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The right ventricle Echocardiographic dimensions of the heart.

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Abstract

Because of the detailed right ventricular (RV) anatomy, echocardiographic quantitative evaluation of RV function has been difficult for many years. Finding an efficient and comprehensive echocardiographic parameter for RV functional evaluation remains a challenge. The analysis provides a list of the most studied and currently used RV function parameters, along with their observed normal values, as well as the benefits and drawbacks of using them. In everyday clinical practice, combinations of these criteria are used, each of which provides only partial knowledge about the RV status. In the assessment of RV activity, myocardial velocity and stress concentration imaging have shown impressive outcomes. There is a hope that experimental myocardial deformation parameters and three-dimensional echocardiography-derived parameters can improve RV analysis, but numerical calculations are still needed.

Introduction

Quantitative evaluation of cardiac function has mainly focused on the left ventricle (LV), with the right ventricle (RV) sometimes referred to as the "ignored ventricle" despite the fact that it is expected to regulate the same volume as the LV in most individuals. The right ventricle effectiveness as a measure of disease progression over a variety of cardiac conditions has recently become more recognized [1, 2, 3], and as a result, further emphasis has been made to enhance the RV's routine assessment. Echocardiography remains the first-line modality for assessing RV structure and function, but conventional M-mode, two-dimensional imaging, and Doppler parameters have restrictions [[4]]. New measures, such as three-dimensional (3D) echocardiography, Doppler tissue imaging (DTI), and speckle-tracking strain, aim to overcome these limitations and, after demonstrating promise in the field of medical imaging, are increasingly being used for routine clinical use. Considering their limits, currently the best practice suggests performing at least two quantitative tests during a standard transthoracic echocardiogram [[7]]. These can provide diagnostic as well as prognostic information.

Because of the many hypotheses that really should be made, volumetric quantification of the RV function is difficult. As a result, many doctors rely on visual estimation to determine the size and function of the RV. In medical practice, echocardiography is the investigation of choice for assessing the morphology and function of the RV because it is non-invasive, readily available, relatively inexpensive, and has no health effects. Recent advancements have resulted in the development of many new approaches for analyzing the RV, each with advantages and disadvantages. Doppler myocardial imaging (DMI), speckle monitoring, or 3D echocardiographies are all examples of 3D echocardiography. Some of the techniques that can now contribute to a deeper understanding of RV function include Doppler myocardial imaging (DMI), speckle monitoring, and 3D echocardiography (3D Echo).This article will evaluate the widely accessible echocardiographic techniques and criteria for RV assessment in medicinal practice and study, with a focus on acquired heart diseases.

