5th iHEFCARD

The 5th Indonesian Symposium on Heart Failure and Cardiometabolic Disease

Indonesian Working Group on Heart Failure and Cardiometabolic Disease

WHFS World Heart Failure Society

HEART FAILURE SOCIETY (SINGAPORE)

No disclosure

The Echocardiography Conundrums on The Right Heart Failure

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June, 12-14 2025

Sheraton Grand Jakarta Gandaria City, Jakarta, Indonesia

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Points of discussion

- **Pathophysiology of right heart failure (RHF)**
- Challenges in echocardiographic assessment of right ventricle function
- Dilemmas and diagnostic conundrums of right heart failure
- Advanced echocardiographic techniques and other modalities

The RV burden in cardiovascular diseases

Pressure overload

- PH (group 1 – 5)
- Pulmonary valve stenosis
- Pulmonary artery stenosis
- Pulmonary Embolism

Volume overload

- Right valve regurgitation
- Systemic-Pulmonary shunt
- High output state
- **[not widely studied yet]**

Cardiomyopathy

- Myocardial infarction
- ARVC
- DCM, HCM
- Amyloidosis, Sarcoidosis
- Cardiotoxicity
- Sepsis
- Transplant
- Post surgery, post LVAD

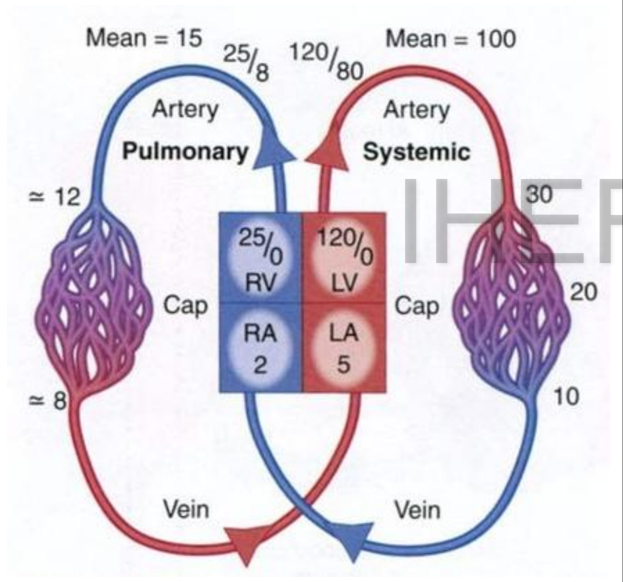
Sanz J, et al. Am Coll Cardiol 2019;73:1463–82)

The importance of RV function

- a major determinant of both untreated and treated outcomes in ***patients with PH***
- significantly increases mortality in patients with ***left heart failure*** .
- plays a role in predicting outcomes after ***cardiothoracic procedures***.
- is important for assessing outcomes in ***congenital heart disease***.
- important predictor for outcome in patients with ***valvular heart disease***.

Systemic vs Pulmonary Circulation

Systemic vs Pulmonary Circulation

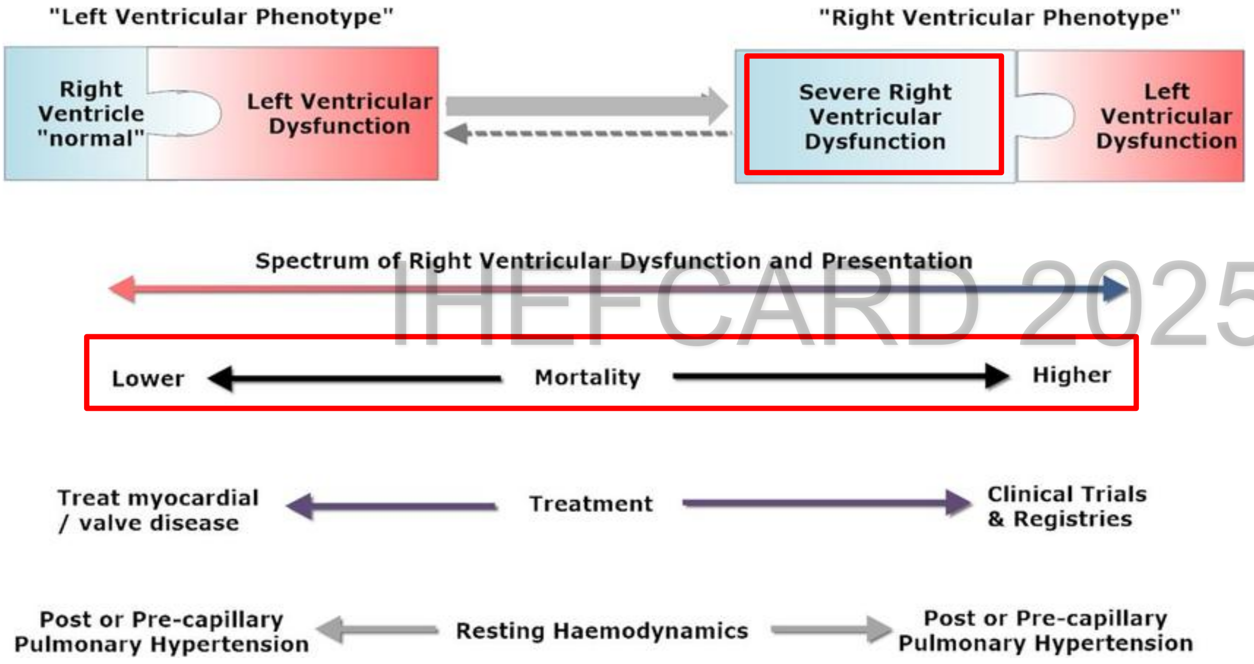


Pulmonary Circulation

- Closed circuit → Qp = Qs
- deoxygenated blood becoming oxygenated
- a shorter circuit
- lower resistance in the pulmonary blood vessels
- operates at lower pressures

Left heart disease → PH (group 2) → right heart problem

RV dysfunction in left heart disease



PH !

