Chamber Quantitation Guidelines - Update II

Right Heart Measurements

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I have no relevant financial relationships to disclose

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I. What to Measure; How to measure

II. Importance of RV Function

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 Afilo, 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

J Am Soc Echocardiogr 2010;23(7):685-713

asecho.org

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):1-39

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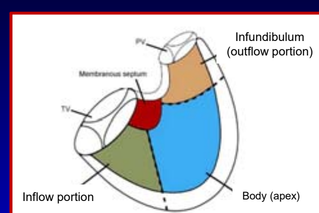
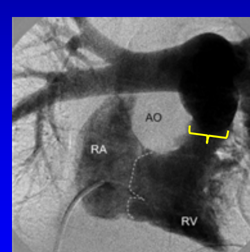
The RV is Challenging

- Close to chest wall
- Nongeometric shape
- Determining RV-focused view
- RV foreshortening
- Endocardial border definition
- Interrelationship with the LV
- Sensitivity to loading conditions





I. What to Measure How to Measure

Imaging the Right Heart:

Views, Anatomy, Normal Values

Imaging the Right Ventricle
Use Multiple Acoustic Windows

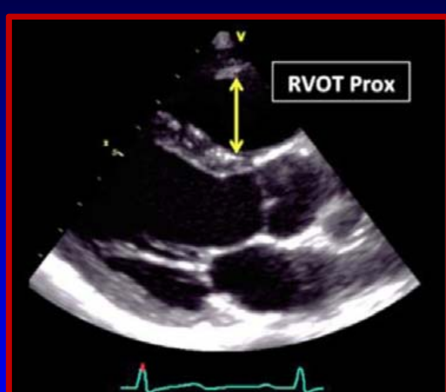
- Apical 4-chamber view
- RV-focused apical 4-chamber view
- Parasternal long axis view
- Parasternal short-axis view
- RV inflow view

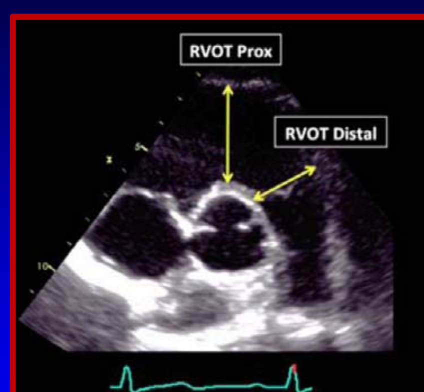
Right Ventricle
Parameters to Perform and Report

- Measure of RV size
- Measure of RA size
- RV systolic function (at least one of following)
  - Fractional area change (FAC)
  - TDI S'
  - Tricuspid annular plane systolic excursion (TAPSE)
- With/without RV index of myocardial performance
- Systolic pulmonary artery pressure
- Estimate of RA pressure (based on IVC)

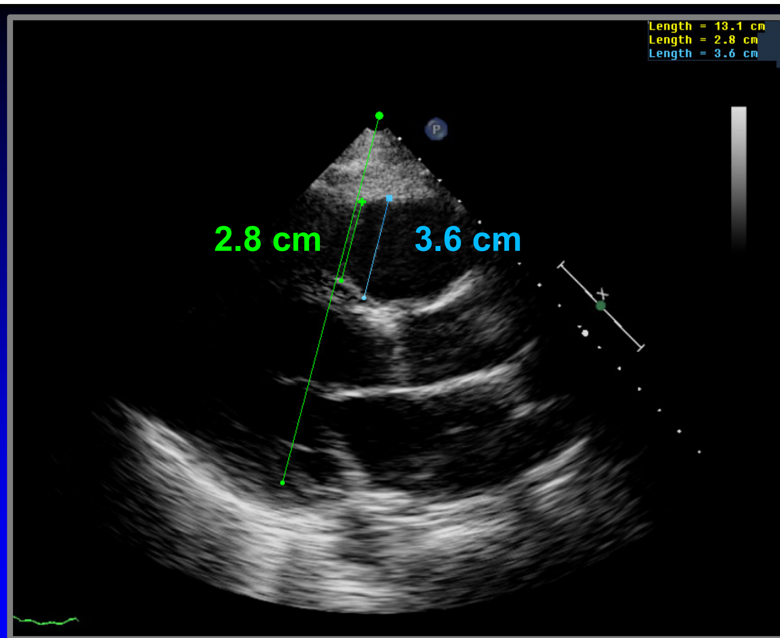
RV Size

Measuring RV Size



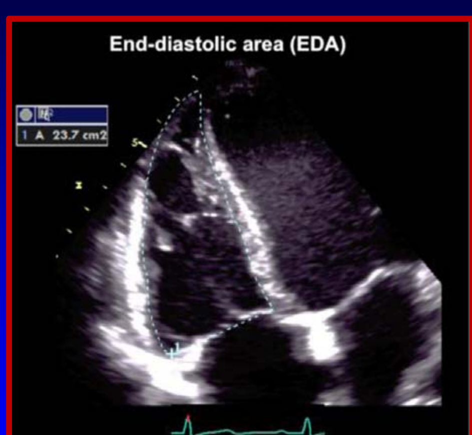


J Am Soc Echocardiogr 2015;28(1):1-39 **asecho.org**



2 measurements - 2.8 cm and 3.6 cm

Measuring RV Size



Challenging/Limitations

- Endocardial border definition (image quality)
- Trabeculations
- Foreshortening
- May not reflect global size

