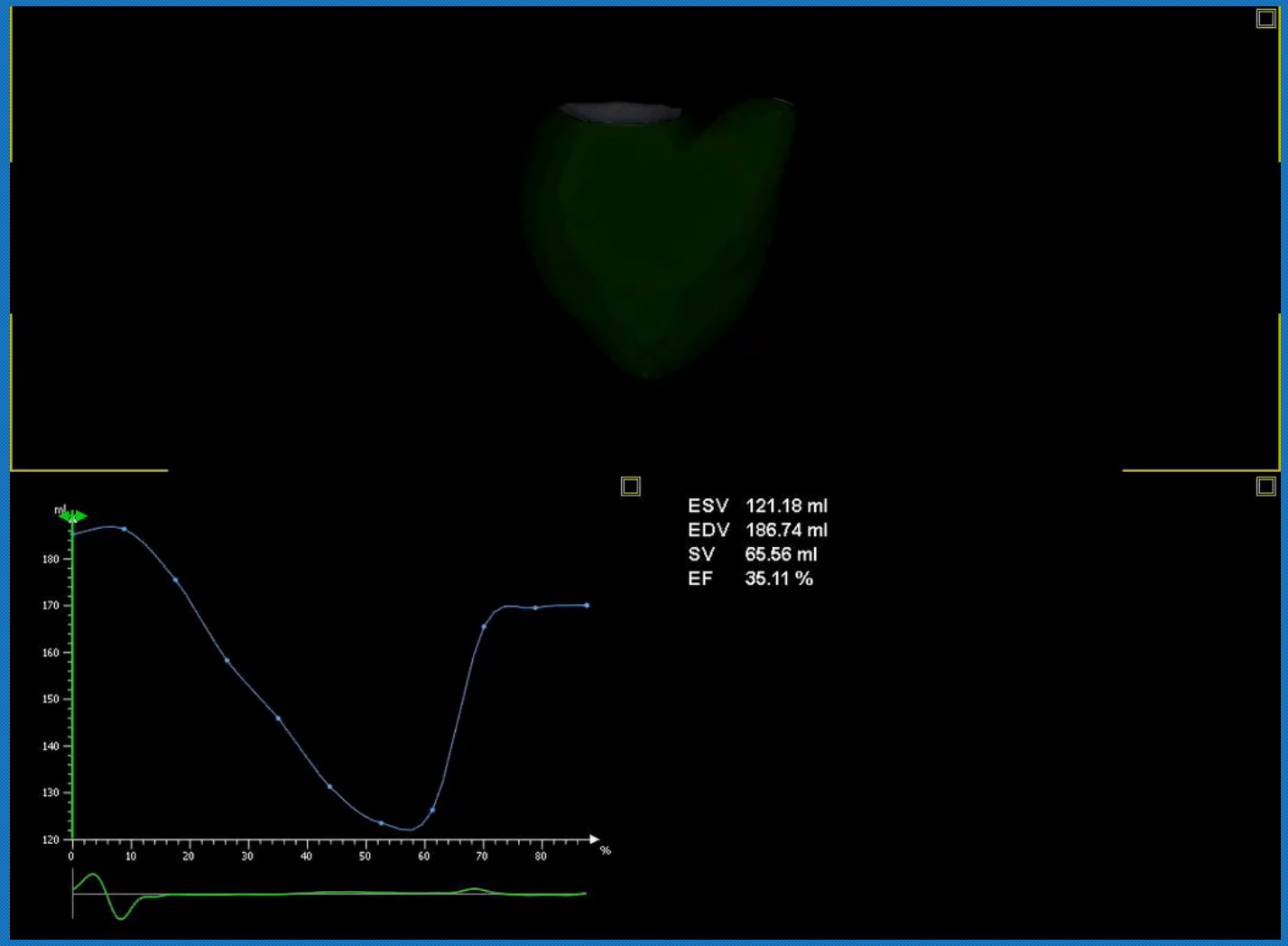


dP = 16 - 4 = 12mmHg

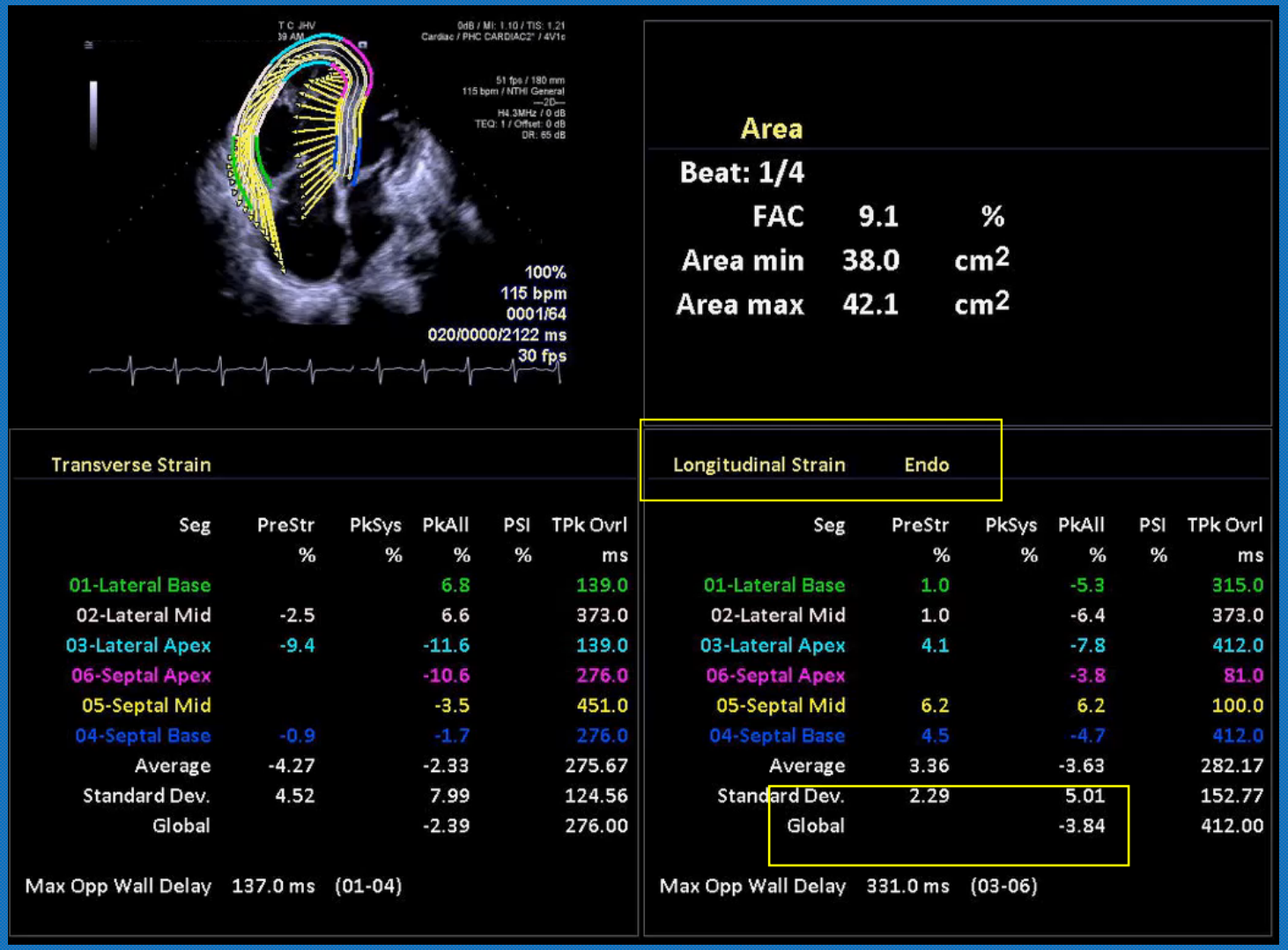
dT = 36msec

dP/dT = 0.333 mmHg/msec
= 333mmHg/sec
(<400mmHg/sec)

3D RVEF


ml
180
170
160
150
140
130
120
0
10
20
30
40
50
60
70
80
%
ESV 121.18 ml
EDV 186.74 ml
SV 65.56 ml
EF 35.11 %

