REVIEW ARTICLE

Pak **Heart J**

RIGHT SIDE OF THE HEART: ASSESSMENT BY TRANSTHORACIC ECHOCARDIOGRAPHY

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Contribution
IH conceived the idea and designed the study, collected data and drafting and finalized the manuscript.

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ABSTRACT

Echocardiographic evaluation of right heart has been a neglected area of Transthoracic studies. As technology improved, it has taken rapid strides, for structure and functional assessment. Right heart function has proven prognostic implications. Echocardiographic evaluation of the Right Heart spans from M-mode to 2 and 3 dimensional studies, Doppler (Pulsed wave, Continuous wave, color and tissue), and recent addition of Speckle Tracking. In this review, the definitions, echocardiographic methods, limitations and prognostic implications of the parameters used to assess Right heart structure and function by Trans-thoracic echocardiography (exclusive of 3D) have been detailed.

Keywords: Transthoracic echocardiography, Right heart assessment, prognosis.

INTRODUCTION

Evaluation of Right heart by echocardiography has been relatively unattended due to:

- The anatomy is very complex.
- Difficult to image as it lies behind the breast bone.
- RV wraps around LV, making the assessment of in- and outflow tracts in one view impossible and coarse trabeculations, make imaging and measurements difficult, Figure 1.[1]

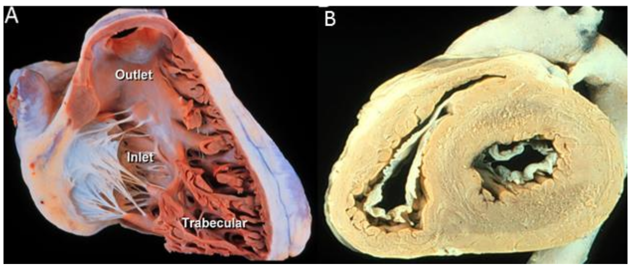

Figure 1: Right Ventricle (anatomical specimen, Cut section (A) to show the heavy trabeculae and wrapping around LV in a crescentic manner (B)

Assessment of different components of Right heart by echocardiography especially for diagnosis and prognosis would be detailed. The range of normal values for each parameter have been derived from authentic and validated guidelines provided by international agencies, i.e. American Society of Echocardiography/European Society of Cardiology[2] and British Society of Echocardiography.[3]

This manuscript covering the above-mentioned aspects will be unique and helpful for echocardiographers, cardiologists and physicians in making clinical decisions.

MATERIAL AND METHODS

An internet search of Pub-Med and Pakistan Heart Journal was done with the key words, “Echocardiography”, “Right Heart”, “Pulmonary Hypertension”, “Chamber quantification” and “Prognosis” which fetched 585 results. From these, 24 were found relevant for this manuscript for the extraction of data and textual facts.

Vena Cavae

Superior Vena Cava can be visualized from Supra-sternal window in Short Axis (Coronal) view, as shown in Figure 2.

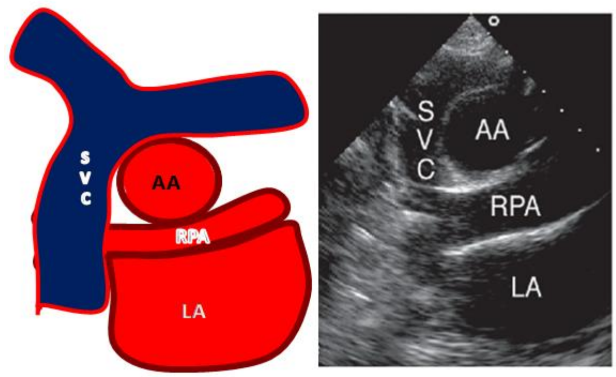

Figure 2: Superior Vena Cava from Supra-sternal View

The entry of inferior vena cava into RA is guarded by “Eustachian Valve”, usually rudimentary but at times is quite big, confusing for a cardiac tumor, Figure 3.

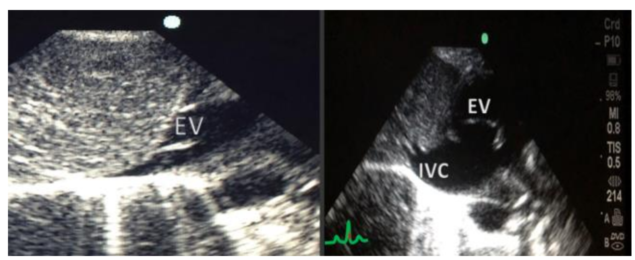

Figure 3: Eustachian valve Rudimentary (usual) and very large (unusual)

IVC is examined from sub-costal window along the short and long axes and the caliber is measured in long axis 1-2 cm distal to its opening into RA, Figure 4.

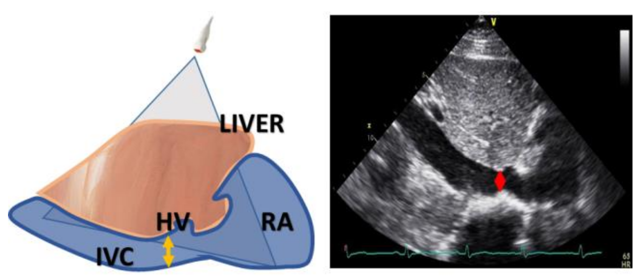

Figure 4: IVC measurement from sub-costal Long Axis View

The size and collapsibility of IVC varying with respiration (> 20%) or with a sniff (caval index > 50%) help in the measurement of RA Pressure, Table 1.