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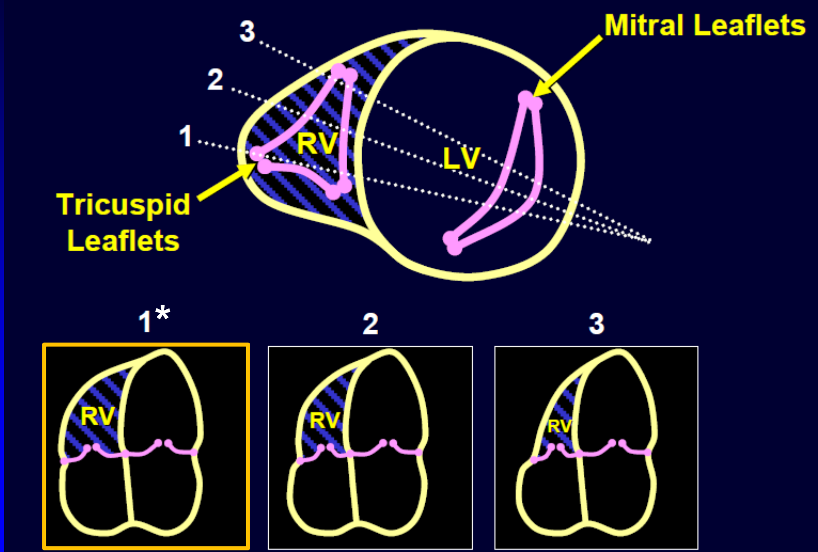
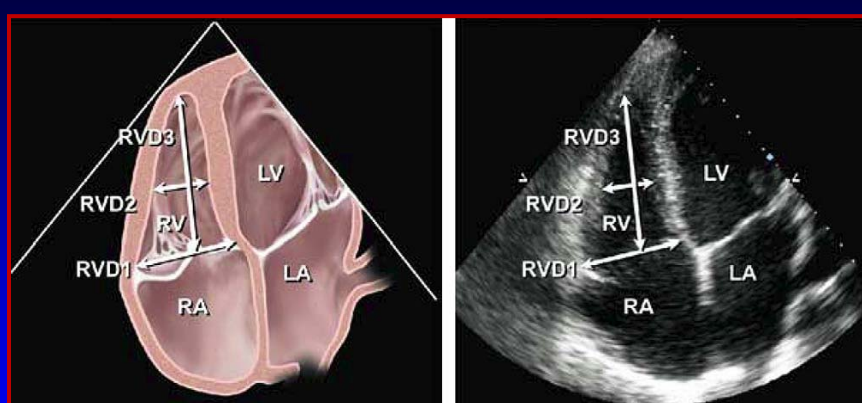
RV VOLUME BY 2D … which A4C view ?



Rudsky et al, J Am Soc Echocardiogr 2010;23:685

2D Echocardiography



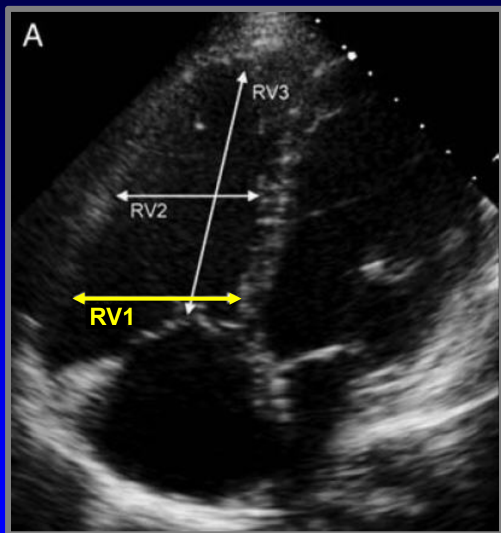
RV EDD basal: 24-42 mm → now 25-41 mm

RV EDD mid: 20-35 mm

RV EDD long: 56-86 mm

Rudsky et al, J Am Soc Echocardiogr 2010;23:685

Measurement of RV Dimensions



Longitudinal dimension (RV3)
(from middle of TV to RV apex)

Midcavitary dimension (RV2)
(middle third of the RV at the papillary muscle level)

Basal dimension (RV1)
(maximal dimension of the RV in the basal 1/3 of RV)

Table 8 Normal values for RV chamber size

Parameter	Mean ± SD	Normal range
RV basal diameter (mm)	33 ± 4	25-41
RV mid diameter (mm)	27 ± 4	19-35
RV longitudinal diameter (mm)	71 ± 6	59-83
RVOT PLAX diameter (mm)	25 ± 2.5	20-30
RVOT proximal diameter (mm)	28 ± 3.5	21-35
RVOT distal diameter (mm)	22 ± 2.5	17-27
RV wall thickness (mm)	3 ± 1	1-5
RVOT EDA (cm^2)		
Men	17 ± 3.5	10-24
Women	14 ± 3	8-20
RV EDA indexed to BSA (cm^2/m^2)		
Men	8.8 ± 1.9	5-12.6
Women	8.0 ± 1.75	4.5-11.5
RV ESA (cm^2)		
Men	9 ± 3	3-15
Women	7 ± 2	3-11
RV ESA indexed to BSA (cm^2/m^2)		
Men	4.7 ± 1.35	2.0-7.4
Women	4.0 ± 1.2	1.6-6.4
RV EDV indexed to BSA (mL/m^2)		
Men	61 ± 13	35-87
Women	53 ± 10.5	32-74
RV ESV indexed to BSA (mL/m^2)		
Men	27 ± 8.5	10-44
Women	22 ± 7	8-36

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

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Right Ventricle-Focused View

- Adjust from usual focus on LV
- Rotate tsdr until max plane obtained
- Aim to see RV lateral wall

RV Basal Diameter

	Studies	n	LRV (95% CI)	Mean (95% CI)	URV (95% CI)
2010	10	376	24 (21-27)	33 ± 2	**42** (39-45)
2015	12	695		33 ± 4	**41** (25-41)

LRV – lower reference value
URV – upper reference value

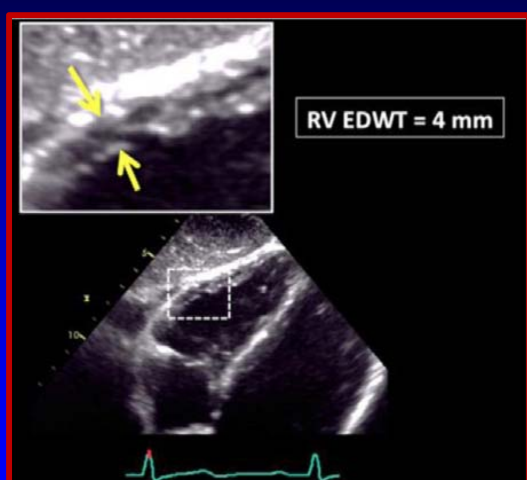
Rudski J Am Soc Echocardiogr 2010;23:685-713
Lang J Am Soc Echocardiogr 2015;28:1-35

RV Size - Reference Values (cm)

	Ref Range	Mildly Abnl	Mod Abnl	Severely Abnl
RV dimensions				
Basal RV diameter	2.0–2.8	**2.9–3.3**	3.4–3.8	≥3.9
Mid-RV diameter	2.7–3.3	**3.4–3.7**	3.8–4.1	≥4.2
Base-to-apex length	7.1–7.9	8.0–8.5	8.6–9.1	≥9.2
RVOT diameters				
Above aortic valve	2.5–2.9	3.0–3.2	3.3–3.5	≥3.6
Above pulm valve	1.7–2.3	2.4–2.7	2.8–3.1	≥3.2

Foale Br Heart J 56:33(1986) → 41 "normal" adults (age 19–46; $\overline{32}$ yrs)

