Review Article

# My Approach to Right Ventricular Longitudinal Strain with Automated 2D and 3D Software

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## Abstract

Right ventricular strain analysis has emerged as an important diagnostic tool in the detection of early right ventricular systolic dysfunction not detected by conventional echocardiography techniques. Furthermore, it is capable of providing additional diagnostic and prognostic information to the traditional parameters for evaluating right ventricular systolic function in various pathologies. The echocardiography method of choice for its assessment is longitudinal strain derived from speckle-tracking. This method has been shown to be more sensitive for small changes in systolic function when compared to tricuspid annular plane systolic excursion, tissue Doppler imaging of the tricuspid annular s' wave, and right ventricular fractional area change. Advances in artificial intelligence and software with automated analysis have been introduced to this scenario with the aim of making the method simpler and quicker to apply, with lower inter- and intra-observer variability. The objective of this review article is to demonstrate the technique step by step, from image optimization and acquisition to interpretation of results, with illustrative figures of selected cases.

## Introduction

The assessment of right ventricular (RV) systolic function has long been neglected. In recent years, there has been a great leap in the understanding of the importance of the RV in cardiac function. This has given rise to advanced non-invasive echocardiographic techniques that make functional assessment more accurate.

Several different acquired and congenital cardiac diseases can affect RV systolic function, leading to reduced stroke volume and cardiac output.

The analysis of RV systolic function has extremely peculiar characteristics. First, its complex geometry prevents two-dimensional (2D) volumetric analysis with the application of geometric assumptions routinely used to measure left ventricular volumes. The RV is composed of an inlet, body, apical region, and outflow tract (Figure 1), making it necessary, by means of 2D echocardiography, to use different views in different echocardiographic windows to assess its function, and it is impossible to estimate RV ejection fraction using 2D echocardiography. Furthermore, estimated RV systolic function is influenced by phasic changes in breathing and left ventricular mechanics that interfere with ventricular interdependence. It is also fundamental to understand that the myocardial contractility of the RV walls shows a different pattern of deformation in relation to the left ventricle. Finally, the RV myocardial wall is more trabeculated, which makes it more difficult to define its endocardial borders and the blood-tissue interface.[1]

RV systolic shortening occurs mainly due to the myocardial deformation of the fibers with longitudinal arrangement, which correspond to approximately 75%, and the contribution of the deformation of the radial fibers is very low. It is precisely for this reason that RV longitudinal strain has emerged in recent years as an

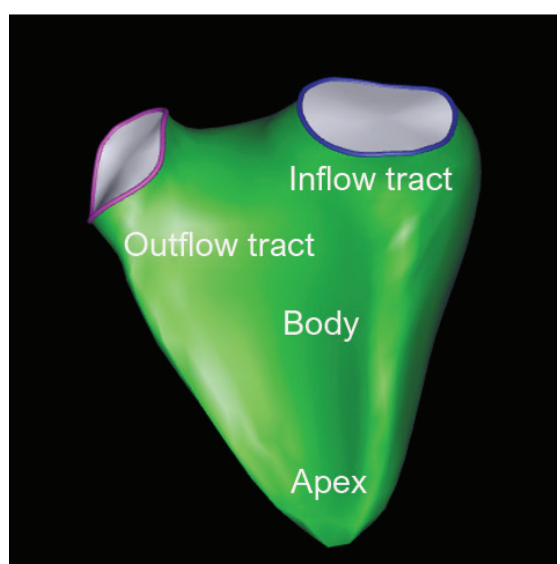


**Figure 1 –** *Three-dimensional reconstruction of the right ventricle using automated software demonstrating its peculiar geometry.*

## Keywords

Echocardiography; Myocardium; Left Ventricular Dysfunction.