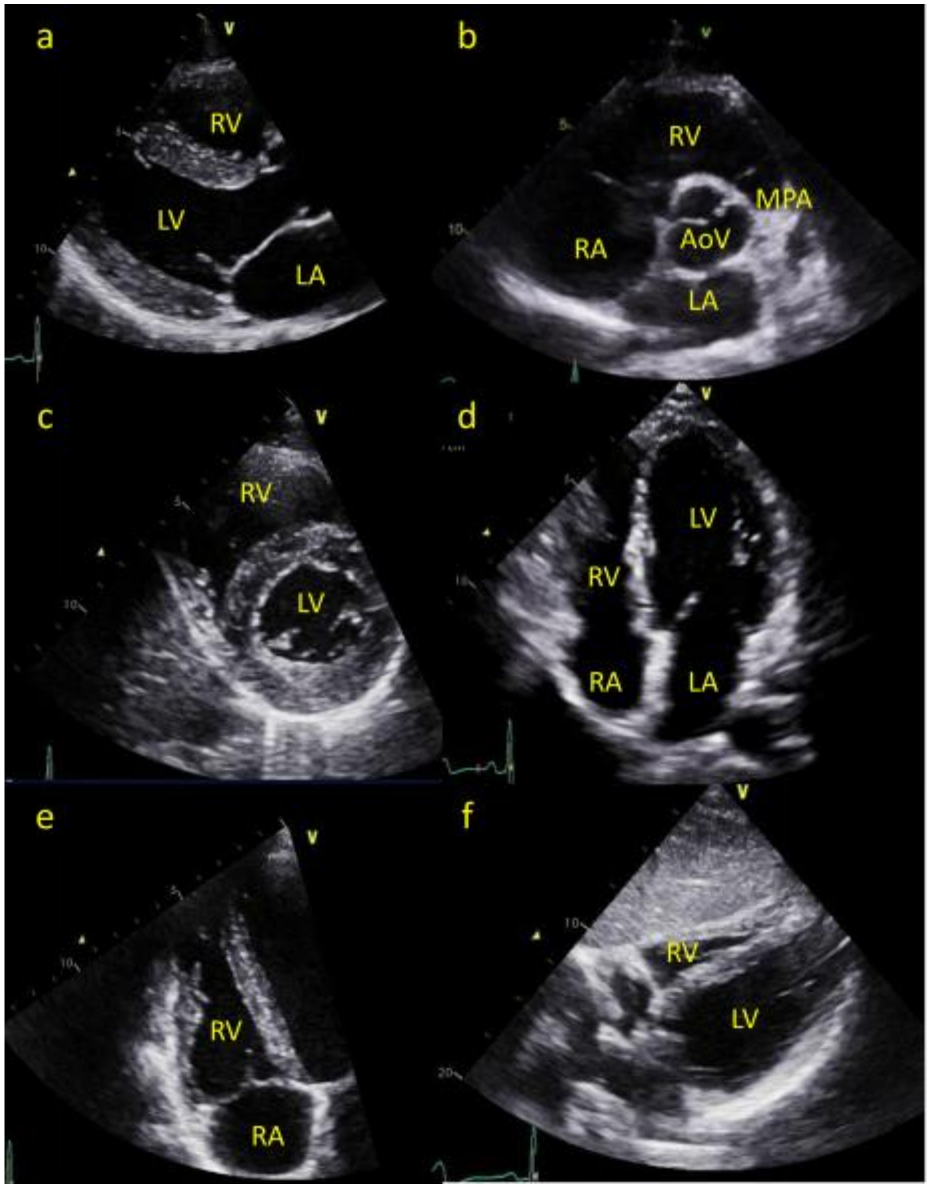
Right Ventricular Structure and Function

The right ventricle is the heart's most anterior organ, situated behind the lower sternum. It has a complicated structure, appearing triangular from the front and crescent from the circumferential portion of the heart, with the septum being the most significant outline factor. The septum overhangs into the RV in both systole and diastole under typical loading conditions. Since this complex geometry cannot be matched to basic geometrical models, measurement of RV volume and function based on two-dimensional (2D) tomographic views is severely limited.

The right ventricle is composed of 3 distinct portions:

- the smooth muscular inflow (body)
- the outflow region
- the trabecular apical region

These structures are bundled around the left ventricle to form a structure whose presence varies greatly depending on the echocardiographic picture planes used.



Three Different anatomical segments of the RV can be differentiated in a normally formed RV with atrio - ventricular and ventriculo-arterial conjunction and regular tricuspid and pulmonary valves:

- The inlet part, which accommodates the tricuspid valve
- The trabeculated apical part
- The outlet part.

The composition of myocytes in the RV wall varies from that of the three-layered LV. In the subendocardial layer, myocytes are primarily directed longitudinally.

As a result, the RV contraction mechanism is primarily longitudinal. The diameter of the RV free wall is just 3–5 mm, (13–14,) and the RV mass is roughly one-fourth that of the LV. (15 , 16) Despite this, the RV will pump blood at about the same rate and volume as the LV due to the lower displacement and higher peripheral resistance of the pulmonary artery bed. The capacity of both ventricles is to ensure continued cardiac output and providing sufficient organ perfusion is dependent on three key mechanism: 1) the contractile state of myocardial tissue, 2) the pre-load, which presents the actual stretching of cardiac myocites prior to contraction, 3) and the afterload, which is known as the load against which the heart must contract to pump blood. Furthermore, due to ventricular interference, RV output is directly affected by LV functional ability. (18) During the cardiac cycle, the interventricular septum, pericardium, and typical muscle fibers all play important roles in promoting force transfer from the LV to the RV. (19) The LV contraction determines about one-third of the pressure produced in the RV.