RV-Focused View



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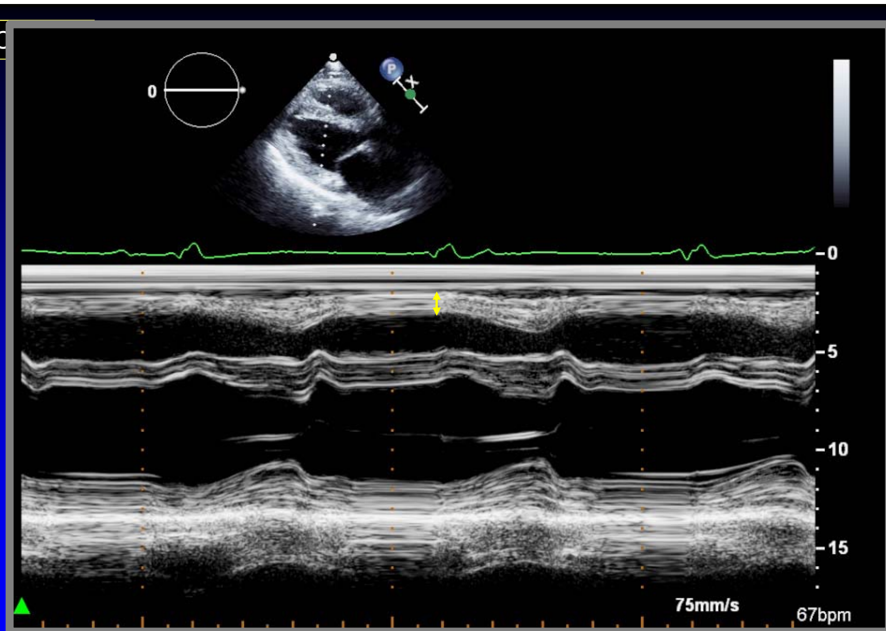


RV thickness = 1 cm

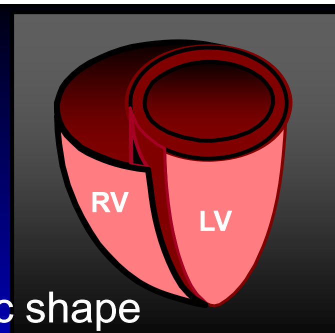
RV Function

Functions of LV and RV ARE Different

RV **LV**

Low pressure system
< 1/10 resistance to flow of systemic bed

RV Physiology



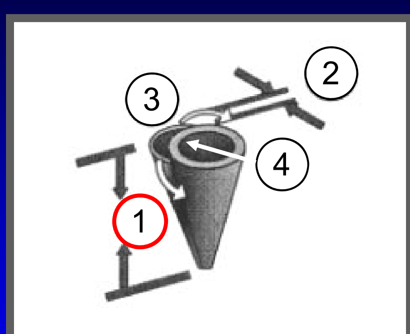
- Thin free wall and crescentic shape impart high degree of compliance
- Ability to accommodate large volumes
- Low vascular impedance of pulm circul’n
  (PVR ≈ 1/10 SVR)

Right Ventricular Physiology

- RV suited to eject across low resistance of the pulmonary circuit
- Performs at a lower dP/dt than the LV
- RV wall motion not like LV:
  - LV → all walls and base move more or less equally toward the center
  - RV → base-to-apex shortening more pronounced
- RV ejection is a complex mechanism

RV Ejection is Complex

Several Components



1. **Contraction along long-axis** (TV toward apex) ++++
2. Inward movement of RV free wall ++
3. Bulging of septum into RV chamber +
4. Circumferential contraction of RV outflow tract +

Visual assessment of RV function is inadequate

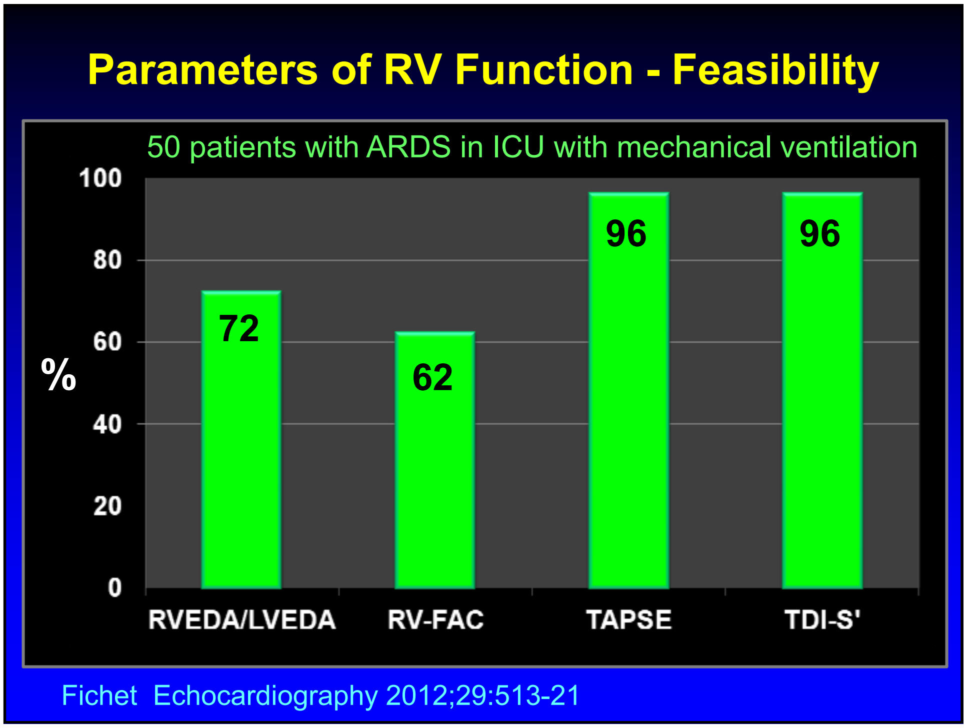
RV Systolic Function
Echo Methods of Assessing