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important tool in the assessment of RV systolic function.[2]

There are two ways to study RV longitudinal strain: strain derived from tissue Doppler and strain derived from speckle-tracking. The second form is preferred and is widespread in the main echocardiography laboratories worldwide, due to the non-dependence on the angle between the longitudinal deformation and the ultrasound beam. Using the speckle-tracking technique, it is possible to measure RV free wall longitudinal strain (mean peak systolic strain of the 3 free-wall segments) and the 6-segment longitudinal strain (mean peak systolic strain of the 3 septum segments and the 3 segments of the free wall) (Figure 2). RV free wall longitudinal strain is the most validated technique due to the fact that left ventricular mechanics participate greatly in septal deformation.[3-5]

Initially, the existing software on the market for evaluating 2D strain derived from speckle-tracking were exclusively intended for evaluating left ventricular myocardial deformation, and analysis of the RV was performed using this same software, which often made the analysis difficult, leading to inaccurate results.

With technological advances and the emergence of artificial intelligence, it is now possible to analyze RV longitudinal strain in a completely automated manner, using 2D and 3D images with dedicated software for this purpose, with minimal need for adjustments.[1]

## Clinical applicability

There are multiple clinical indications for evaluating RV systolic function by means of longitudinal strain. It plays an important role in several diseases involving the RV. It is already well documented in the literature that RV longitudinal strain has additional prognostic value to conventional echocardiographic parameters as a predictor of death and rehospitalization due to heart failure, detection of subtle involvement in patients with hypertrophic cardiomyopathy, and prediction of the development of this disease in family members. It is also able to predict survival of major cardiac events after acute myocardial infarction more accurately than the tricuspid annulus plane systolic excursion (TAPSE) and the RV fractional area variation (FAC),[2] RV longitudinal strain having a better correlation with magnetic resonance imaging in estimating its systolic function.[6-10]

RV longitudinal strain already demonstrates superiority to TAPSE in predicting events in different etiologies and degrees of pulmonary hypertension. In severe tricuspid insufficiency, it is an independent factor associated with all-cause mortality, demonstrating additional prognostic value to TAPSE and FAC. Finally, in congenital heart diseases such as tetralogy of Fallot, it is a sensitive parameter for detecting RV systolic dysfunction and a predictor of functional capacity on exertion and postoperative systolic dysfunction.[2,11]

## Image acquisition

The quality of the images acquired is fundamental to obtain accurate results. The steps for acquiring ideal images for 2D longitudinal strain derived from speckle-tracking in automated software are as follows:

1. Acquire an apical 4-chamber view focused on the RV (Figure 3). Analysis in this view is preferable because of better visualization of the RV free wall. For acquisition, after performing a conventional 4-chamber apical view, it is