Pellicori et al, in 693 patients with heart failure, found a correlation for adverse prognosis between IVC diameter and log NT-BNP, an indicator of heart failure (r= 0.55; p < 0.001).[4]

Table 1: Right atrial pressure estimation from ivc size and collapse

American Soc. of Echocardiography[2]		British Society of Echocardiography[3]	
Size and collapsibility	Pressure	Size and collapsibility	Pressure
< 21mm;> 50%	3 (0 – 5)	< 21mm; > 50%	0-5
>21 mm; <50%	15 (10 - 20)	< 21 mm; < 50%	5-10
In between values	8 (5- 10)	>21; > 50%	5-10
		>21; < 50%	15

Right Atrium

Comprising of body and appendage, it is evaluated in apical 4C view. The parameters are dimensions, area and volume. Dimensions are transverse and vertical, former is measured from the mid of interatrial septum to the lateral wall and later from mid of superior wall to the mid of Tricuspid annulus, Figure 5A. The area of Right Atrium is also measured in this view, Figure 5B. Right atrial volume is measured by Modified Single Plane Simpson's method, Figure 5C or by Area-Length method by the formula 0.85 x (RA 4C Area2 ÷ RA Length), Figure 5D. The values for various RA measurements are as shown in Table 2.

Ronald J. Raymond et al, reported in 41 patients, "in severe primary pulmonary hypertension, indexed right atrial area is a predictor of mortality, while pericardial effusion and indexed RAA of an adverse outcome (transplant or mortality) in multi-variant analysis".[5]

Table 2: Normal right atrial parameters

Parameter	Male	Female
American Society of Echocardiography[2]		
Minor Axis Dimension	2.9-4.5	2.9-4.5
Minor Axis Dimension/BSA	1.7-2.5	1.7-2.5
Major Axis Dimension	3.4 - 5.3	3.4 - 5.3
Major Axis Dimension/BSA	2.4 ± 0.3	2.5 ± 0.3
Rt. Atrial Area	10 - 18	10 - 18
Rt. Atrial Volume	25 ± 7	21 ± 6
British Society of Echocardiography[3]		
Rt. Atrial Area	≤ 22	≤ 19
Rt. Atrial Area/BSA	≤ 11	≤ 11

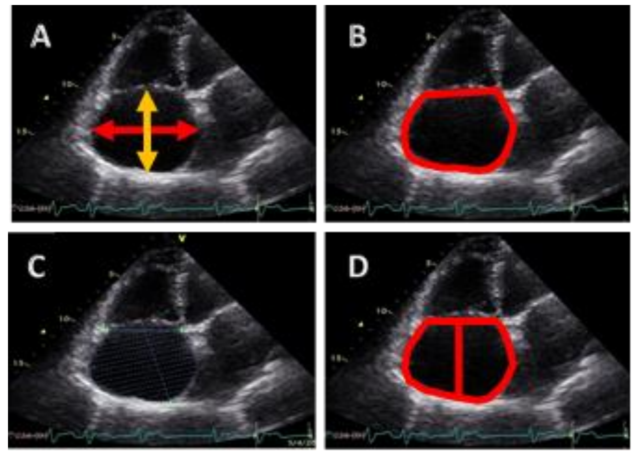

Figure 5: Right Ventricular dimensions. A- Transverse and Vertical dimensions, B- Area measurement. C- Volume measurement by Single Plane Simpson's method and D- by Area length method.

Tricuspid Valve

This is the largest valve comprising of annulus, leaflets, chordae and papillary muscles. Tricuspid annulus is oriented nearly vertically at an angle of approximately 45 degrees from the Sagittal plane, saddle shaped with outline varying from triangular to ovoid. A nearly 40% dilatation of Tricuspid annulus results in significant regurgitation. Functional TR results more from dilatation of anterior and posterior portions with relative sparing of septal region. Full analysis of tricuspid valve by 2D echocardiography requires multiple views as shown in Table 3.

Table 3: Standard 2D views for the assessment of tricuspid valve anatomy (echo images)

View	Structures seen
PS LAX RV inflow view with septum visible	Anterior and septal leaflets (Figure 6A)
PS LAX RV inflow view with coronary sinus visible	Anterior and posterior leaflets (Figure 6B)
PS SAX view at aortic root	Anterior leaflet normally (Figure 7)
Apical 4C view (standard)	1. Tricuspid annulus size 2. Septal and anterior

	leaflet 3. Tenting of tricuspid valve
Apical 4C RT ventricular focused view with aorta visible	Septal and anterior leaflets (Figure 6C)
Apical 4C RT ventricular focused view with coronary sinus visible.	Septal and posterior leaflets (Figure 6D)

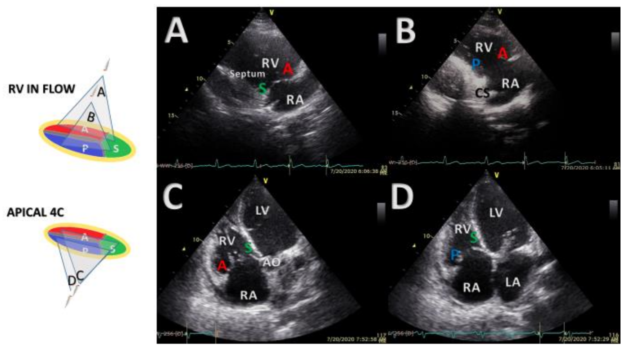

Figure 6: Tricuspid Valve: A and B: RV in-flow views with the leaflets as depicted in sketch on left, color coding corresponds to the leaflet seen in a particular plane of echo. C and D show the leaflets seen in RV directed 4C view with anterior angulation and without.

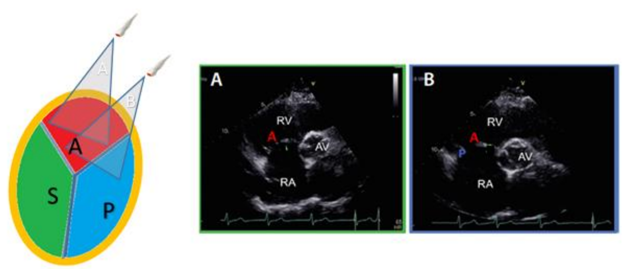

Figure 7: PS SAX view showing that only the anterior leaflet is visible (A) but when the transducer is angled medially the two leaflets seen are anterior and posterior (B).