The RV function is important

Rosenkranz S, et al. doi:10.1093/eurheartj/ehv512

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Why Assessing the Right Ventricle Is So Difficult?

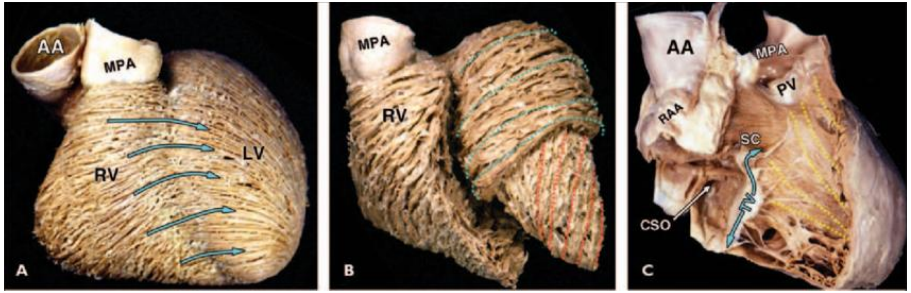
1 Complex crescent-shaped geometry

2 Heavily trabeculated structure

3 Function **depends on load conditions**

4 Influence of **interventricular dependence**

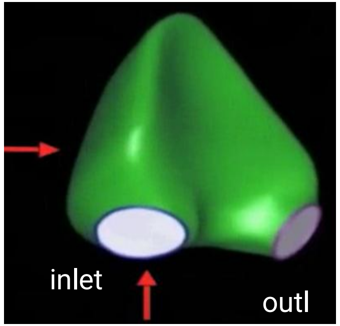
5 RV is a low-pressure pump with high adaptability

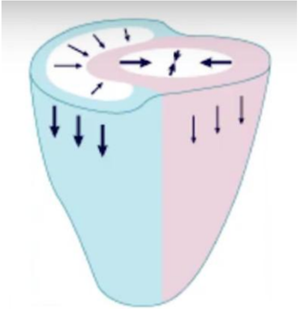


- Superficial (circumferential) fibers continuity between RV and LV
- Absence of prominent circumferential middle layer of normal RV
- Deep or subendocardial layer in RV (like in LV)

RV contraction is sequential and "peristaltic"

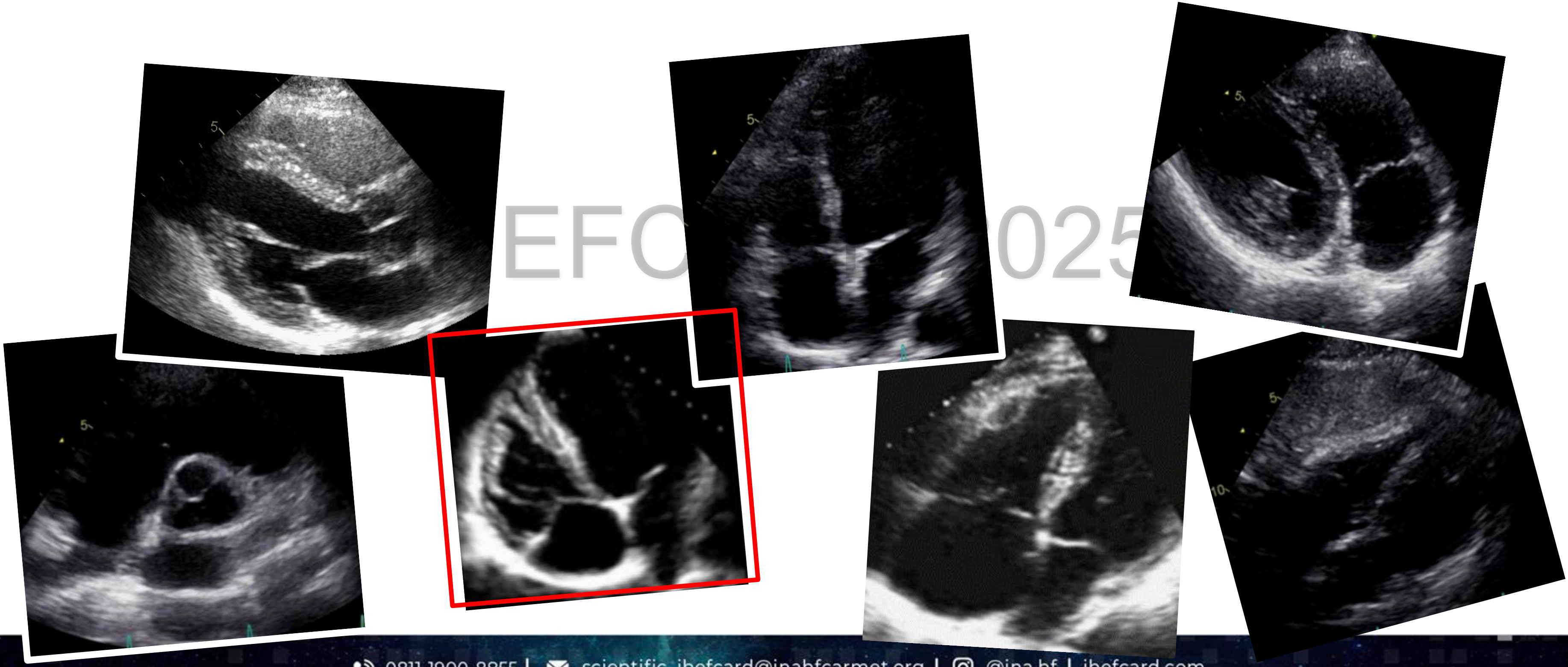
- Inlet → trabecular myocardium → infundibulum
- RV failure: peristaltic movement is lost (becoming more "LV like")