The physiology of the right ventricle varies greatly from those of the LV, and they are optimized to cope with changes in volume load when working at low pressure. The dominant RV muscle fibers run longitudinally from the tricuspid annulus to the apex. Right ventricular function is vulnerable to increased afterload, with a narrow pressure range against which it can maintain normal cardiac output.(6) It, on the other hand, condones volume overload better, which changes RV geometry but has no effect on ejection sequence. (22) The right heart's specific physiologic environment has a direct impact on the phases of the cardiac cycle in the RV. During standard circumstances, the pulmonary artery's low end-diastolic pressure is easily exceeded by the pressure increase in the RV, resulting in a very short or even absent repolarization contraction time. Another feature that distinguishes RV physiology from LV physiology is the presence of a ‘hold' time during ejection. During the timeframe between the fall of RV pressure and the closing of the pulmonary valve, (24) ejection of blood is sustained, possibly due to the high electrical conductivity of the pulmonary circulation, which enables the preservation of blood velocity.

Structural Assessment of the Right Ventricle

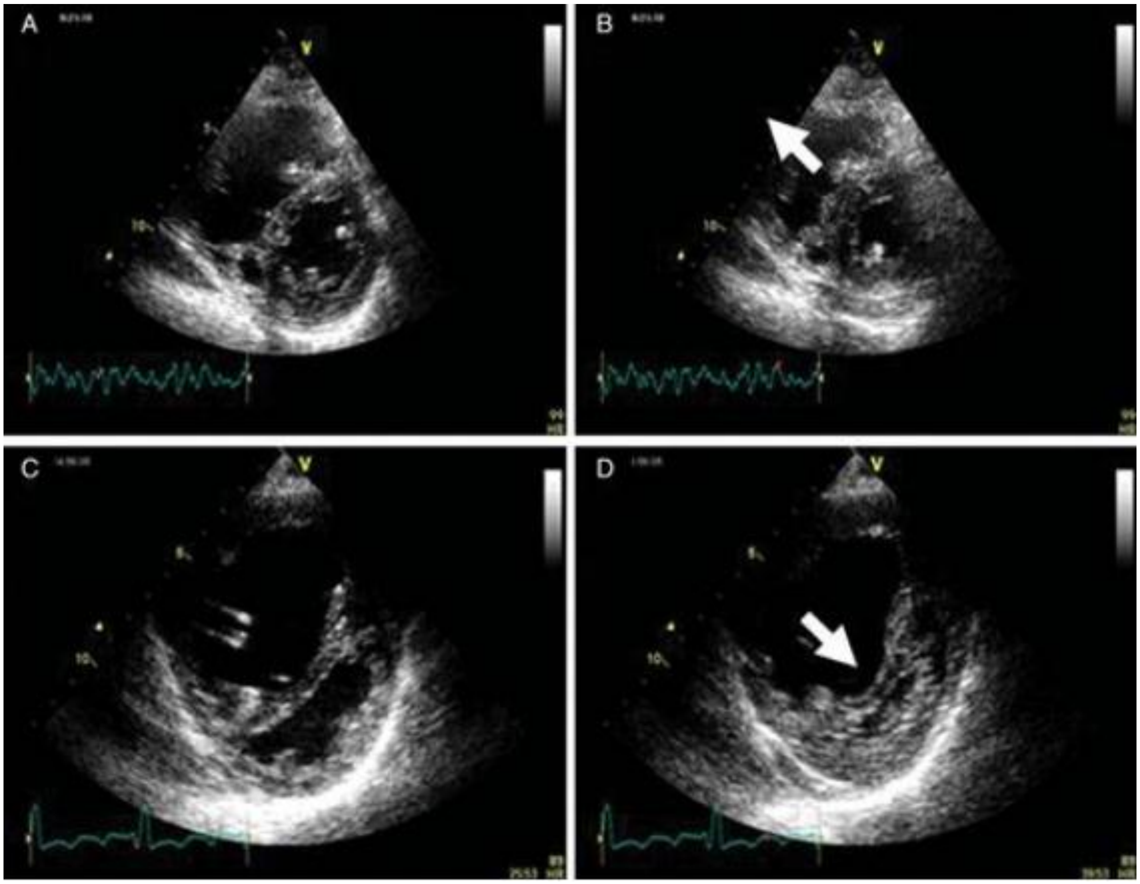
Both regular transthoracic echocardiograms should provide RV evaluation and should be conducted from several angles, including the anterior - posterior long-axis, parasternal right ventricular inflow and outflow perspectives, Apical four-chamber, apical viewpoint with a right ventricular focus, and subcostal views are all possible. Given the geometric complexity of the right ventricular, each view adds to the assessment of right ventricular function [10].