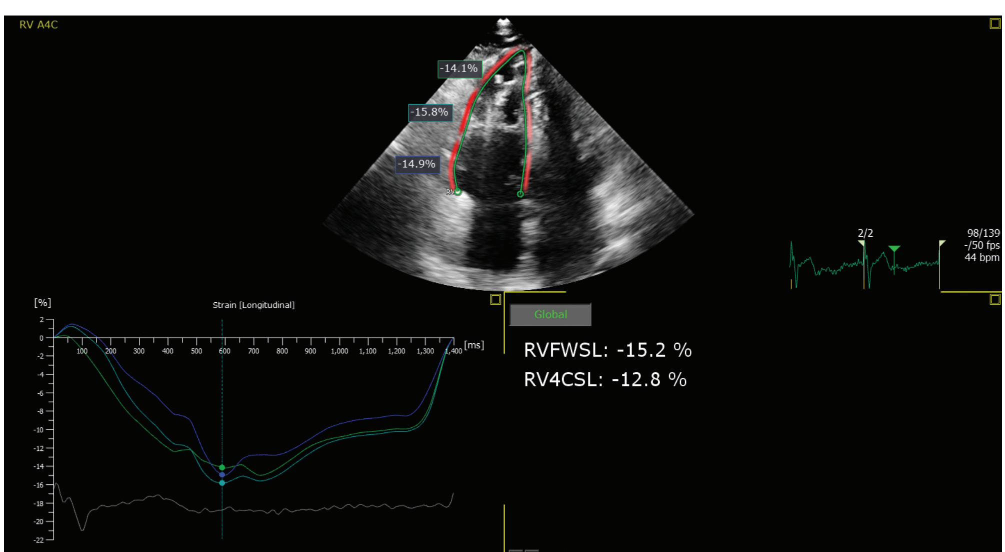


**Figure 2 –** *Analysis of free wall longitudinal strain and 6-segment longitudinal strain, estimated at –15.2% and –12.8%, respectively, in a patient with arrhythmogenic RV cardiomyopathy, using automated software.*

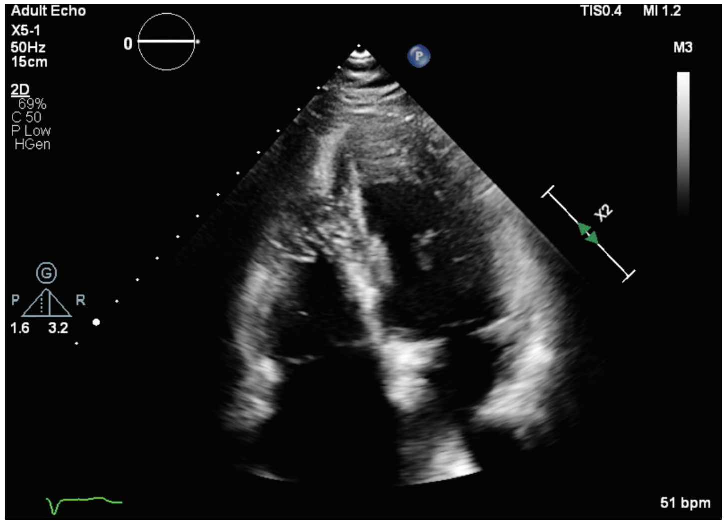


**Figure 3 –** *Apical 4-chamber view focused on the right ventricle.*

necessary to move the patient's right shoulder backwards and tilt the transducer toward the liver. In this manner, it is possible to keep the emitting ultrasound source close to the apex of the left ventricle with the RV properly positioned in the center of the image.

2. The image must have a frame rate between 50 and 80 Hz. To optimize the temporal resolution, it is necessary to reduce the sector width and the depth.

3. The image must be acquired after at least 2 to 3 cardiac cycles with the patient in expiratory apnea, with the goal of better subsequent recognition of the speckles by the software.

4. In the current automated software, it is not necessary to mark the effective time of RV systole (time from the peak of the R wave to the closure of the pulmonary valve), which was routinely done for analysis in non-automated software and usually acquired by means of pulsed Doppler of the RV outflow tract.

5. For accurate results, it is ideal for the patient to have a heart rate between 60 and 100 bpm and a regular heart rhythm. If the patient is in atrial fibrillation rhythm, heart rate variability between beats should not exceed 10%.[2,3]

When measuring RV longitudinal strain by means of 3D echocardiography with automated software that uses artificial intelligence, it is possible to measure RV free wall longitudinal strain from a "full volume" acquisition in the dynamic heart model (DHM) modality. The steps to acquire a large 3D pyramidal block that contains the entire RV geometry consist of the following:

1. Perform an apical 4-chamber view focused on the RV.

2. Activate the heart model (HM) acquisition mode, preferably with a double layout, paying attention to the fact that the lateral size of the 3D block and the width of the elevation contain the entire RV (Figure 4).

3. Ideally, the volume rate of the 3D block should be greater than 20 Hz, requiring adjustments to the width of the elevation and the lateral size to optimize the temporal resolution.