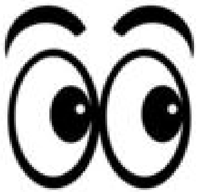




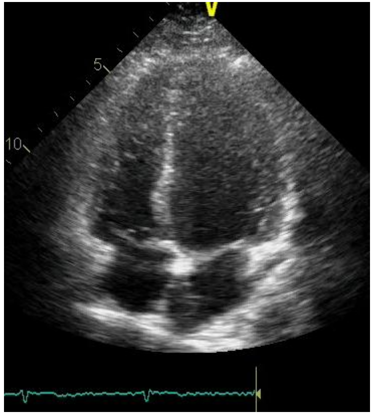
Echo Windows to View the Right Ventricle

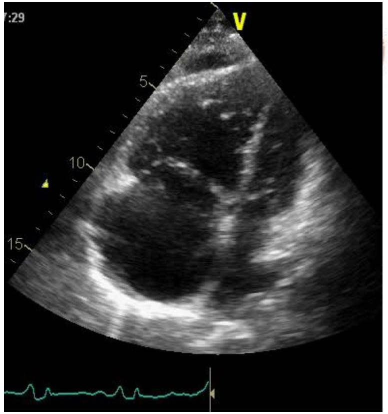
Needs ≥ 1 projections for a comprehensive evaluation of RV structure and function





Eye-ball assessment ?





Accuracy and Interobserver Concordance of Echocardiographic Assessment of Right Ventricular Size and Systolic Function: A Quality Control Exercise

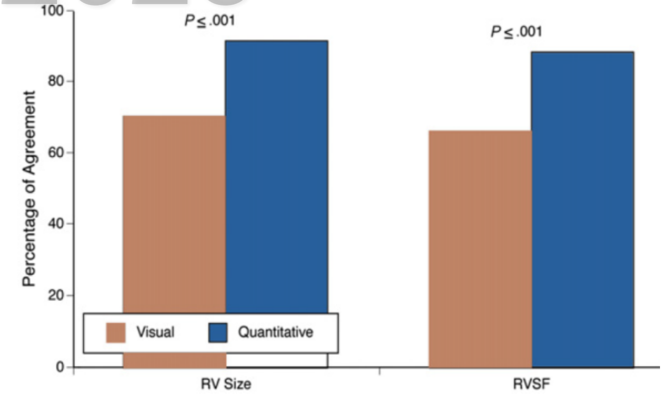
Lee Fong Ling, MBBS, Nancy A. Obuchowski, PhD, Leonardo Rodriguez, MD, Zoran Popovic, MD, Deborah Kwon, MD, and Thomas H. Marwick, MBBS, PhD, MPH, *Cleveland, Ohio*

Visual assessment
RV Size and RV Syst Funct

→ CMR

Quantitative assessment
RVS (basal and mid, & longitudinal ϕ
RVSF (FAC, TAPSE, s', RVIMP)

better → CMR



Ling LF, et al . JASE 2012;25:709-13

Echocardiographic Parameters of RV Function

RV size
basal, mid, longitudinal diameters

FAC
RV Fractional Area Change

TAPSE
Tricuspid Annular Plane Systolic Excursion

S′ wave
Tissue Doppler Imaging

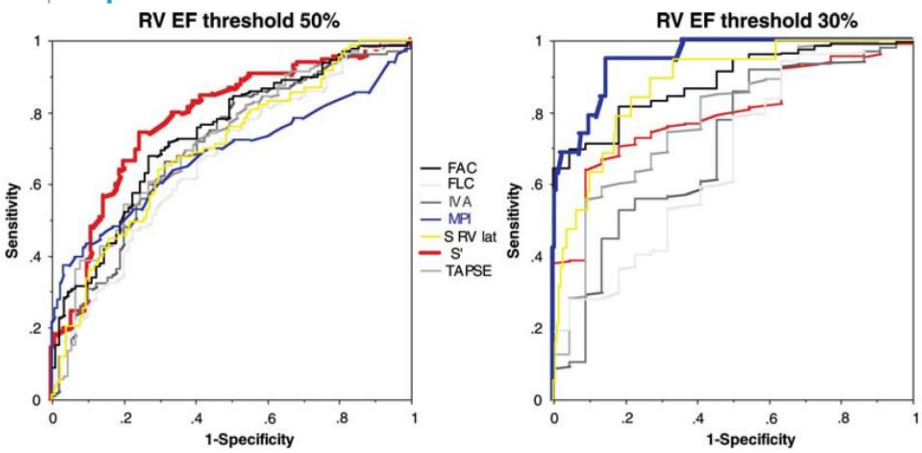
Strain
RV free wall

RA size and pressure
IVC diameter + collapsibility

3D volumes
optional, limited availability

- **Routinely used, with several limitations:** load-dependency, angle-dependency, and localized regional assessment
- the failing RV is always in **a complex loading condition** →alters the values of echocardiographic parameters and confuses clinicians