Tenting area is bounded by the Septal and Anterior leaflets along with TV annulus, Figure 8, whereas, Tethering Height is the distance from mid of Tricuspid Annulus to the meeting point of Tricuspid leaflets at end systole. Tethering distance > 0.76 cm or Tenting area > 1.63 cm^2 are indicators of post-operative recurrent TR".[6]

Girish Dwivedi et al in 554 normal adults, more than 60 years of age measured these parameters as shown in Table 4.[7]

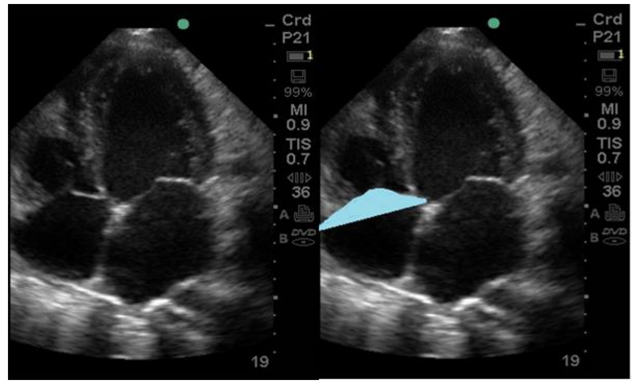

Figure 8: Tenting Area of Tricuspid valve

Tricuspid valve is mainly affected either by stenosis or regurgitation.

Table 4: Tricuspid annulus measurements[7]

Parameter	Mean	SD	5-95 Percentile
Male			
TA (ES)	2.8	0.39	2.3-3.4
TA (ED)	3.15	0.43	2.5-3.9
TV Tenting	0.71	0.17	0.5-1.1
TV tenting area (cm^2)	1.2	0.36	0.8-1.9
Female			
TA (ES)	2.8	0.43	2.0-3.4
TA (ED)	3.01	0.47	2.3-3.9
TV tenting	0.65	0.15	0.4-0.9
TV tenting area (cm^2)	1.31	0.35	0.7-1.8

Tricuspid Stenosis

For stenosis assessment, the TTE parameters are: 2D planimetry, pressure gradient assessment, mean and peak (by applying Bernouilli's equation), and valve area estimation (by pressure half time, and continuity equation).

In case of Tricuspid stenosis, 2D planimetry is not possible.

Pressure gradients across TV are assessed by CW Doppler. The time taken for the peak pressure to drop to half give pressure half time and dividing 190 by it will give the area.

By measuring the diameter of LVOT in PS long axis and VTIs of flows across LVOT (in apical 5C view) and Tricuspid valve (in apical 4C view), Figure 9 and applying the following equation, the area of a stenotic Tricuspid valve can be obtained.

$$A2(TV) = \frac{A1 \times VTI\ (LVOT)}{VTI\ (TV)}$$

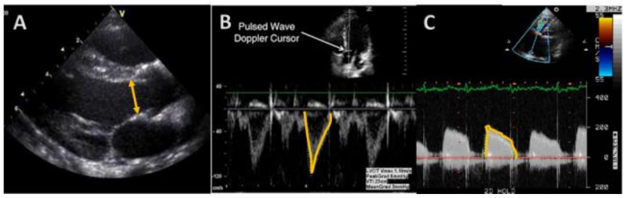

Figure 9: TV Area by Continuity Equation. A- LVOT Diameter (A1=D^2 x 0.785); B- TVI of LVOT; C-TVI of Tricuspid Valve flow

The parameters of severe Tricuspid stenosis are as shown in Table 5.[8]

Table 5: Parameters of significant tricuspid stenosis[8]

Parameters	Cutoff
Pressure Half Time	≥ 190
Peak Velocity	≥ 1
Inflow Time Velocity Integral	>60
Mean Gradient	≥ 5
Valve Area by Continuity Equation	≤ 1

Tricuspid Regurgitation

Assessment of regurgitation severity for any valve is done mostly by qualitative, semi-quantitative and quantitative methods. 2D assessment of morphology of the leaflets is the beginning point. The parameters are: Vena-contracta width, regurgitant area, regurgitant area to recipient chamber's area ratio, regurgitant volume (estimated by continuity equation or PISA), and effective regurgitant orifice area (EROA).

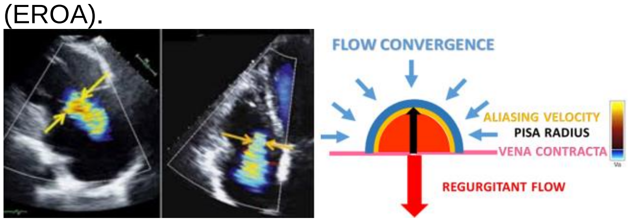

Figure 10: Vena Contracta width (Left Panel) and Various Components of PISA method for the Estimation of Tricuspid Regurgitation Severity.

Vena contracta, the narrowest point of regurgitant flow, Figure 10 is easy to measure and is highly specific for regurgitation severity.

As regurgitant flow converges towards the valve orifice, iso-velocity concentric layers forming hemi-spherical shells are seen. Flow through the surface area of each shell is equal to the amount of blood passing through the orifice. As the velocity of shells increases, aliasing is noted on color doppler. From the radius of the first aliased hemi-sphere and the aliasing velocity (from color velocity bar), the regurgitant flow can be discerned by the formula:[9]

$$\text{Regurgitant Flow} = 2\pi r^2 \times \text{Aliasing Velocity}$$

$$\text{EROA} = \frac{\text{Regurgitant Volume}}{\text{Peak Velocity of Regurgitant Flow}}$$

$$\text{Regurgitant Volume} = \text{EROA} \times \text{VTI}_{\text{(REG.)}}$$

"The regurgitation severity could be mild, moderate or severe as elaborated by the European Association of Cardiovascular Imaging in their recommendations"[10] Lately, two further grades have been added viz, massive and torrential as shown in Figure 11.[11]