4. At least 2 to 3 cardiac cycles must be acquired, with the patient in expiratory apnea and preferably regular heart rhythm.[1,12]

## Analysis of results

In recent years, despite demonstrating that the evaluation by RV longitudinal strain using the speckle-tracking method in 2D echocardiography has important implications for diagnosis, prognosis, and treatment of patients in different clinical contexts, its application in daily practice has been challenged by a lack of the standardization of methods, software, and reference values. A 2016 publication suggested cutoff values of −20.2% for the arithmetic mean of the 6-segment model (including the free wall and interventricular septum) and −23.3% for the 3-segment model (free wall).[13]

Since then, a task force[3] and a review article[14] have attempted to standardize the acquisition method, strengthening as a standard the acquisition of an apical 4-chamber view focused on the RV. However, in many articles published to date, evaluation began from the apical 4-chamber view. There is also a great variability of results depending on manufacturer, software developer, and sex (higher values for women).

Furthermore, data are limited for healthy individuals over 60 years of age and are still scarce and inconsistent for the pediatric population, with values ranging from −20.8% to −34.1%, with a mean of −30.1% in the 3-segment model (free wall), for example.

The use of automated software with artificial intelligence, in addition to optimizing the workflow, may help standardize the results in the future, reducing the interobserver difference.

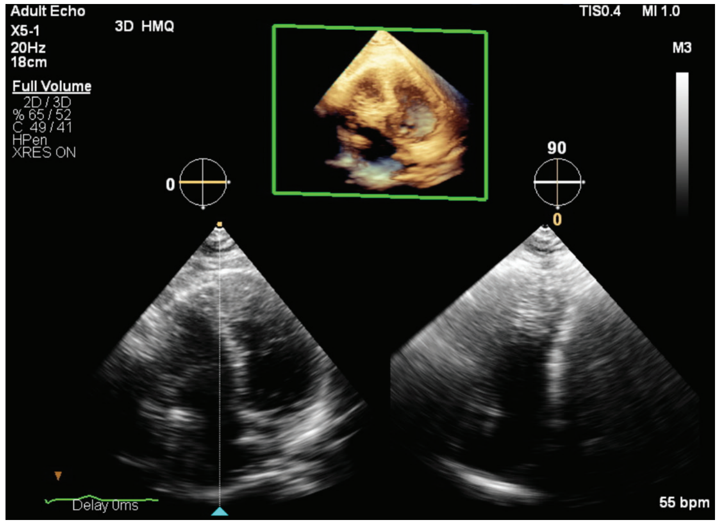


**Figure 4 –** *"Full volume" 3D acquisition in HM mode with dual layout.*

As previously mentioned, RV strain derived from speckle-tracking can be used to evaluate patients with pulmonary hypertension (including patients with acute or chronic pulmonary embolism), valve diseases (mitral stenosis, functional tricuspid insufficiency), and heart failure with reduced or preserved ejection fraction. A recent review article[15] cited the advantages of the method as an additional parameter in the assessment of RV systolic function, with high predictive value, high reproducibility, and mechanical assessment of the entire RV free wall thickness that are relatively load- and angle-independent. In addition, it has high availability, low cost, short acquisition time, and no need for advanced training, albeit with the disadvantages of lack of consensus regarding normality values and the 6- or 3-segment model, the need for a high temporal resolution, difficulty with limited echocardiographic windows and free wall visualization, and the need for stable heart rhythm. The applicability of RV longitudinal strain has shown to be more robust in studies focused on the assessment of pulmonary hypertension, heart failure with reduced ejection fraction, and tricuspid insufficiency. In other clinical contexts, such as heart failure with preserved ejection fraction, aortic stenosis, and mitral insufficiency, data remain scarce and further investigation is needed.[15]

Regarding the analysis of the results, instantaneous strain values are displayed on a percentage myocardial strain rate curve as a function of time. In the case of longitudinal strain, the curves are traced below the neutral horizontal line, considering the nadir as the maximum value (Figures 5, 6, 7, 8 and 9). By convention, systolic fiber shortening is represented by negative values, and lengthening is expressed by positive values. The result is shown in percentage values. Normal longitudinal strain values vary according to age, sex, and software. The lower limit of normality is −20.0% for the 3-segment model (free wall) and −18.2% for the 6-segment model, using TomTec automated software with images from Philips, Siemens, and General Electric ultrasound systems, as suggested in a recent study,[16] with a sample of 1,913 patients in which this system was used.