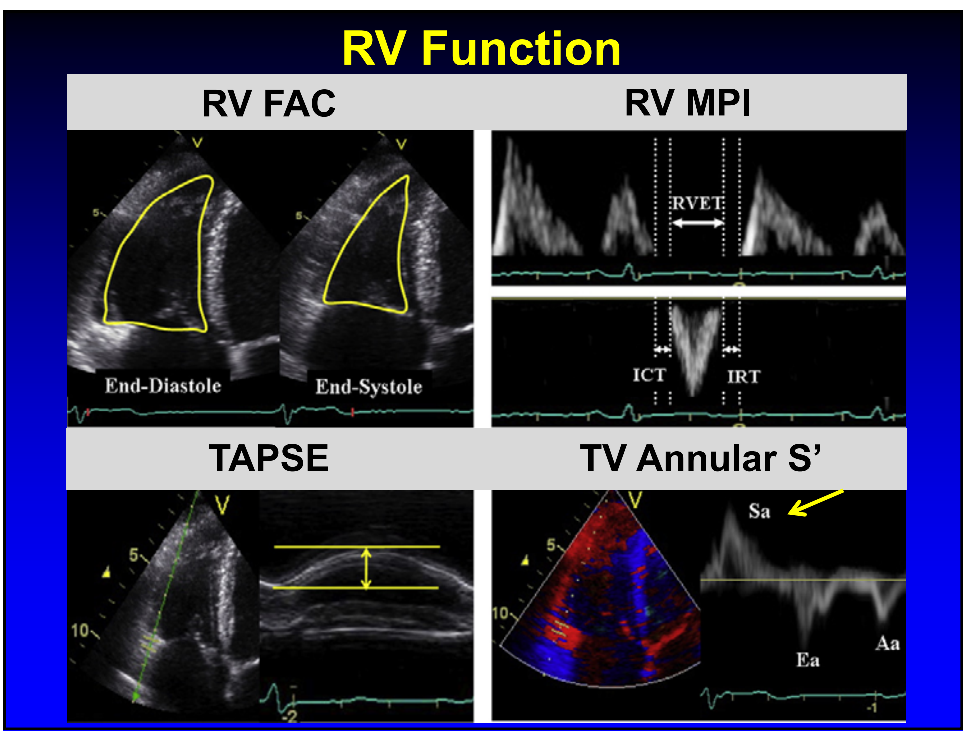
- Visual assessment ("gestalt")
- Fractional area shortening
- **TAPSE**
- **Tissue Doppler imaging of RV free wall (S')**
- Tei index
- RV dP/dt from TR signal
- RV strain and strain rate
- RV acceleration time

TAPSE

RV Contraction

- Predominantly longitudinal shortening
- RV outflow tract plays minor role
- Twisting and rotational movements do not contribute significantly

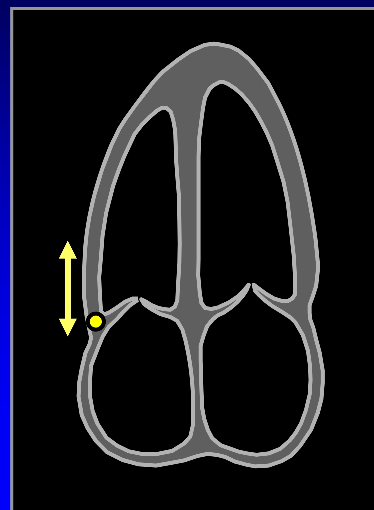

Parameters of RV Function - Feasibility
50 patients with ARDS in ICU with mechanical ventilation
100
80
60
40
20
0
%
72
62
96
96
RVEDA/LVEDA
RV-FAC
TAPSE
TDI-S'
Fichet Echocardiography 2012;29:513-21


RV Function
RV FAC
RV MPI
End-Diastole
End-Systole
RVET
ICT
IRT
TAPSE
TV Annular S'
Sa
Ea
Aa

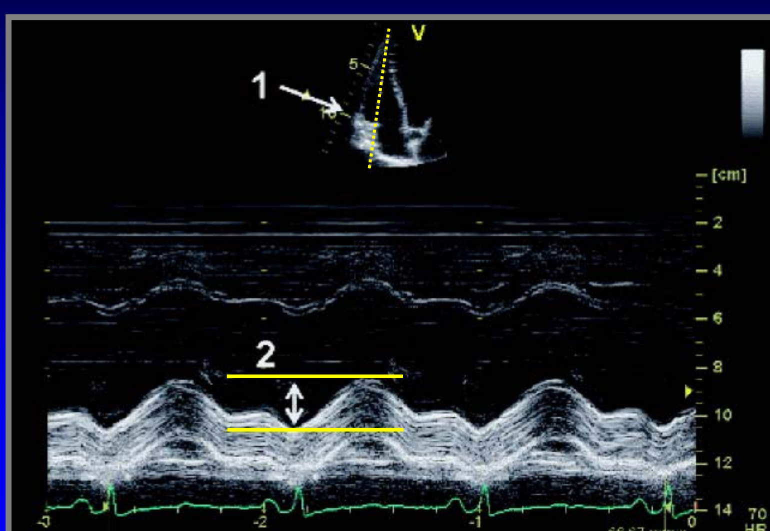
RV Function

Tricuspid Annular Plane Systolic Excursion

- Descent of RV base toward relatively fixed apex
- Represents function of longitudinal muscles
- Apical 4-chamber view
- 2D-echo and TEE



Tricuspid Annular Plane Systolic Excursion (TAPSE)