	Mild	Moderate	Severe	Massive*	Torrential*
QUALITATIVE					
TV morphology	Normal/abnormal	Normal/abnormal	Abnormal/flail/large coaptation defect		
Color Doppler of TR jet	Small, central	Intermediate	Very large central jet or eccentric wall impinging jet		
CW signal of TR jet	Faint/parabolic	Dense/parabolic	Dense/triangular with early peaking	Peak TR velocity <2 m/s	—
SEMIQUANTITATIVE					
VC width (mm)§	<3	3–6.9	7–13.9	14–20	>21
PISA radius (mm)	≤5	6–9	>9	—	—
Hepatic vein flow	Systolic dominance	Systolic blunting	Systolic flow reversal		
Tricuspid inflow	Normal	Normal	E wave dominant (≥1 cm/s)		
QUANTITATIVE					
EROA (mm^2) by PISA	<20	20–39	40–59	60–79	≥80
EROA (mm^2) by quantitative Doppler	—	—	75–94	95–114	≥115
EROA (mm^2) by 3D	–	–	75–94	95–114	≥115
R Vol (ml) by PISA	<30	30–44	45–59	60–74	≥75

Figure 11: "Grading of tricuspid regurgitation (Adapted from Frontiers of Cardiovascular Medicine-open access)"[11]

Right Ventricle

Eyeball comparison of LV and RV sizes can indicate RV enlargement (1).

- RV < 2/3 LV –Normal
- RV = 2/3 LV—Mildly enlarged
- RV = LV—Moderately enlarged
- RV > LV – Severly enlarged

RV function should be assessed by multiple parameters[12] with proven diagnostic and prognostic values.

Right Ventricle Dimensions

Three dimensions are taken in Apical 4C RV directed view as follows:

Get a good quality apical 4C view, move the transducer laterally, focusing medially to make RV lie in the center but with LV apex remaining central at the top of the image. Lastly, rotate the transducer to get the maximum dimension at the base and along the long axis",[13] Figure 12.

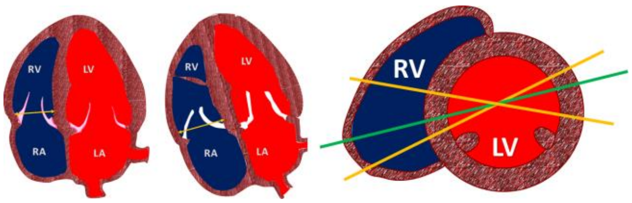

Figure 12: Apical 4C view on left and RV Focused Apical 4C chamber view (centre) making the basal diameter to be seen in its full extent (see the green line on right).

The three dimensions measured are (Figure 13):

- D1- at the base
- D2- at papillary muscle
- D3- from mid of Tricuspid annulus to apex

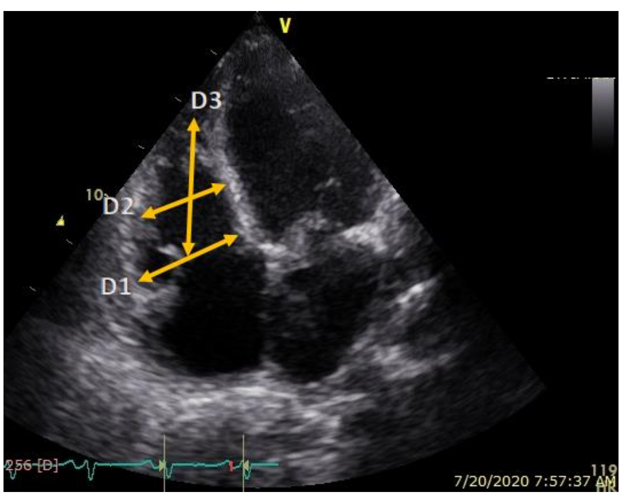

Figure 13: The three linear dimensions of RV

RV thickness is measured from subcostal view, either by M-mode or 2D with trabeculations excluded, Figure 14.

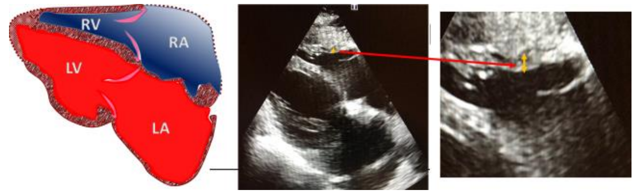

Figure 14: Sub-costal 4C view showing RV free wall measurement (yellow arrow).

RV outflow tract is measured at proximal and distal site, former in PLAX or PSAX view, whereas, later in PSAX view, just proximal to the pulmonic valve at end systole (Figure 15), Normal values are shown in Table 6.

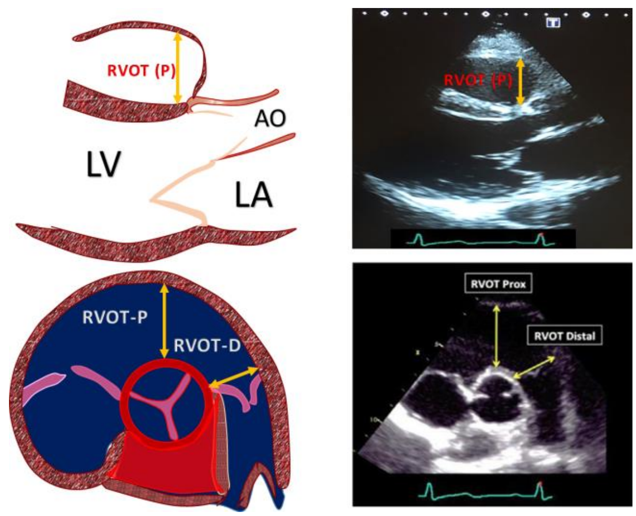

Figure 15: Parasternal Long and Short Axis views. Yellow lines show the dimensions of proximal and distal RVOT.

Increase in RV size is a marker of adverse prognosis in many conditions like chronic pulmonary disease, idiopathic pulmonary hypertension, acute pulmonary embolism, myocarditis and chronic heart failure.