Table 1 Abnormal values for routine clinical measures of RV structure and function.

Parameter	Abnormal	Notes\Limitations
RV basal dimension	>4.2 cm	From apical 4-chamber view. Rotation of transducer may produce error.
RV outflow tract proximal dimension	>27 mm	From parasternal short axis view, anterior to the aortic valve. Limited normative data. Endocardial definition may be limited.
RV fractional area change	<35%	From apical 4-chamber view, excluding trabeculation. May be difficult to acquire due to poor endocardial definition. Load dependent. Neglects contribution of RVOT.
Tricuspid annular plane systolic excursion	<16 mm	M-mode from apical 4-chamber view. May underestimate RV function due to regionality. Only assesses longitudinal motion of the free wall. Highly angle dependent. Dependent on LV function.
Tricuspid annular systolic excursion velocity	<10 cm/sec	Tissue Doppler from apical 4-chamber view. Highly angle dependent. Only assesses longitudinal motion of the free wall.
3D RV ejection fraction	<44%	Image quality remains problematic.
RV index of Myocardial performance (DTI)	<0.55	Tissue Doppler imaging of lateral tricuspid annulus. May be normal if RA pressure is elevated.
RV index of Myocardial performance (PW)	<0.4	Pulsed wave blood pool Doppler of RVOT and tricuspid inflow. May be pseudo-normal if RA pressure is elevated.

Parameters of various RV segments can be calculated in each of the perspectives with reported normality limits in guideline documents (Table 1) [7]. When collecting these measurements, care should always be taken to ensure that the views are correctly aligned to demonstrate that the values obtained are valid.

The shape of the RV, which can be viewed in a parasternal short-axis view, can be used to achieve a qualitative assessment of the RV. When the RV is overwhelmed, the crescent shape disappears and the septum flattens, causing the LV to take form of the letter 'D,' resulting in impaired LV filling and a drop in cardiac performance. In conditions defined by RV volume overload, the septum flattens only in diastole, returning to its usual form in systole. When the RV is exposed to a pressure overload, the septum moves towards the RV in systole in the first step, retaining the altered form during the cardiac cycle as the condition worsens.