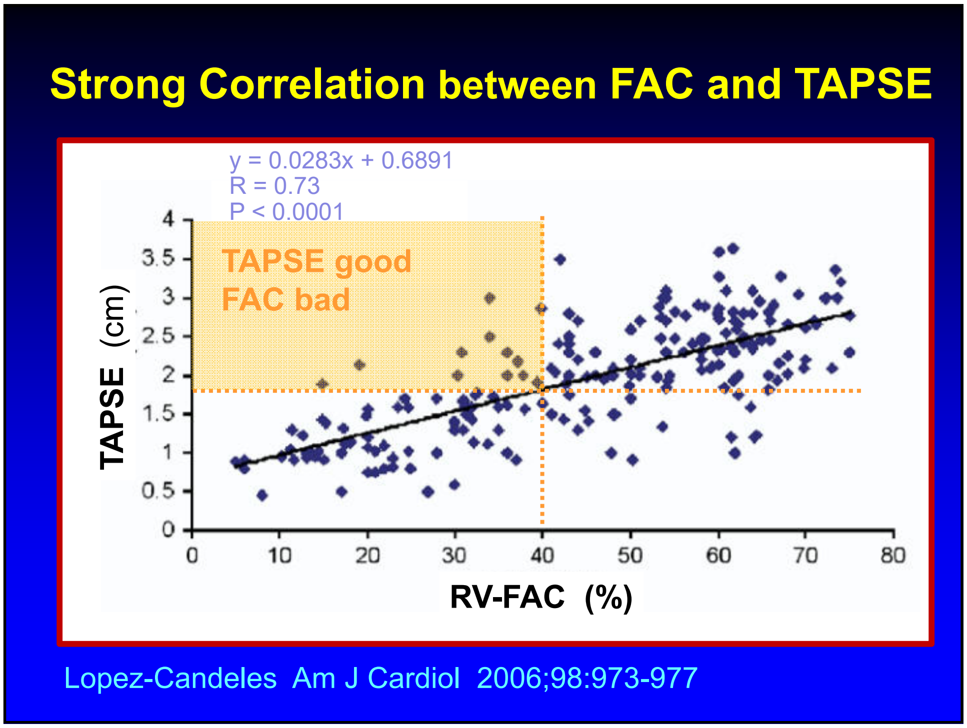


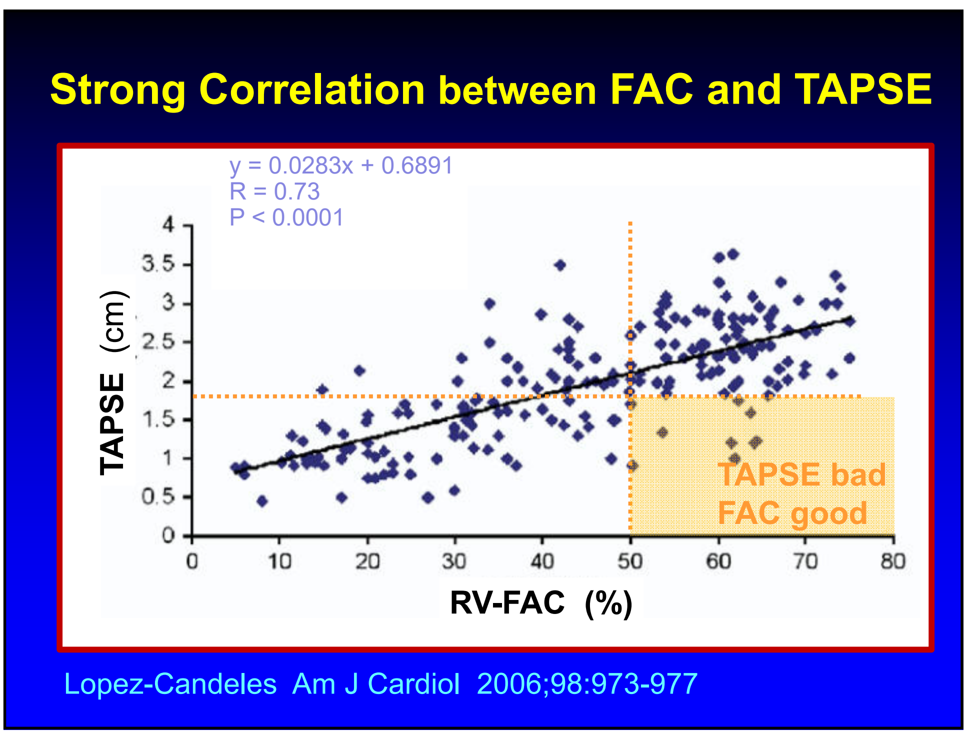
Advantages of TAPSE

- Highly feasible and easy
- Highly reproducible
- Numerical
- Not affected by dropout or trabeculations
- Reflects longitudinal RV shortening

TAPSE - Limitations

- Angle dependency
- Atrial fibrillation → ↓TAPSE; → NSR ↑TAPSE
- Patients on ventilators
- Highly dependent on RV loading conditions (may become pseudo-normailzed)
- Ventricular interdependence


Strong Correlation between FAC and TAPSE
y = 0.0283x + 0.6891
R = 0.73
P < 0.0001
TAPSE good
FAC bad
TAPSE (cm)
RV-FAC (%)
Lopez-Candeles Am J Cardiol 2006;98:973-977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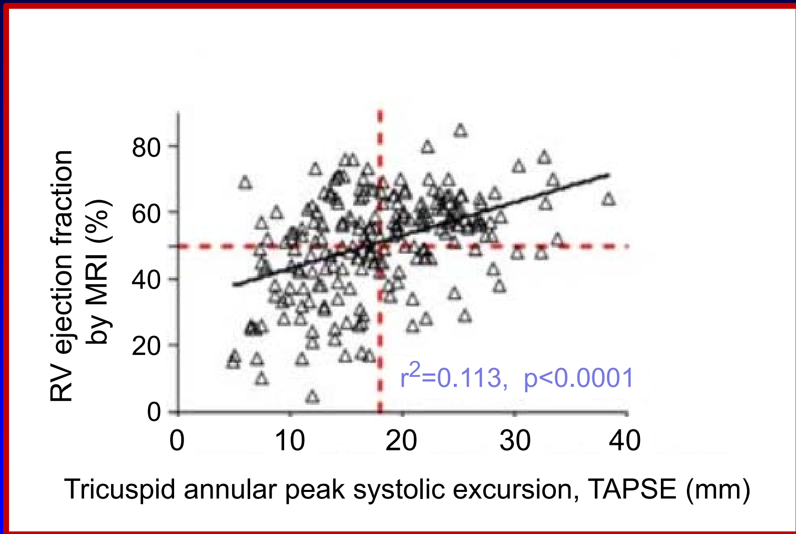
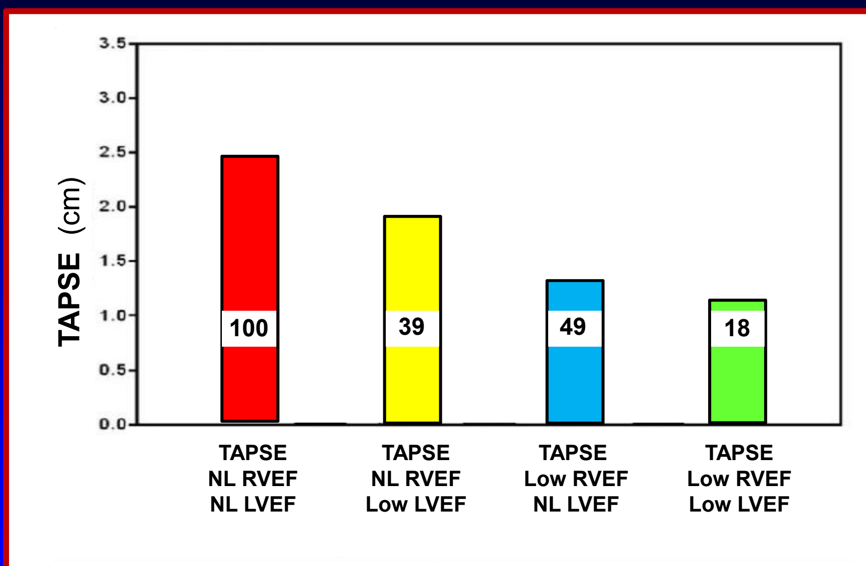
y = 0.0283x + 0.6891
R = 0.73
P < 0.0001
TAPSE bad
FAC good
TAPSE (cm)
RV-FAC (%)
Lopez-Candeles Am J Cardiol 2006;98:973-977

Correlation between RV EF (CMR) and TAPSE (Echo)