Table 6: Normal right ventricular dimensions

Right Ventricular Dimensions	ASE	BSE	
		Male	Female
RV/LV basal diameter ratio	-	< 1	< 1
RV base	25-41	≤ 47	≤ 43
RV mid	19-35	≤ 42	≤ 35
RV length	59-83	≤ 87	≤ 80
RV free wall thickness	1-5	≤ 5	

RV outflow tract proximal	21-35	PS LAX < 43 PS SAX < 44	PS LAX < 40 PS SAX < 42
RV outflow tract distal	17-27	≤ 29	≤ 28

ASE = American Society of Echocardiography[2]
BSE = British Society of Echocardiography[3]

Right Ventricle Functional Assessment

These parameters could be focal, Tricuspid Annular Plane Systolic Excursion (TAPSE) and S' velocity or global, which include RV Fractional Area change, Myocardial Performance Index and RV free wall strain assessment. The normal values have been tabulated in Table 7.

1. RV Tricuspid Annular Plane Systolic Excursion (TAPSE):

TAPSE is the distance moved by the lateral annulus of Tricuspid valve during systole. It is measured in A4C view by M-mode, Figure 16 and the main advantages are its easy obtainability and universal availability but, it is angle and volume dependent.

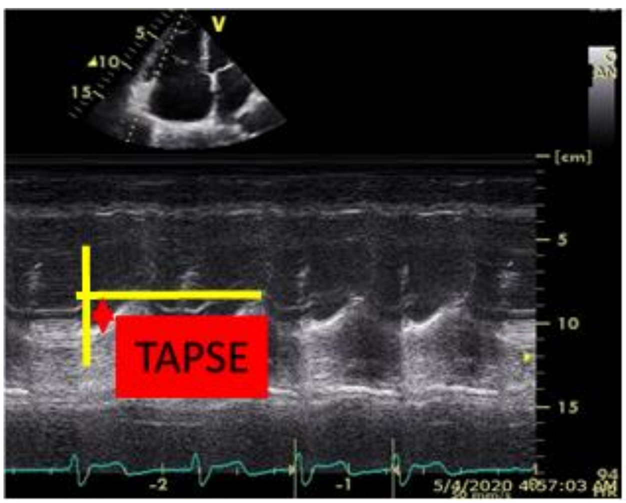

Figure 16: Tricuspid annular plane systolic excursion.

Paul R. Forfia et al, demonstrated that in patients with pulmonary arterial hypertension (PAH; n = 47), survival estimates at 1 and 2 years were 94% and 88%, respectively, in those with a TAPSE of 1.8 cm or greater versus 60% and 50%, respectively, in subjects with a TAPSE less than 1.8 cm.[14]

Since it measures a part of RV, it may remain normal in some cases of severe PAH with depressed function and, on the contrary, TAPSE may be reduced in some cases of post cardiac surgery although RV function is preserved. A TAPSE of less than 15 has a sensitivity of 59% and a specificity of 94%.[15]

2. RV Fractional Area Change (RV FAC):

Area of Right ventricle is measured in A4C RV directed view at end diastole and end systole, Figure 17. Difference of these two per end diastolic area expressed in %age gives the RV Fractional Area Change:

$$FAC = \frac{A4C\ diastole - A4C\ systole}{A4C\ diastole}\ X\ 100$$

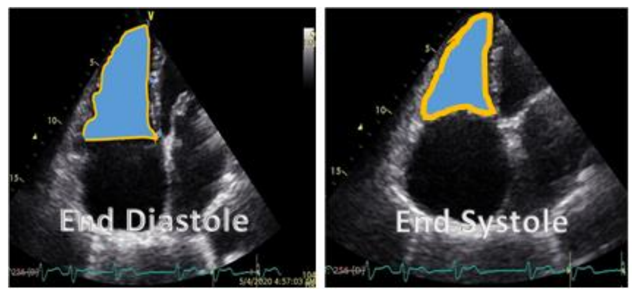

Figure 17: Fractional Area Change measurement.

It has proven value as a predictor of sudden death, heart failure and stroke after MI and Pulmonary Embolism.

3. RV Volumes and Ejection Fraction:

These parameters are not recommended by current guidelines.

4. RV S' Velocity:

Robust and highly reliable. It measures the velocity of RV myocardium in A4C view by TDI or Color-Coded Tissue Doppler. The sample volume is placed at the lateral tricuspid annulus or basal segment of RV free wall, Figure 18. Limitations and advantages are same as of TAPSE and is less load-dependent.

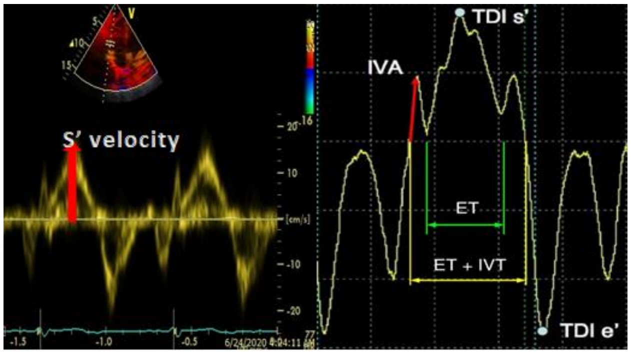

Figure 18: S' velocity measurement by Color coded tissue doppler and Tissue doppler.

Numerous studies have shown the prognostic value (for survival and morbidity) of S' velocity with variable cutoffs from 9 cm/s – 10.8 cm/s.[16]

5. RV Isovolumic Acceleration:

A relatively new parameter confined to Isovolumic contraction time. It is relatively less load-dependent and measured by Color-Coded Tissue Doppler like S' velocity. The initial spike during systole in TDI record is the Isovolumic time, Figure 19. Its height represents the maximum velocity and the time to reach it is the Acceleration time. IVA is obtained by the formula:

$$RV\ IVA = \frac{IVV}{AT}\ \text{cm/s}^2$$

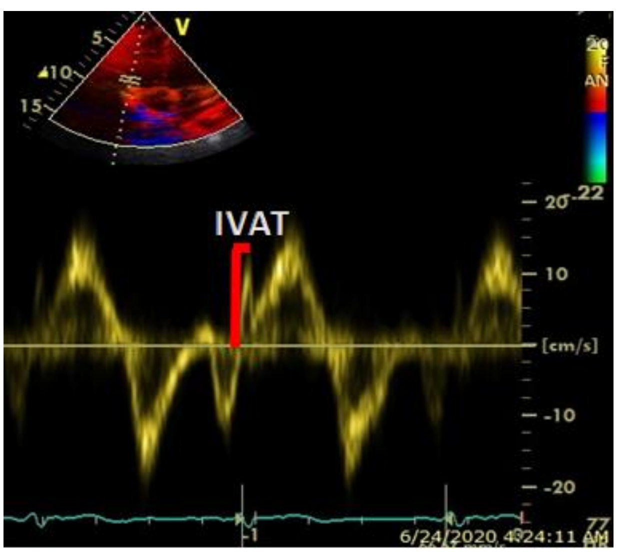

Figure 19: Isovolumic Acceleration Time measurement by Color coded Tissue Doppler imaging.