Haddad F, et al. Circulation.2008;117:1436-1448



RV function assessment; echo vs CMR

	AUC	AUC (95% confidence interval)	P-value	Sensitivity	Specificity	Cut-off
RVEF threshold 50%						
S′ (cm/s)	0.779	0.716–0.843	0.000	0.740	0.753	11
FAC (%)	0.728	0.659–0.797	0.000	0.675	0.707	36
TAPSE (mm)	0.716	0.647–0.785	0.000	0.614	0.708	17
IVA (m/s^2)	0.701	0.630–0.772	0.000	0.622	0.697	2.3
S lateral average (%)	0.697	0.625–0.770	0.000	0.651	0.688	−10
MPI (no unit)	0.681	0.600–0.761	0.000	0.651	0.624	0.30
FLC (%)	0.669	0.599–0.740	0.000	0.620	0.621	21
RVEF threshold 30%						
MPI (no unit)	0.948	0.906–0.991	0.000	0.947	0.852	0.50
FAC (%)	0.884	0.830–0.939	0.000	0.814	0.818	25
S lateral average (%)	0.878	0.805–0.951	0.000	0.789	0.810	−7
S′ (cm/s)	0.795	0.715–0.874	0.000	0.747	0.727	9
TAPSE (mm)	0.787	0.688–0.886	0.000	0.779	0.478	13
IVA (m/s^2)	0.681	0.557–0.805	0.005	0.779	0.622	1.6
FLC (%)	0.663	0.545–0.782	0.011	0.600	0.522	18

- **RVEF ≈ 50% → S′ (≤ 11 cm/s)**
- **RVEF ≈ 30% → MPI (> 0.5)**

Pavlicek M, et al. Eur J Echocardiogr.2011;12(11):871-80

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Determinant of RV function

Afterload

1. Vascular resistance
2. Vascular compliance
3. Wave reflection (blood pulsatility)
4. Inertance of blood during RV ejection

→ **RV – PA coupling**

Preload

1. Pericardial constraint
2. RV-LV diastole interaction

Contractility

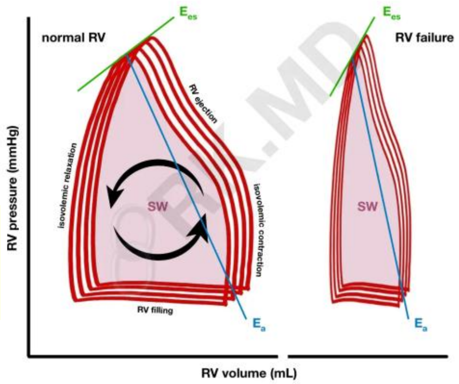
1. RV anatomy
2. RV-LV systolic interaction
3. Intrinsic RV function

Compliance : ability to distend

Elastance : tendency to recoil

Haddad F, et al. Circulation. 2008;117:1436-1448

RV-PA COUPLING

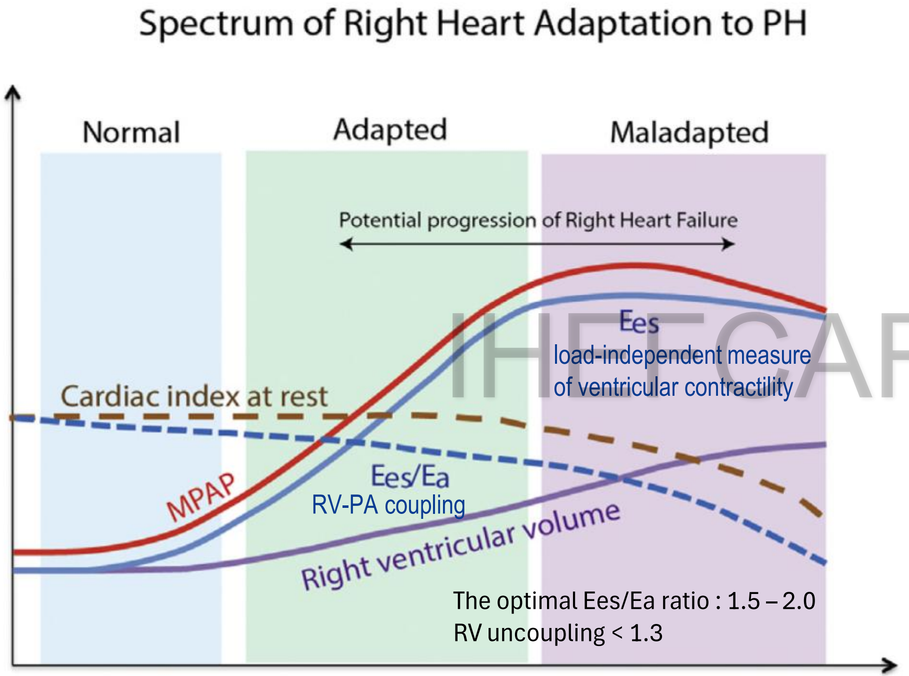


Ees : load-independent measure of ventricular contractility
Ea : ventricular-independent measure of arterial f/ "lumped" afterload (= end syst press/stoke volume)
Ees/Ea : RV-PA coupling (adequacy of RV contractility adaptation to afterload)