Another advantage of evaluating the free wall using the method of RV strain compared to traditional quantification methods is that we can analyze the strain values in the apical, middle, and basal segments, as exemplified in Figure 8 (non-compaction cardiomyopathy) and Figure 9 (hypertrophic cardiomyopathy, apical form), where the absolute values were notably reduced in the apical segments of both cases.

After acquiring a 3D pyramidal block of the RV, it is possible to perform an automated analysis using dedicated software (for example, 3D Auto RV by Philips). In addition to providing detailed information on 3D RV volumes and ejection fraction (Figure 10), it is possible to obtain 2D parameters from the 3D block, such as linear measurements and systolic function parameters, including TAPSE, FAC, and 2D strain in the model that includes the septum and free wall, as in the example below (Figure 11), with values of −17.6% and −18.9%, respectively.

## Conclusion

Automated 2D and 3D software facilitates the workflow, making it possible to incorporate the method of 2D RV longitudinal strain into clinical practice. The results obtained in recent studies demonstrate a prognostic role in the clinical context of different diseases, such as heart failure with reduced ejection fraction, tricuspid insufficiency, and pulmonary hypertension.

A value of −20% is considered as the lower limit of normality for RV free wall strain, considering the latest literature data obtained with TomTec's "agnostic" automated software.[16]

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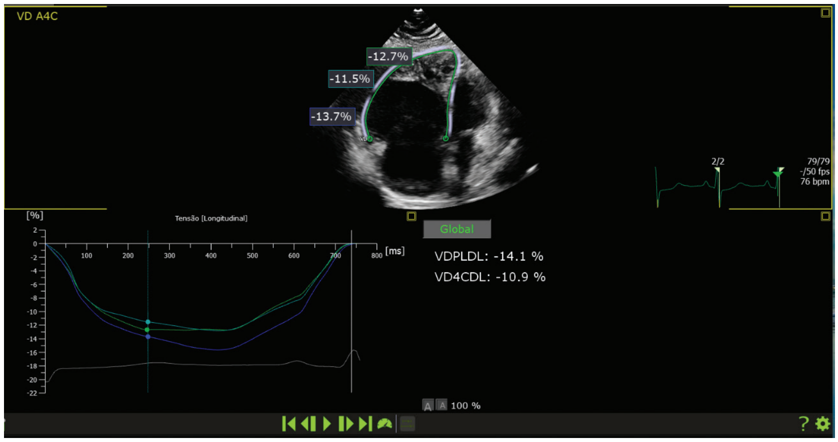


**Figure 5 –** *AutoStrain RV TomTec: Primary pulmonary hypertension (obtained value of –14.1% for free wall longitudinal strain).*

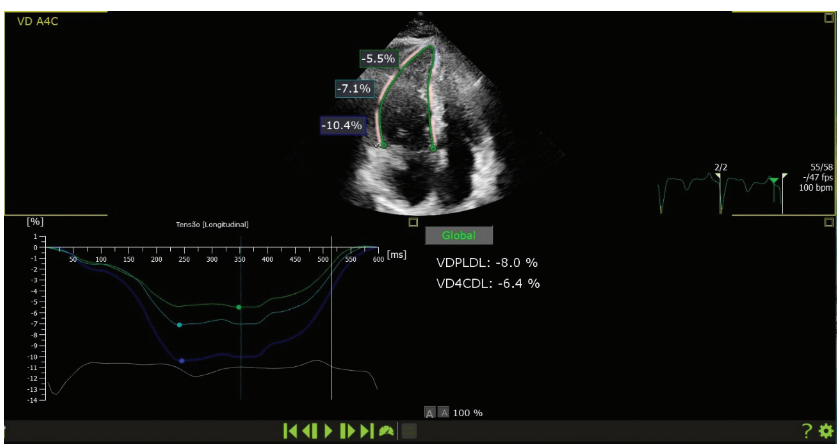


**Figure 6 –** *Pulmonary hypertension due to acute pulmonary thromboembolism (value of –8.0% obtained for free wall strain).*