In their study of 413 subjects, Jerome Peyrou et al, found, "of the newer parameters, RV function assessment by IVA (≤ 1.8 cm/s2) had a sensitivity of 86% and specificity of 97% and is the best parameter in this regard, even surpassing basal 2D strain analysis".[17]

6. RV Myocardial Performance Index (RMPI - TEI INDEX):

It assesses systolic as well as the diastolic function and is obtained by the equation:

$$\text{RIMP} = \frac{IVCT + IVRT}{RV\ ET}$$

It measures the ratio of non-ejection and ejection period. The combination of isovolumic periods can be obtained by measuring the time from the closure of Tricuspid Valve till its opening (TCO) and subtracting the ejection time:

$$\text{RIMP} = \frac{TCO - ET}{ET}$$

Acquisition of RIMP by both the methods has been shown in Figure 20.

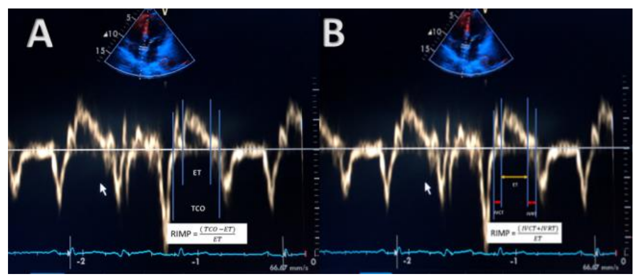

Figure 20: Right Index of Myocardial Performance (RIMP) measurements by two methods.

It is load-dependent but doesn't pose a problem for acquisition and no assumption for geometry is needed. It can be obtained by Color-Coded DTI or PW Doppler. The former is better as all the variables of the equation can be obtained in the same view.

RIMP has proven its prognostic value in clinical trials in multiple clinical scenarios like Pulmonary Hypertension, LV dysfunction, acute RV myocardial infarction, chronic and acute pulmonary thrombo-emboli, after heart valve surgery and in congenital heart disease.

7. Right Ventricular Strain:

It detects myocardial dysfunction earlier than conventional echocardiography. For this, an RV focused view is obtained with a good Region of Interest encompassing the full thickness of the myocardium, Figure 21. Either a six segment approach, or a three segments approach is used, the latter being preferable. 2D strain of only the basal segment of RV indicates RV systolic function. Being angle plus load independent (relatively), and having good reproducibility with low inter and intra observer variability, it is emerging as a robust parameter for RV function assessment.

Focardi et al have demonstrated that RVLS has a strong correlation with CMR-derived RVEF than conventional echo methods.[18]

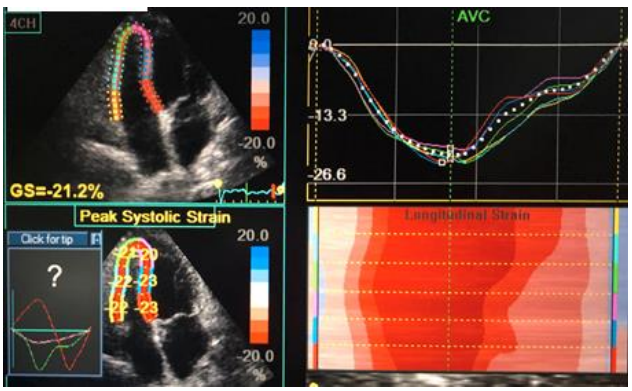

Figure 21: Strain Analysis of Right Ventricle.

The main limitations are: sinus rhythm (with HR 60-100 bpm) is mandatory, good acoustic image, requires a dedicated software, only longitudinal strain can be assessed currently and uniform universal standards are still lacking.

RVLS has shown prognostic value in various clinical scenarios like Acute MI, PAH, Heart failure (moderate), operated cases of TOF, heart transplant recipients and in ARVD.

The normal value of RV (mean) strain is -26 (-21 to -32) whereas the value for RV free wall is -27 (-24 to -29).

Table 7: Right ventricular functional parameters-normal ranges

Parameters	Male	Female
American Society of Echocardiography[2]		
RV area, diastole	10-24	8-20
RV area systole	3-15	3-11
RV EF	>45%	
TAPSE	>1.7	
RV FAC	>35%	
S' wave velocity	>9.5	
RIMP (Pulsed Doppler)	< 0. 43	
RIMP (Tissue Doppler)	< 0. 54	
RV free wall strain	< - 20%	
British Society of Echocardiography[3]		
TAPSE	≥ 1.7	
RV FAC	≥ 30%	≥ 35%
S' wave velocity	≥ 9	
RIMP (Pulsed Doppler)	< 0. 43	
RIMP (Tissue Doppler)	< 0. 54	

Right Ventricular Diastolic Function

In apical 4C view with the sample volume of PW Doppler placed between the tips of Tricuspid leaflets, Figure 22, flow velocities are measured, either in held respiration or an average of 5 cycles taken.

Velocities of early flow (E-wave), late flow (A- wave), their ratio (E/A) and the deceleration time of E wave should be recorded. With the sample volume of Tissue Doppler placed at the lateral Tricuspid annulus, Isovolumic relaxation time (IVRT), E' velocity, A' velocity, E'/A' ratio and E/E' ratio are obtained.