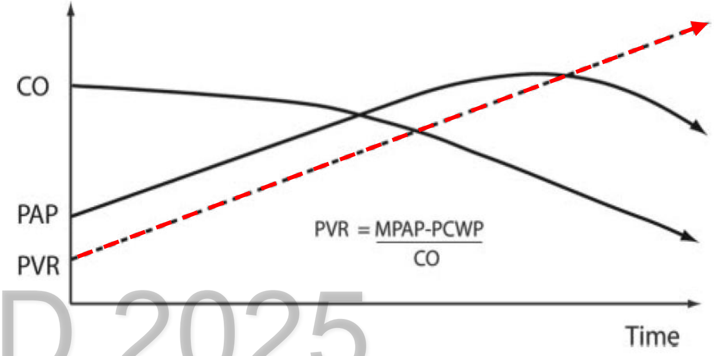
*"RV failure occurs under 2 general conditions: **excessive RV afterload** and **LV septal dysfunction**"*

Dell'Italia. Cardiol Clin 30 (2012) 167–187

The RV adaptation in pressure overload



Sanz J, et al. Am Coll Cardiol 2019;73:1463–82)
Amsallem M, et al. J Am Coll Cardiol HF 2018;6:891–903



- Disease progresses → severe RV failure → low output
- PA pressure may decrease as a consequence of low CO (RV cannot generate enough pressure)

⇩

the ***interpretation of PA pressure*** (PH pts) should always consider **the degree of RV failure and effective CO**

Haddad F, et al. Circulation. 2008;117:1436-1448

The Conundrum of Load Dependency

RV: thin-walled, crescent shaped, compliant chamber

- RV is more sensitive to pressure overload
- RV can tolerate volume overload better

Problem: RV metrics (TAPSE, s', FAC) are heavily load-dependent

To improve the decision-making process and prognosis assessments in clinical practice.

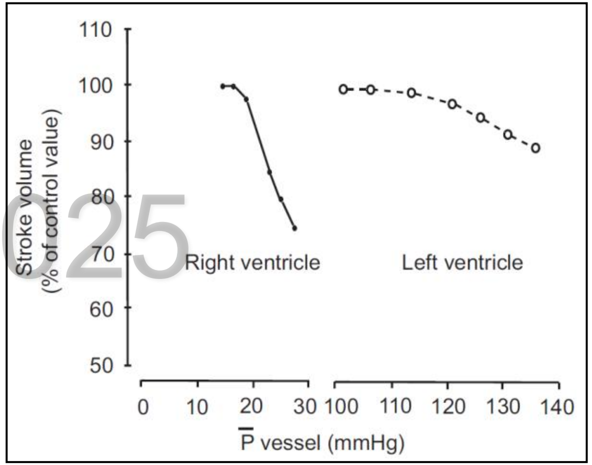
→ Assess RV evaluation in relation with loading conditions

New echo loading parameter:

•*RV load adaptation index* (TR VTI : [RV AED/RV LED]) → LVAD

•*RV-pulmonary artery coupling* (Ees/Ea) → echo: TAPSE/SPAP

Dandel M,et al. Circulation 2013; https://doi.org/10.1161/CIRCULATIONAHA.112.000335

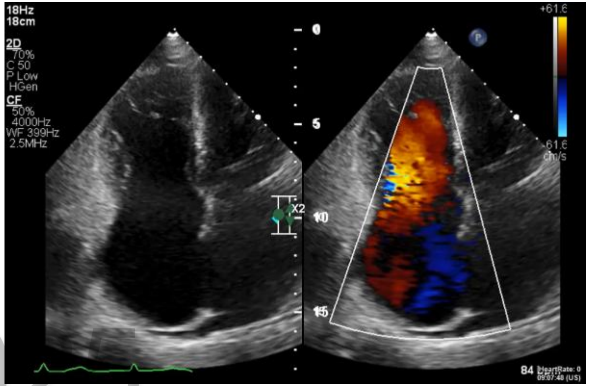


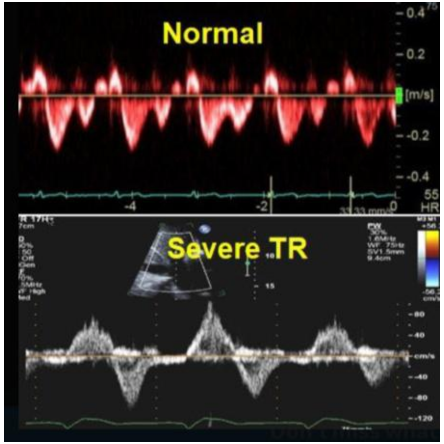
Compare to LV, RV is more sensitive afterload change