Pavlicek Eur J Echocardiogr 2011;12:871-80

RVF Is Not the Sole Determinant of TAPSE



Lopez-Candeles Am J Cardiol 2006;98:973-977

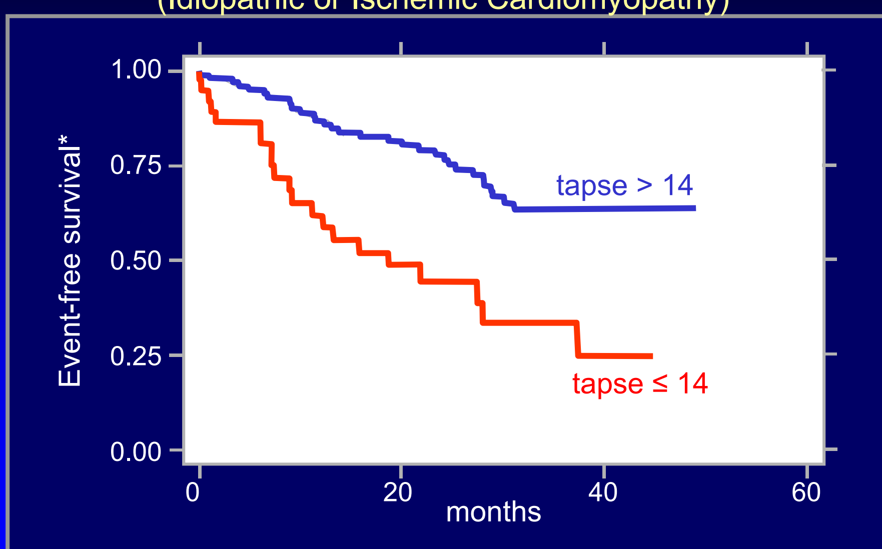
Recommended Measures of RV Function
Summary of Reference Limits (2015)

Variable	Abnormal
TAPSE	**<1.7 cm**
Pulsed Doppler peak velocity (S') (at the annulus)	<9.5 cm/s
Pulsed Doppler MPI	>0.43
Tissue Doppler MPI	>0.54
FAC	<35 %

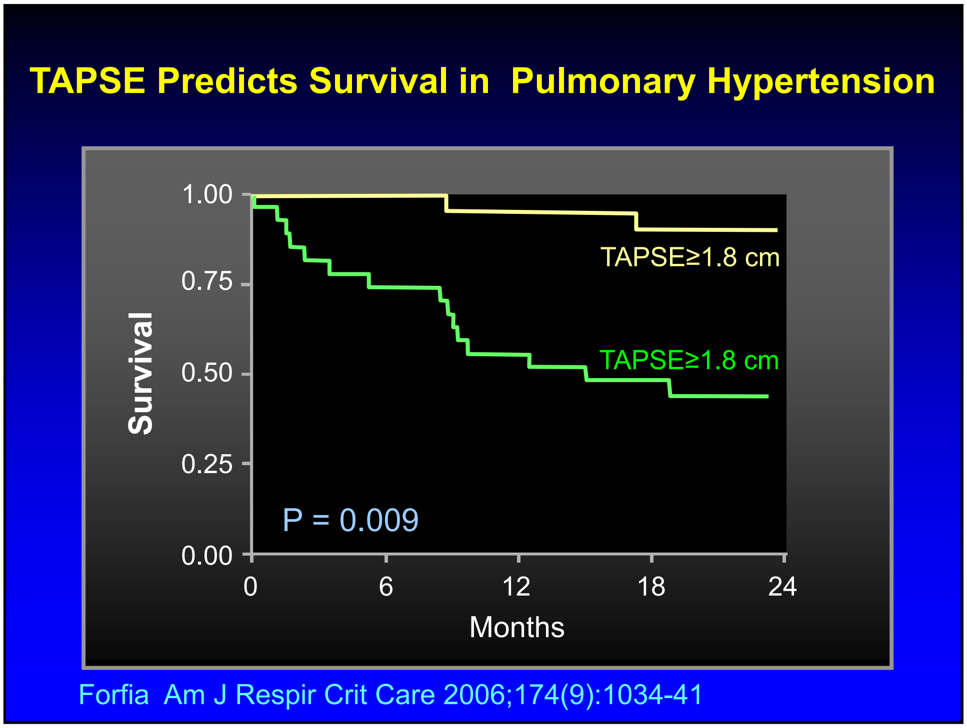
MPI = myocardial performance index

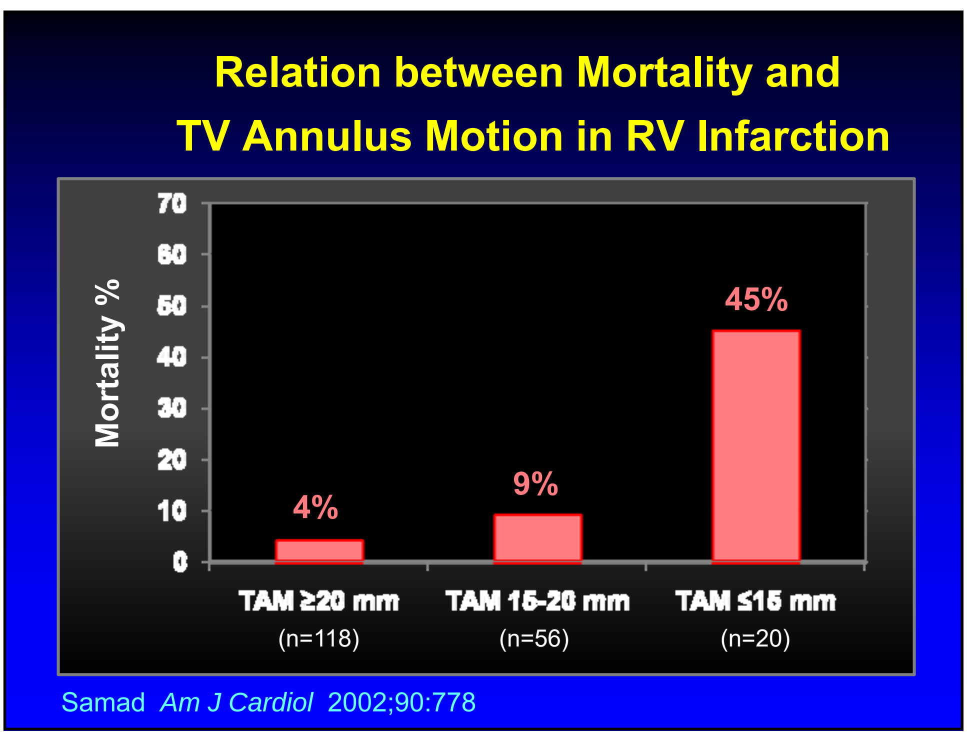
Prognostic Value of TAPSE in CHF

(Idiopathic or Ischemic Cardiomyopathy)