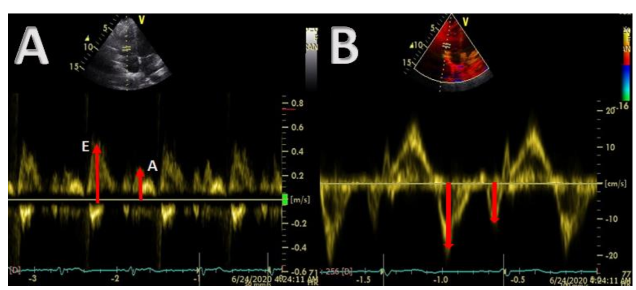

Figure 22: Measurement of Diastolic Functional Parameters by Pulsed Wave Doppler (A) and Tissue Doppler (B).

Diastolic dysfunction has been graded as:

- Mild--- E/A < 0.8 ,
- Moderate--- E/A is 0.8- 2.1 and E/E' < 6 or dominant diastolic flow in the hepatic veins,
- Severe--- E/A > 2.1 and DT < 120 ms.

The normal ranges of diastolic parameters of Right ventricle are as shown in Table 8.

Noha H et al demonstrated that in hypertensive patients, RVDD accompanies LV diastolic dysfunction. The overall prevalence of RVDD was higher than that of RVSD, and the highest prevalence of the latter was recorded in subjects with elevated PASP and dilated left atrium.[19]

Table 8: Right ventricle diastolic function parameters- normal ranges

Parameter	Normal Range
British Society of Echocardiography[3]	
E wave	≥ 35
A wave	21-58
E/A	0.8 – 2.1
E wave Decelaration time	120-229
RV IVRT	≤ 73
E’	< 8
E/E’	< 6
Hepatic Vein Diastolic/Systolic	≥ 1
Hepatic Vein Systolic Filling Fraction	≥ 55

Pulmonary Valve

Located most superiorly and anteriorly it is the most difficult to image. Imaged in RV outflow tract view, PS SAX, and sub-costal sagittal view. In any view, only two leaflets are visible. Pathological affliction results in stenosis or regurgitation.

2D echocardiography assesses morphology, and grading of stenosis severity[8] is done by estimation of Peak and mean gradients. Valve area is estimated by Continuity equation, Table 9.

Table 9: Grading of pulmonary stenosis.[8]

	Mild	Moderate	Severe
Peak Velocity	< 3	3-4	>4
Peak Gradient	<36	36-64	>64
Valve area			<1

Pulmonary regurgitation is seen in 40-78% people, normally and assessed like TR by qualitative, semi-quantitative and quantitative methods. However, not all the methods have been well-validated and this remains an area of research. Parameters for grading the severity, have been elaborated by European Association of Cardiovascular Imaging.[14]

Pulmonary Artery

Main Pulmonary artery is seen in PS LAX and SAX views whereas the later view shows branches clearly and their sizes can be measured from PS SAX or Suprasternal view, Figure 23. The normal ranges and the cut-offs for severity assessment are shown in Table 10.

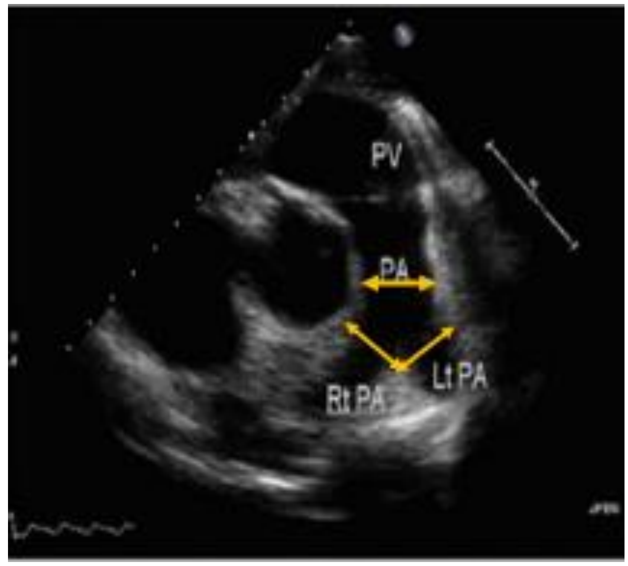

Figure 23: PS SAX View: Main and branched PA size measurements.

Table 10: Pulmonary artery dimensions and cut off ranges for severity[20]

Severity	Pulmonary Artery Diameter
Normal	1.5 – 2.1
Mildly enlarged	2.2 – 2.5
Moderately enlarged	2.6 – 2.9
Severely enlarged	>3.0

Adapted from: https://www.echopedia.org/wiki/Normal_Values_of_TTE)[20]

Assessment of Pulmonary artery pressure is extremely important. It could be peak systolic, mean and end-diastolic. Pulmonary Vascular Resistance can also be derived from these parameters.

Pulmonary artery hypertension, traditionally defined as mPAP ≥ 25 mmHg, was revised at the Sixth World Symposium on PAH in 2018 and the thresholds suggested were as shown in Table 11.[21]

Table 11: Definition of pulmonary artery hypertension[21]

Parameter	Cut-off value for PAH
Mean Pulmonary Artery Pressure	≥ 20 mmHg
Pulmonary Vascular Resistance	≥ 3 Woods unit
Pulmonary Wedge Pressure	≥ 15 mmHg

For the assessment of Peak PA systolic pressure, Trans-Tricuspid gradient (Modified Bernoulli equation, Gradient = 4V2) is utilized, which, in the presence of even trivial Tricuspid Regurgitation, can be adequately measured, Figure 24. To this Right Atrial pressure is added. Inferred from size and collapse of IVC, Table 2.

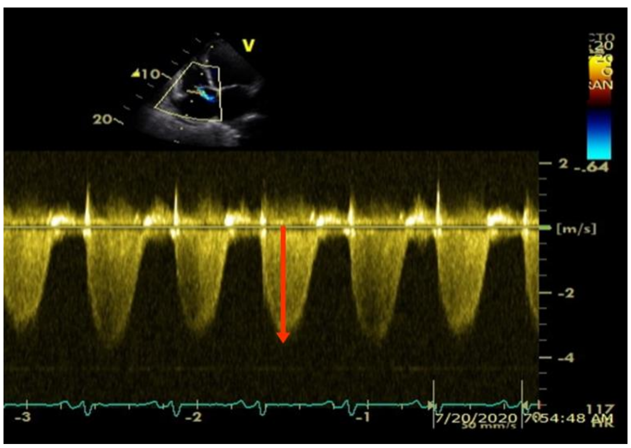

Figure 24: CW Doppler of Tricuspid Valve Regurgitation showing Peak Velocity.