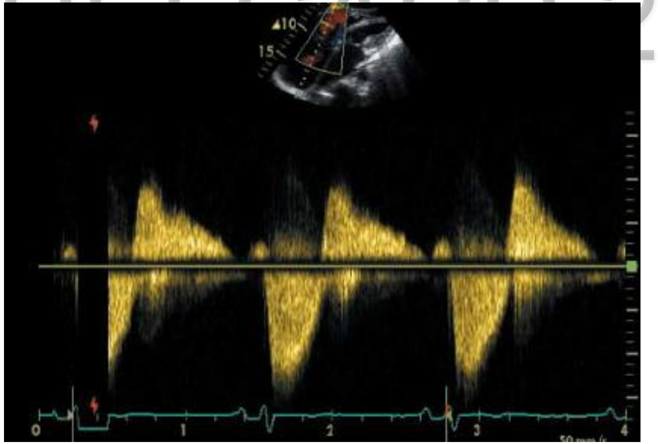
Champion HC, et al. Circulation 2009; 120: 992-1007

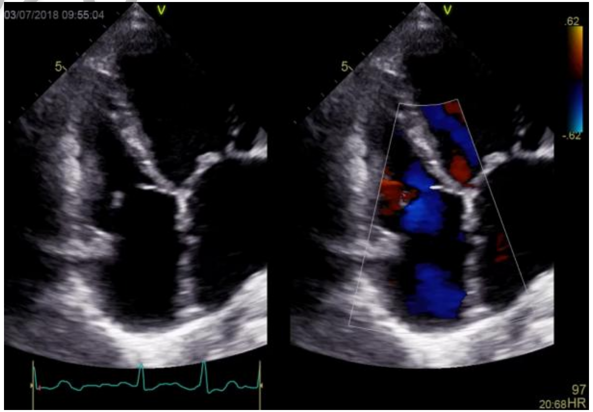
The TR Conundrum

- Severe TR can “mask” RV dysfunction
- Low afterload, large stroke volume, overestimate FAC or TAPSE
- Role of hepatic vein flow + RA pressures
- More than severe TR can underestimate SPAP using TR V max









RV – LV interaction

ventricular interdependency

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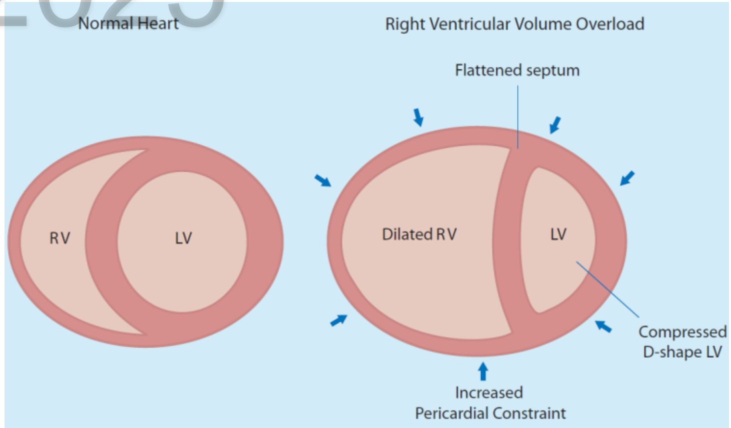
Shared aggregated cardiomyocyte → LV contribution to RV contractility (50-60% of RV contractility)
Shared interventricular septum → contribute 20-40% of RV stroke volume → systolic interdependency
Shared pericardial space → diastolic interdependency

RV dilatation → IVS shifts to the left, changing LV geometry.
Acute RV distension → increase in pericardial constraint.

→ decreasing LV distensibility, preload, and ventricular elastance
→ low LV CO



Haddad F, et al. Circulation. 2008;117: 1717-1731
Haddad F, et al. Circulation. 2008;117:1436-1448

Septal Motion: Friend or Foe?

- Interventricular dependence
- Paradoxical septal motion (septal flattening):
  - D-shaping from volume or pressure overload? → timing is important (end-diastolic vs end-systolic flattening)
  - challenging to pinpoint the specific etiology based solely on echocardiography.
- Limitation:
  - May mimics other LV pathologies; paradoxical septal motion in LBBB, post-cardiac surgery, infarction
  - inter-observer variability in visual assessment and the Eccentricity Index (EI) used to quantify flattening
  - Difficult to detect the timing of flattening → use ECG
- Important: Assess septal curvature throughout cardiac cycle !!

When Metrics Disagree

Case: 68M with chronic dyspnea, known PH

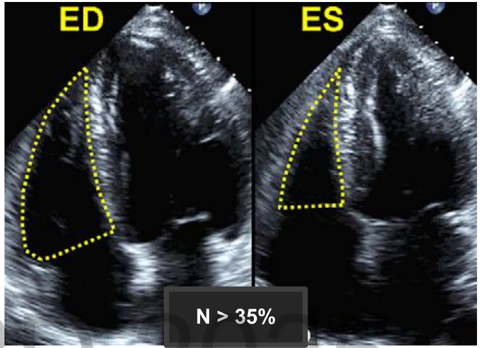
- TAPSE = 2 cm (normal)
- RV s' 8 cm/s% (reduced)
- FAC = 30% (low-normal)

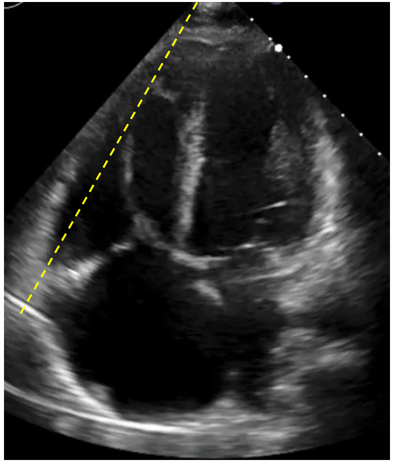
Which metric do you trust?