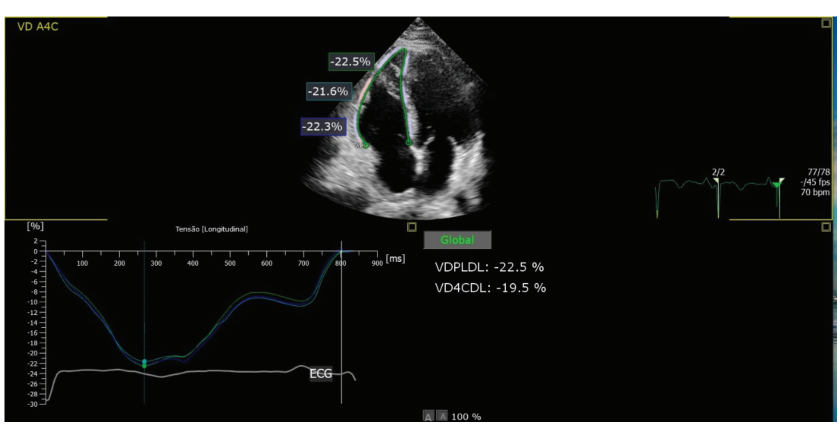


**Figure 7 –** *AutoStrain RV TomTec: examination performed on the same patient in Figure 6 with acute pulmonary thromboembolism two days after treatment with fibrinolytics and full anticoagulation (value of –22.5% obtained for free wall strain).*