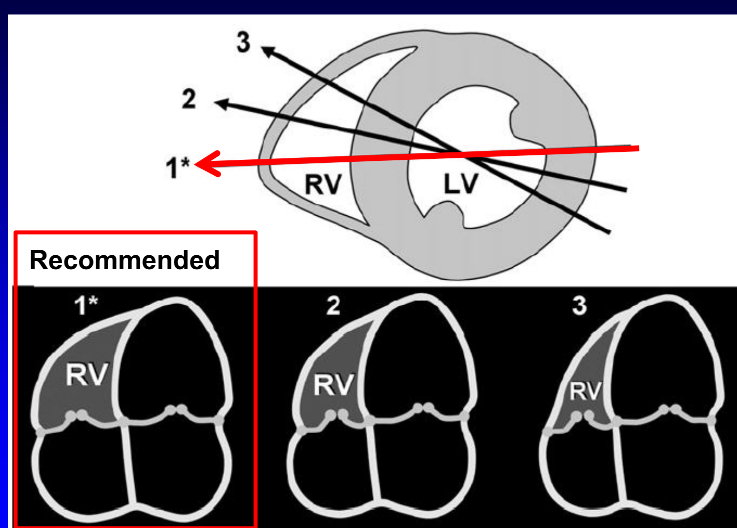
Ghio Am J Cardiol 2000;85:837-42 * death or emergency transplantation


TAPSE Predicts Survival in Pulmonary Hypertension
1.00
0.75
0.50
0.25
0.00
Survival
TAPSE≥1.8 cm
TAPSE≥1.8 cm
P = 0.009
0
6
12
18
24
Months
Forfia Am J Respir Crit Care 2006;174(9):1034-41


Relation between Mortality and
TV Annulus Motion in RV Infarction
Mortality %
70
60
50
40
30
20
10
0
4%
9%
45%
TAM ≥20 mm
(n=118)
TAM 15-20 mm
(n=56)
TAM ≤15 mm
(n=20)
Samad Am J Cardiol 2002;90:778

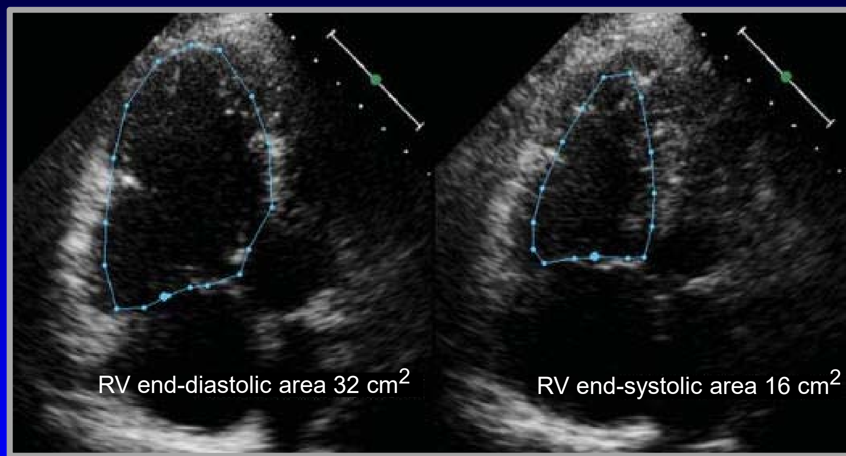
FAC

Recommended Apical 4-Chamber View (1*)



Sensitivity of RV size to angular change

RV Fractional Area Change



$$FAC = \frac{32 - 16}{32} = 50\%$$

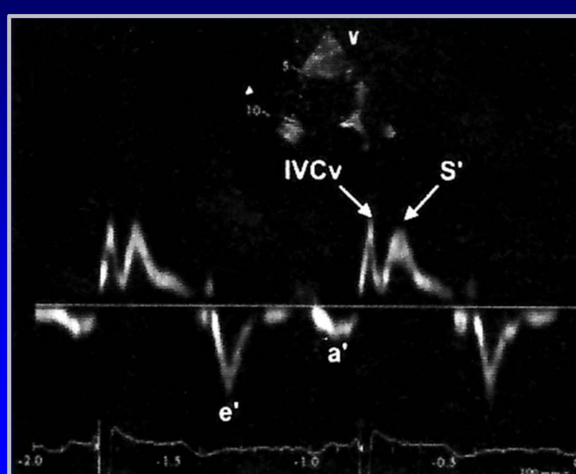
Recommended Measures of RV Function
Summary of Reference Limits (2015)

Variable	Abnormal
TAPSE	<1.7 cm
Pulsed Doppler peak velocity (at the annulus)	<9.5 cm/s
Pulsed Doppler MPI	>0.43
Tissue Doppler MPI	>0.54
FAC	**<35 %**

MPI = myocardial performance index

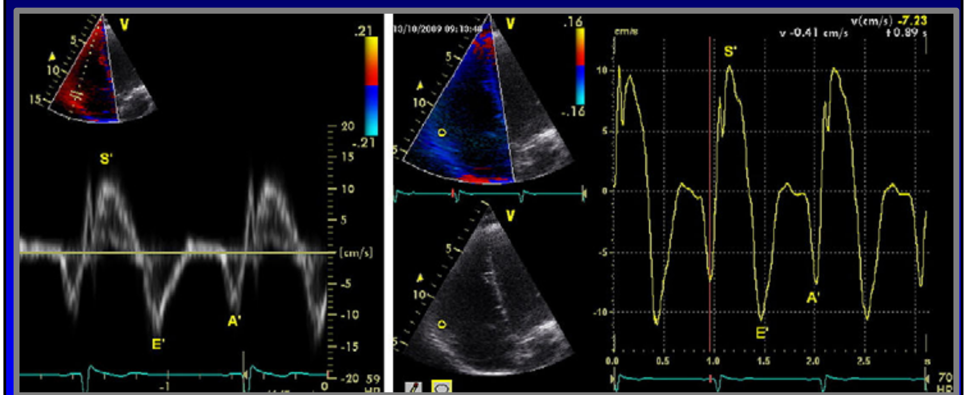
S’ (TDI)

Pulsed Tissue Doppler Imaging
Tricuspid Annular Velocity Profile



TDI of Tricuspid Annulus

(normal RV systolic function)