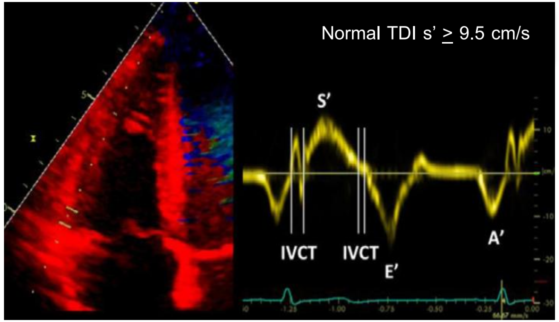
- M-mode vs TDI vs 2-D echo
- Longitudinal function

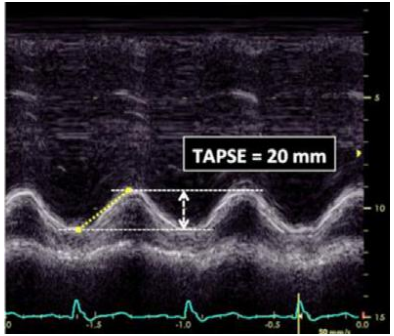
  (TAPSE= displacement vs s'= velocity)

  vs more global function (FAC= area)



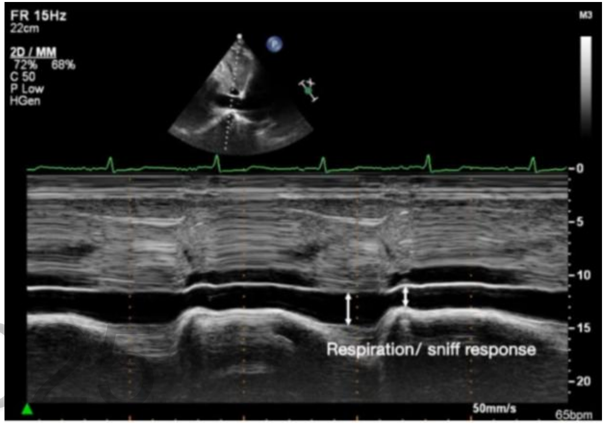






Inferior Vena Cava (IVC) Assessment

- Collapsibility index → RAP estimation
- But…
  - Variability with respiration, intra-abdominal pressure
  - Not reliable in ventilated patients
  - Affected by obesity, lung disease, dehydration, age, and BMI
  - often inaccurate in severe PH, especially when RAP is elevated.
- Tip: Use in conjunction with RA size and hepatic vein flow



	IVC Size	% Collapse	RA Pressure
Low	< 2.1 cm Normal	> 50% Normal	3 mmHg
Intermediate	< 2.1 cm Normal	< 50% Abnormal	8 mmHg
	> 2.1 cm Abnormal	> 50% Normal	8 mmHg
High	>2.1 cm Abnormal	< 50% Abnormal	15 mmHg

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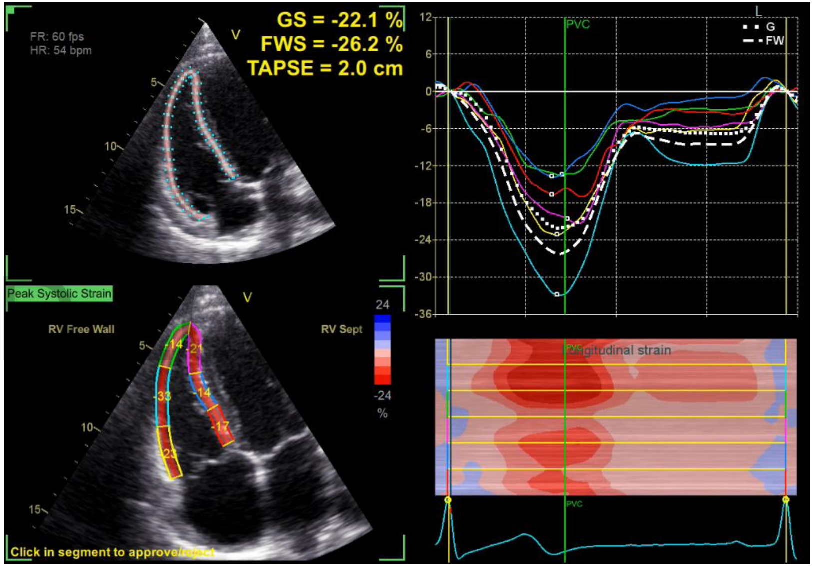
Role of RV Strain

- Global and free wall RV strain
- Less load- and angle- dependent,
- Less affected by translational motion
- Early marker for systolic dysfunction (intrinsic systolic function)
- Predictive of outcomes in PH, HFpEF, and post-LVAD



Limitations: require good image quality, vendor variability

Role of 3D Echocardiography

Advantages:

- Volumetric RV assessment → geometry-independent
- Better correlation with CMR
- Improved reproducibility

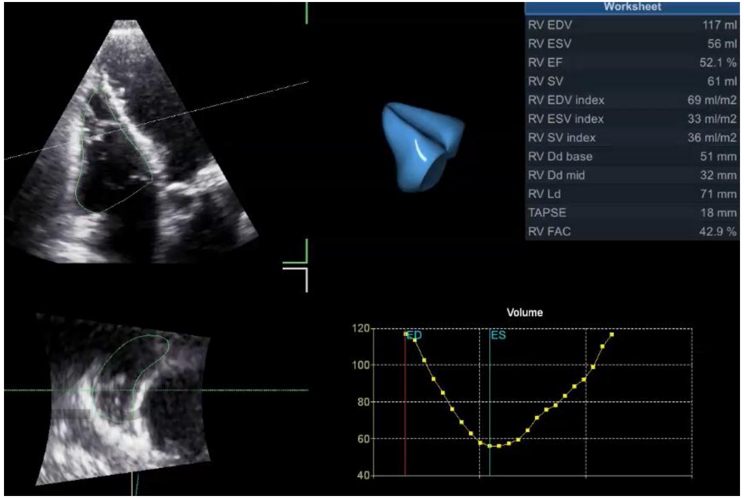
Limitations:

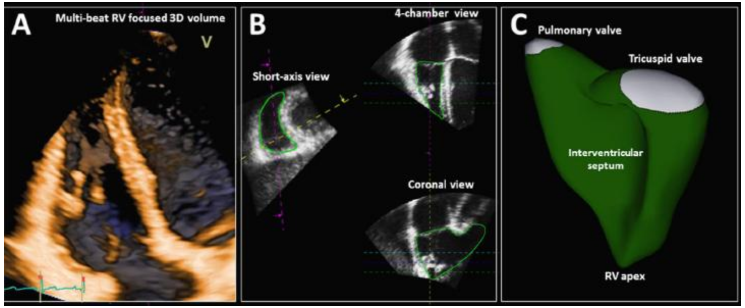
Load dependency

Acquisition time, specific software dependency

Needs experienced operator

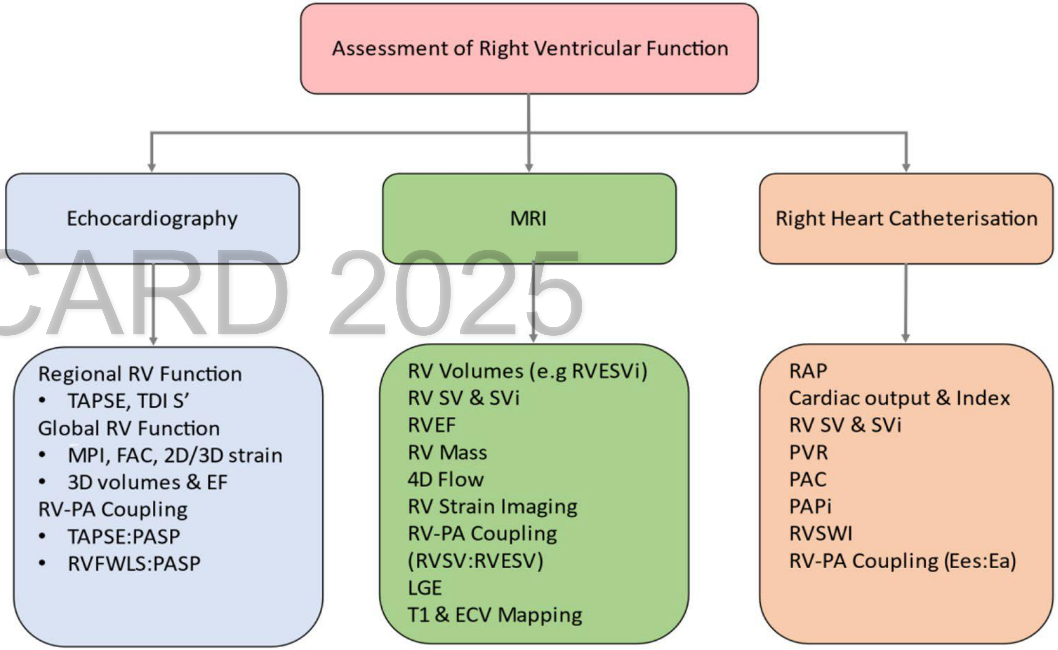
Dependent on image quality





Integrative Approach

- Multiple echo parameters
- Other imaging modalities are helpful
  - **MRI**: gold standard for RV volumes and fibrosis
  - **CT**: useful for CTEPH, congenital, structural anomalies
- Invasive Hemodynamic measurements
- Clinical correlation essential !!



Hameed A, et al. Current Heart Failure Reports (2023) 20:194–207

Take-Home Messages

1. RV is important in the pathophysiology of heart failure, disease course, and prognosis.
2. RV assessment is challenging due to the unique anatomy, myocardial architecture, hemodynamic, and cardio dynamic features.
3. Load dependency is a major diagnostic pitfall.
4. Assessment requires multiple echo parameters, no single parameter is sufficient.
5. Multimodality approach is sometimes needed.
6. Always correlate with clinical findings

Thank you