If the velocity of TR jet > 3.4 m/s, diagnosis of PAH is highly likely, whereas if it is < 2.8 m/s, PAH is unlikely and for values in between, other parameters should be taken into account.

Mean Pulmonary Artery Pressure, can be measured by:

1. Early diastolic flow velocity of a Pulmonary Regurgitation jet as TR jet velocity is used for PASP estimation and, with addition of mean RA pressure, Figure 25.

2. Pulmonary Acceleration is measured from the inception of PA flow till its peak by PWD. Two formulae have been proposed for the estimation of mean PAP:

a) 79 – (0.45 X PA AT)

b) 90 – (0.62 X PA AT)

Formula b is used if the heart rate is > 100 bpm or PA AT is < 120 msec. "Shakeel AQ et al found a significant correlation of the first formula with Catheterization-derived mean Pulmonary Artery Pressure in their study of 18 patients as nearly 83% of patients (PDE= 38 ± 12 vs Cath. 37 ± 15) had the same value".[22]

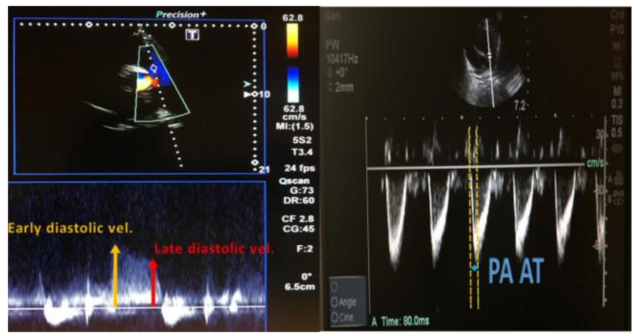

Figure 25: Estimation of Mean Pulmonary Artery Pressure by End-diastolic velocity of PR signal (Left) and By PA Acceleration Time (Right).

3. From mean RV-RA gradient with addition of RA pressure.

4. Can also be calculated from peak PAP:[23]

Mean PA pressure = 0.6 (peak systolic PAP) + 1.95

Pulmonary Artery Diastolic pressure can be estimated from end pulmonary regurgitation flow by modified Bernoulli equation and adding to it mean Right Atrial pressure, Figure 25.

Other parameters like TVI of PA systolic flow, sizes of RA, RV and Pulmonary arteries should be taken into account when labelling for PAH.

Hepatic vein flow helps in diagnosing PAH. By PW Doppler, Hepatic venous flow is recorded, which, shows two prominent negative waves, one each in diastole and systole, later bigger than former. Two smaller waves are also recorded, as shown in Figure 26.

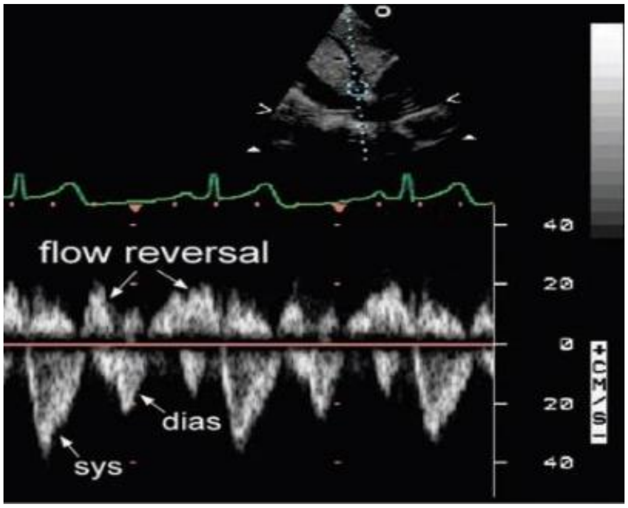

Figure 26: Hepatic Vein flow from Sub-costal window

An attenuation in the size of systolic wave flow signifies elevated RA pressure, and hence PAH, and, in cases of severe Tricuspid Regurgitation, this wave may get totally reversed. Nagueh et al, found that if the ratio of TVI of systolic flow and the sum of the TVIs of systolic and diastolic flow < 55%, then mean RAP > 8 mmHg.[24]

Pulmonary vascular resistance (PVR) is the most important parameter, especially for pre-capillary hypertension. An estimation of it can be done from the TR jet by measuring the peak velocity and TVI of TR jet and applying the following formula:

$$PVR = \frac{10\ X\ TR\ Velocity}{RVOT\ TVI} + 0.16$$

Pulmonary Vascular Resistance is measured in Woods unit and the above formula pertains till a value of 8 WUs.

Pulmonary artery hypertension is a progressive disease with poor prognosis and the 1-, 2- and 3-years survival rates are 87%, 76% and 67% respectively. Pericardial effusion, indexed right atrial area, degree of septal shift towards the right ventricle in diastole, TAPSE, pulmonary vascular resistance and Tei index have prognostic value in patients of pulmonary artery hypertension.[25]

CONCLUSION

Thus, it is clear that Trans-thoracic echocardiographic evaluation of Right Heart has many facets. It can now be done with much ease and the plethora of parameters obtained have great diagnostic and prognostic importance. A detailed evaluation is hence mandatory for any echocardiographic study.

Declaration: Figure 1, and Table 6 published under CC4 have been adapted from literature and, as per requirement, have been appropriately cited with reference of author and publication journal. The remaining figures are author's own work. Data of rest of tables have been derived from sources appropriately referenced.

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Units of Measurements: In this manuscript the units of measurements are: linear dimensions in cm, area in cm2, volume in cubic centimeters, velocity in m/s (cm/s for TD), pressure in mmHg, time in msec and VTI in cms.

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