RV GLOBAL LONGITUDINAL STRAIN

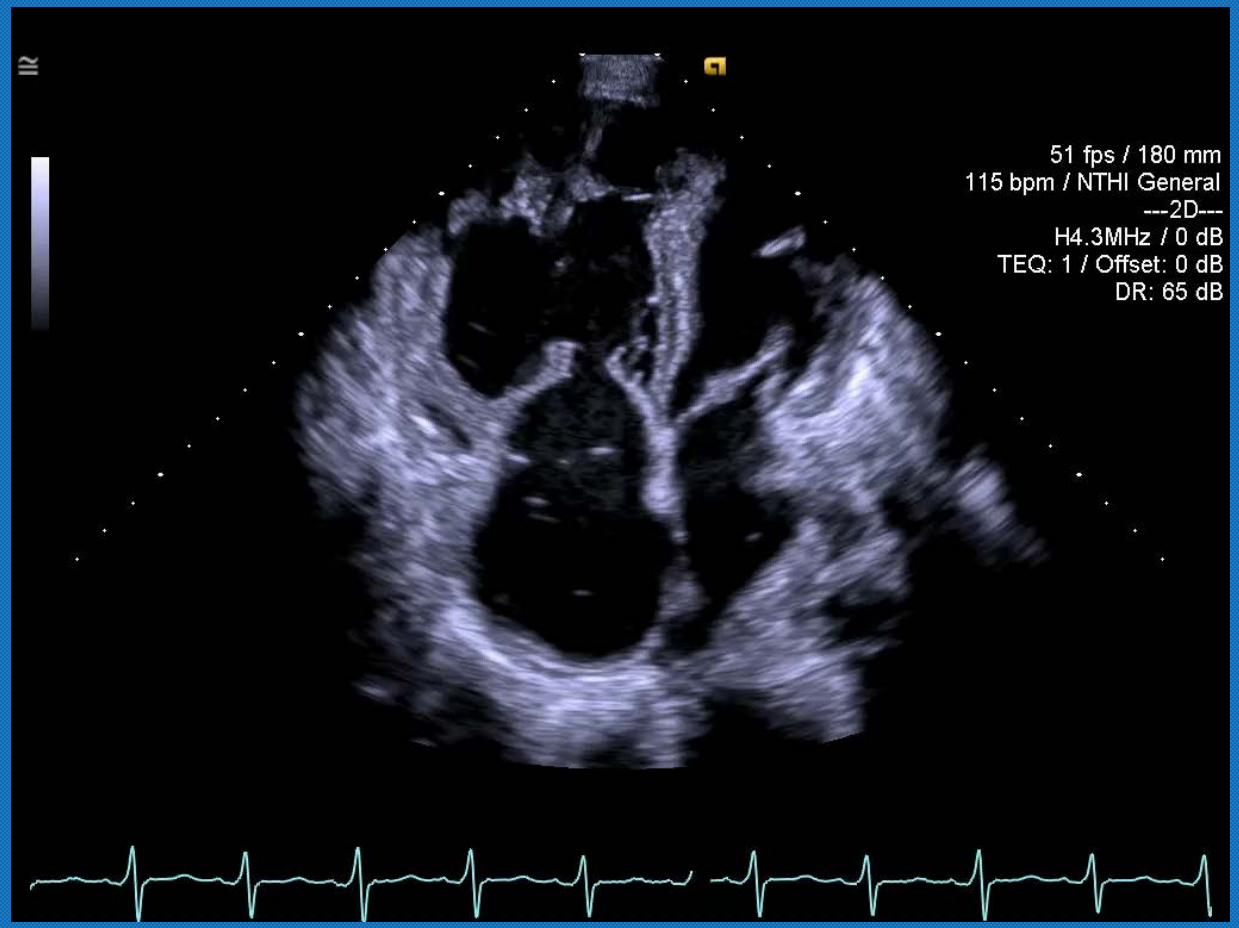


-3.8%

Case

Smoker
Easy fatigability
No orthopnea
Bipedal edema

DILATED HYPERTROPHIED RV
RIGHT VENTRICULAR SYSTOLIC DYSFUNCTION
SEVERE PULMONARY HYPERTENSION



THANK YOU