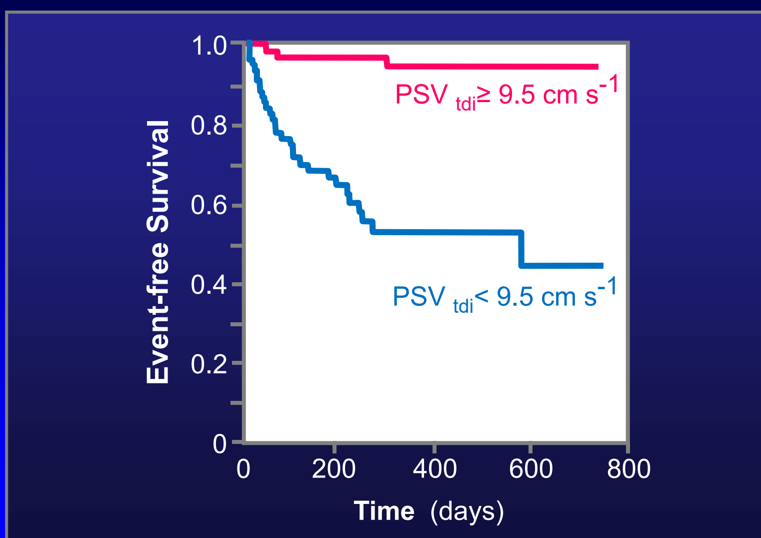
Evaluation of RV Systolic Function
TDI of Tricuspid Annulus

- Simple rapid method
- Feasibility high (>95%)
- Primarily reflects function of longitudinal myocardial fibers
- Peak systolic annular velocity correlates with RV ejection fraction (MUGA)
- Normal peak systolic velocity > 9.5 cm/s

Evaluation of RV Systolic Function
Limitations of TDI of Tricuspid Annulus

- Primarily reflects function of longitudinal myocardial fibers
- Influenced not only by myocardial function, but also by translational and rotational motion of the whole heart (but, LV translational motion and rotation in the long-axis is not important)
- Peak systolic TV annular velocity is load dependent

Kaplan-Meier Curves for Subgroups Stratified by Pulsed Wave Systolic Tissue Doppler Imaging (PSV_{tdi})



Damy Eur J Heart Failure 2009;11:818-24

S'

RV Systolic Function

	2010	2015
TAPSE	< 16 mm	< 17 mm
S'	<10 cm/s	< 9.5 cm/s
RIMP (PW Doppler)	>0.40	>0.43
RIMP (DTI)	>0.55	>0.54
FAC	<35%	<35%

Rudski J Am Soc Echocardiogr 2010;23:685-713
Lang J Am Soc Echocardiogr 2015;28:1-35

RIMP

TEI Index of Myocardial Performance Right Ventricle (RIMP)

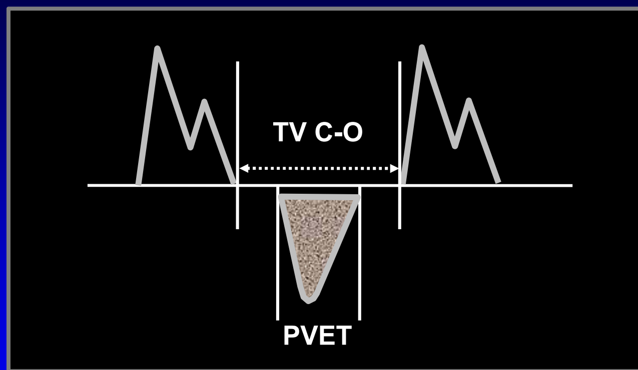
- Doppler-derived index of myocardial performance of RV (RIMP)
- Represents global RV function independent of ventricular geometry
- Indicated for patients with increased TR velocity ≥ 3.0 m/sec

Calculation of TEI Index (RIMP)

- Optimize right heart Doppler signals
- Measure pulm valve ejection time (PVET)
- Measure atrioventricular closure-opening (TV C-O)
- Calculate RIMP

$$\text{RIMP} = \frac{\text{TV C-O} - \text{PVET}}{\text{PVET}}$$

Calculation of TEI Index (RIMP)



$$\text{RIMP} = \frac{\text{TV C-O} - \text{PVET}}{\text{PVET}}$$

Example of RIMP Calculation

Measurements

TVC – TVO	440 msec
PVET	280 msec

$$\text{RIMP} = \frac{\text{TVC-TVO} - \text{PVET}}{\text{PVET}}$$

$$\text{RIMP} = \frac{440\text{ msec} - 280\text{ msec}}{280\text{ msec}} = 0.57$$

Normal values for RIMP → >0.43 (PW Doppler)
>0.55 (TDI)

Clinical Implication of ↑RIMP

- The higher the RIMP, the more abnormal the RV
- RIMP predicts survival in PHTN

IVC

Estimation of RV Pressure

	Normal (0-5 [3] mm Hg)	**Intermediate** (5-10 [8] mm Hg)		**High** (10-20 [15] mm Hg)
IVC diameter	≤ 21 cm	≤ 21 cm	>21 cm	>21 cm
Collapse with sniff	>50%	< 50%	>50%	< 50%

Rudski J Am Soc Echocardiogr 2010;23:685-713
Lang J Am Soc Echocardiogr 2015;28:1-35

Estimation of RA Pressure
Limitation of IVC Assessment

Caveats

Dilatation of the IVC with normal RAP has been observed in athletes and in patients on mechanical ventilation

Secondary Indices of Elevated RA Pressure

(Use to downgrade or upgrade RV pressure)

- Restrictive filling
- Tricuspid E/e’ > 6
- Hepatic vein → diastolic predominance

Caution:
- Athletes
- Patients on ventilators

Strain

3D

RV Function
3D-Echo

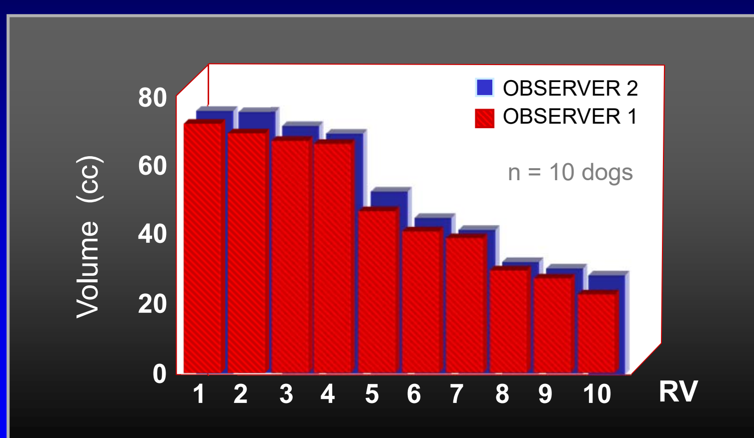
- Possible to visualize entire RV and re-slice it in short-axis cuts
- Eliminates need for simple geometric model
- Resolution and wall delineation marginal, but improving

3D-Echo for RV Volumes

- Avoid RV trabeculae and moderator band
- 3DE tends to underestimate RV volumes compared to cardiac MRI

3D-Echo RV Volume Interobserver Variability

Interobserver variability = 1.86 mL or 4.0% of mean



Intraobserver variability = 1.23 mL or 2.0% of mean

Jiang, Siu, Handschumaker, et al Circulation 89:2342(1994)

Case 7

RV infarct → McConnell's sign

The End