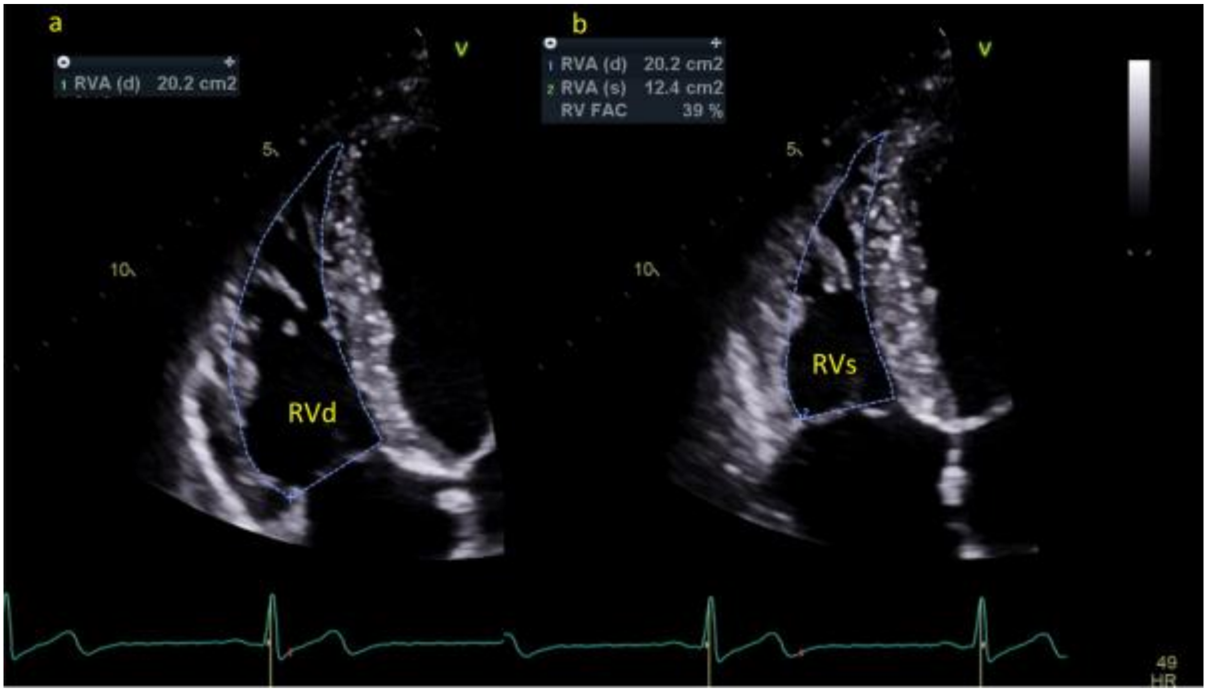
Views from the parasternal short axis at the mid-ventricular stage are showed in the above dimensions. (A & B) Patient with ostium secundum of atrial septal defect, right ventricular volume overload, and slightly elevated pulmonary artery pressures—flattening of the interventricular septum at end diastole (A) and recovery of form at end systole (arrow) (B) of (C and D) Patient with extreme pulmonary arterial hypertension and consequent severe right ventricular pressure excessive workload of the interventricular septum at end of the diastole (C) and at the end systole (arrow) (D).

Functional Assessment of the Right Ventricle

1) ***Right Ventricular Area and Fractional Area Change****:* The Fractional Area Change (FAC) is defined as

$$\frac{\text{End Diastolic Area} - \text{End Systolic Area}}{\text{End Diastolic Area}} \times 100$$

Configure tracking of the right ventricular endocardium at both end-diastole and end-systole in a four chambers or RV oriented apical view, without including the trabeculation in the wall, gives fractional area improvement (as the figure below showed).