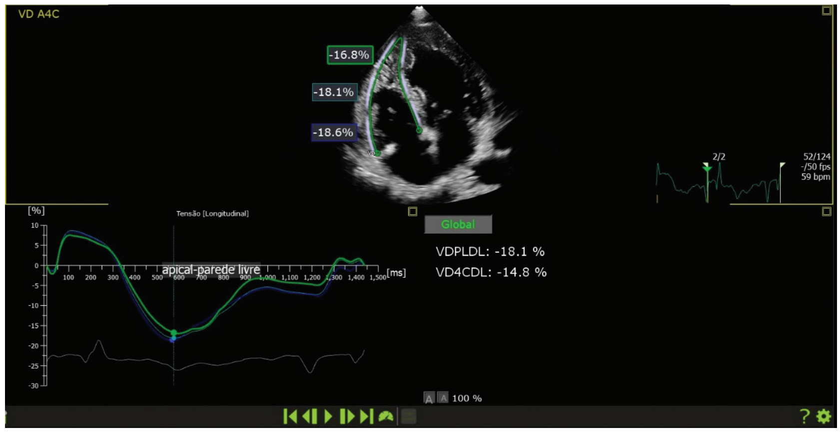


**Figure 8 –** *AutoStrain RV TomTec: non-compaction cardiomyopathy (value of –18.1% obtained for free wall strain).*

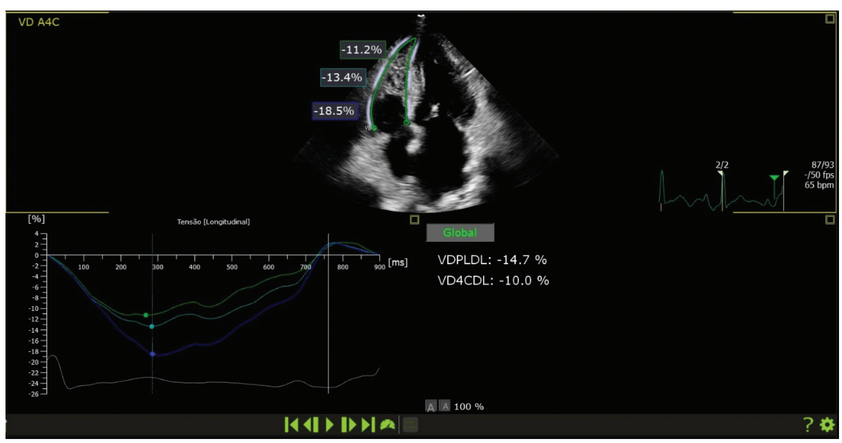


**Figure 9 –** *AutoStrain RV TomTec: apical form of hypertrophic cardiomyopathy (value of –14.7% obtained for free wall strain, with a lower absolute value in the apical segment).*

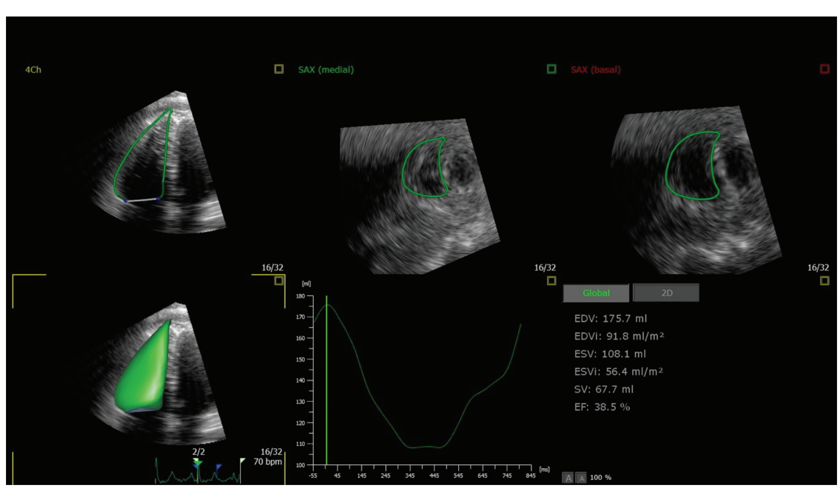


**Figure 10 –** *RV volumes and ejection fraction obtained automatically using the software 3D Auto RV (TomTec).*

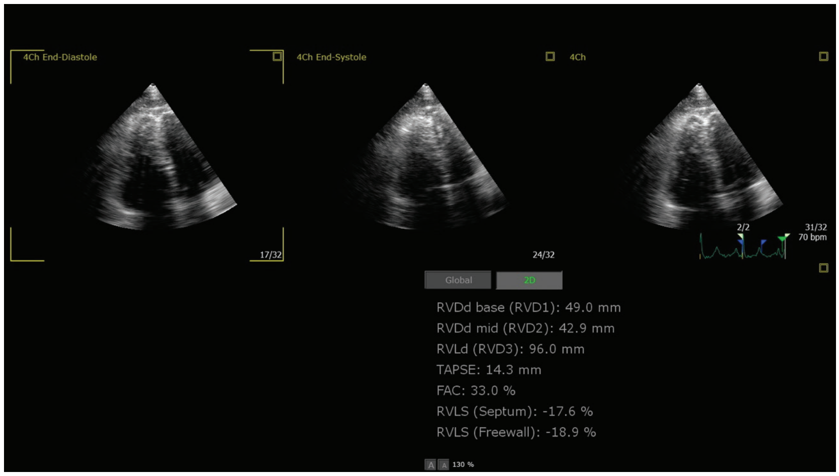


**Figure 11 –** *Information obtained automatically from a 2D image derived from the 3D volume, using the software 3D Auto RV (TomTec).*


### Author contributions

Writing of the manuscript e critical revision of the manuscript for intellectual content: França LA, Dutra LV.

### Potential Conflict of Interest

No potential conflict of interest relevant to this article was reported.

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### Study Association

This study is not associated with any thesis or dissertation work.

### Ethics approval and consent to participate

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