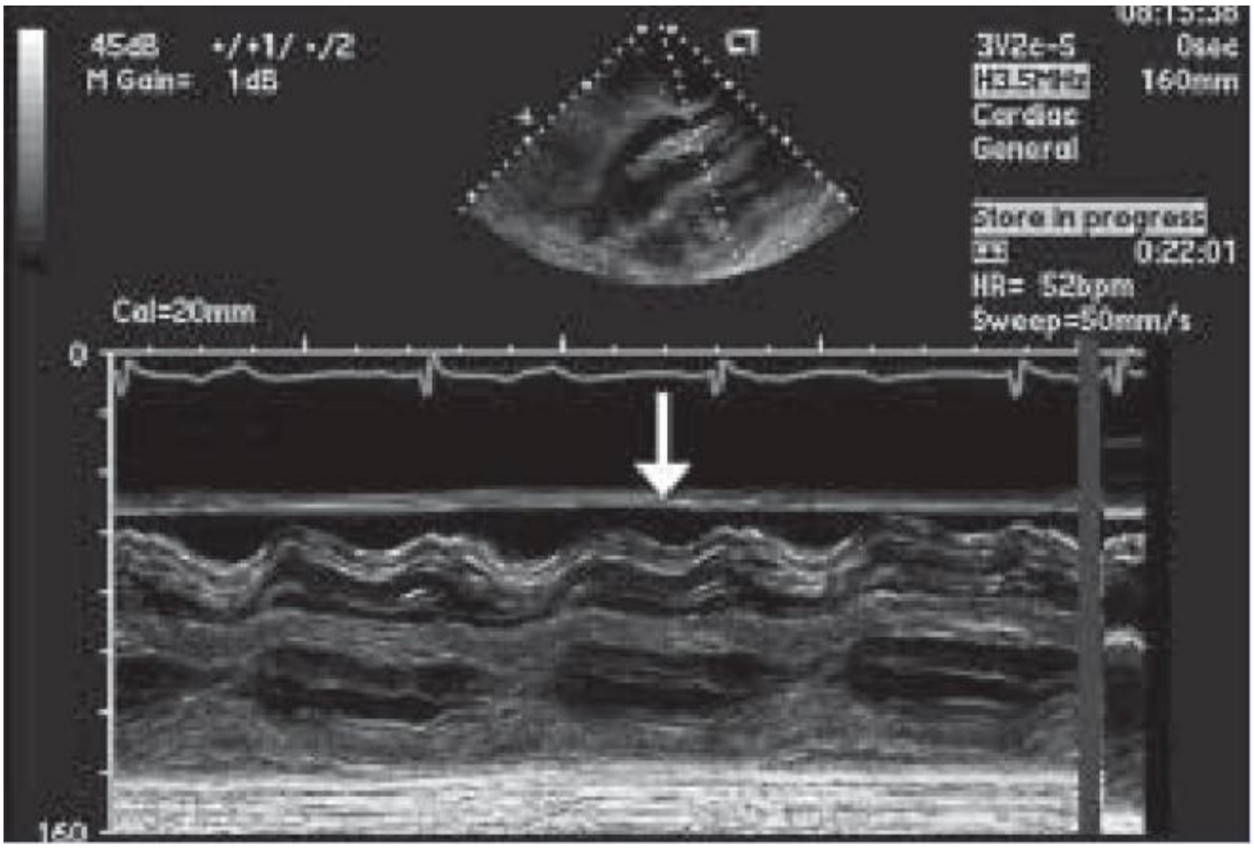
Measurement of right ventricular fractional area changes (RV FAC). Panel a, RV endocardial border traced at end-diastole; Panel b, RV endocardial border traced at end-systole. Abbreviations: RV, right ventricular; RVd, right ventricle at end-diastole; RVs, right ventricle at end-systole; FAC, fractional area change.

On cardiac magnetic resonance imaging (CMR), this parameter, FAC, has been found to be positively correlated well with right ventricular ejection fraction, with a rate larger than 35% assumed natural [7]. Decreased FAC was shown to be an alternative indicator of heart failure, cardiovascular problems, stroke, and mortality in pulmonary embolism cases [14]. A meta-analysis indicates that it is more reliable as a measure of RV feature than tricuspid annular plane systolic excursion (TAPSE), though good views must be obtained [15].

*2) **Two-Dimensional (2D) Volume and Ejection Fraction (EF) Estimation***

Because of the uncertainty of the right ventricular mechanics, 2D EF measurement is complicated and restricted by the assumptions need. It is divided into two types:

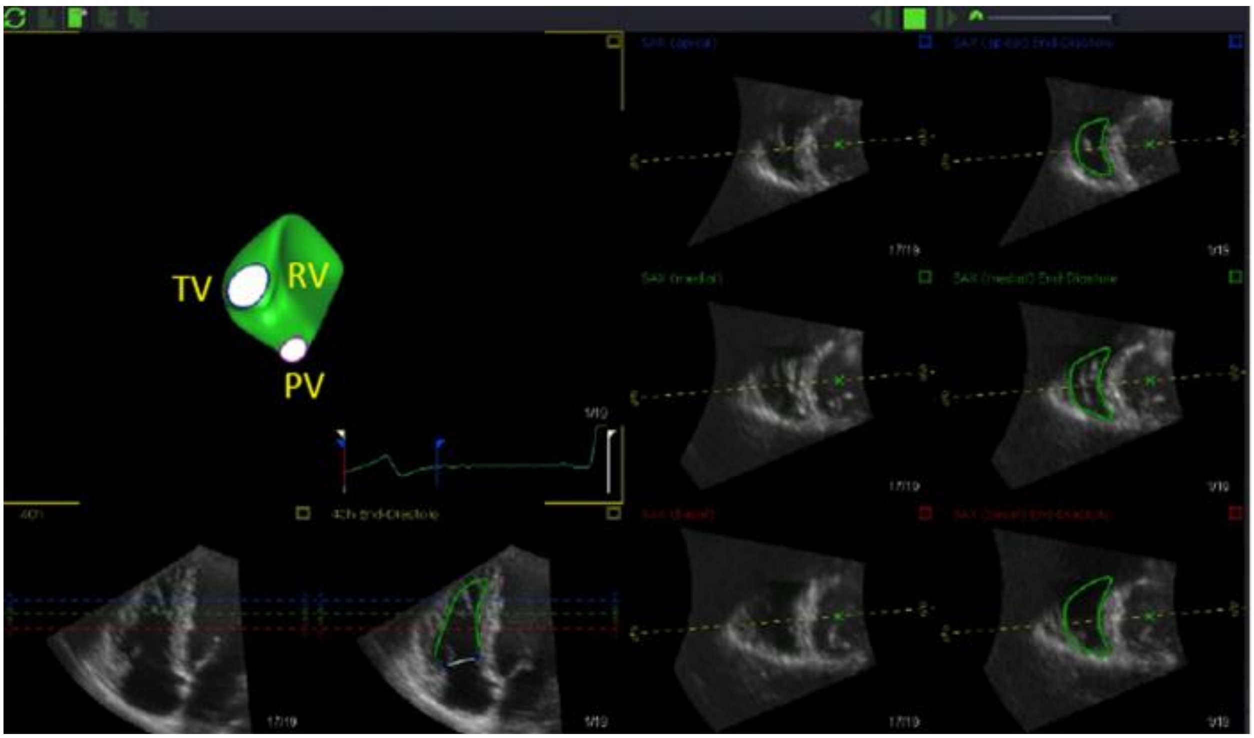
- Area-length approaches: was traditionally derived from angiographic evaluation, necessitates approximation of right ventricular geometry, which is typically based on ellipsoidal projections.
- Disk summation measures: This is typically performed in the apical view, excludes the right ventricular outflow tract (RVOT) and thus underestimates EF. Both methods are not recommended for routine RV evaluation due to their inaccuracy [7].



Two-dimensional (2D) subcostal view of the right ventricle (RV); subcostal M-mode of RV with 2D inset demonstrating late diastolic collapse of the RV free wall (arrow).

3) ***Three-Dimensional (3D) Volume and Ejection Fraction Estimation:*** Since it takes into account complex RV geometry, three-dimensional volume measurement outperforms two-dimensional volume measurement. Studies have confirmed the positive association between MRI and in vitro studies [17]. The latest suggested guideline ranges, on the other hand, indicate a substantial difference between low and upper values. For example, the 'normal' end systolic

volume ranges from 12 to 45 mL/m2 [7]. As compared to 2D evaluation, three-dimensional echocardiography has been shown to have less systemic underestimation and better test-retest reliability [18]. Owing to 3D imaging's technological limitations as well as system performance limitations, the prevailing recommendation is that 3D echocardiography is used in combination with 2D imaging in the evaluation of RV ventricular volumes and function.



3D echocardiography is also used to determine RV volumes and ejection fraction. After identifying the endocardial borders in the 3D dataset, end-diastolic and end-systolic volumes are calculated and used to measure the correct ventricular ejection fraction. On a modelled RV chamber, the influence of the convex RV surface of the interventricular septum on the shape of the left venticular cavity can be seen. RV, right ventricle; TV, tricuspid valve; PV, pulmonary valve; 3D, three dimensional.

Conclusion

The right ventricle's echocardiographic testing is still facing difficulties due to technical reasons in the imaging studies, as well as its complex geometry and function. Although qualitative methods of assessment are widely used, current recommendations advocate for the incorporation of more quantitative methods into routine echocardiography. When traditional techniques to right ventricular assessment become accessible, such as 3D echocardiography, they should be used in combination with more proven quantitative measures to ensure that an effective assessment of the right ventricle is part of routine managements.

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