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RIGHT VENTRICULAR FREE WALL STRAIN: REDEFINING EARLY DETECTION OF RIGHT VENTRICULAR DYSFUNCTION IN CONTEMPORARY ECHOCARDIOGRAPHY - A REVIEW.

Cardiology

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ABSTRACT

The right ventricle (RV) plays a fundamental role in maintaining efficient cardiopulmonary circulation and overall cardiovascular performance. Traditionally, the clinical evaluation of right ventricular function has traditionally been more challenging compared with the assessment of left ventricular function due to the right ventricle's complex crescent-shaped geometry, thin myocardial wall, anterior position within the thoracic cavity, and its pronounced sensitivity to variations in preload and afterload conditions. Unlike the left ventricle, which has a relatively symmetrical structure and well-established volumetric assessment techniques, the right ventricle demonstrates intricate contraction patterns involving longitudinal shortening, radial motion, and interventricular interactions. These structural and functional characteristics make accurate and reproducible evaluation of RV performance particularly difficult using conventional imaging approaches. In routine clinical practice, many echocardiographic parameters have been widely utilized to estimate RV systolic function. These include tricuspid annular plane systolic excursion (TAPSE), RV fractional area change (FAC), and tissue Doppler–derived systolic velocity of the tricuspid annulus (S′). Although these parameters are simple, readily obtainable, and recommended in standard echocardiographic guidelines, they primarily reflect longitudinal motion of the basal RV segments and may not adequately represent global or regional myocardial performance. Furthermore, these indices are influenced by loading conditions and geometric assumptions, limiting their sensitivity for evaluating early or subclinical right ventricular dysfunction. As a result, subtle abnormalities in myocardial mechanics may remain undetected until the disease has progressed to more advanced stages. Recent technological advancements in echocardiographic imaging have significantly enhanced the ability to evaluate myocardial function beyond traditional measures. Among these innovations, speckle tracking echocardiography (STE) has emerged as a powerful and non-invasive technique for assessing myocardial deformation. STE analyzes the motion of natural acoustic markers within the myocardium, enabling quantitative assessment of strain, which reflects the percentage change in myocardial length during the cardiac cycle. This approach allows for detailed evaluation of regional myocardial mechanics independent of geometric assumptions and with minimal angle dependency. Right ventricular free wall strain (RV FWS), derived from speckle tracking echocardiography, has gained increasing attention as a sensitive and reproducible parameter for assessing intrinsic RV myocardial contractility. By focusing specifically on the longitudinal deformation of the RV free wall segments while excluding the interventricular septum, RV FWS provides a more accurate representation of RV myocardial performance. Importantly, multiple clinical studies have demonstrated that RV FWS can detect subtle or subclinical myocardial impairment earlier than conventional echocardiographic indices, thereby offering valuable insights into the early stages of disease progression. This review focuses to provide a comprehensive overview of the evolving role of right ventricular free wall strain in contemporary echocardiographic practice. The article discusses the anatomical and physiological basis of RV mechanics, the principles and methodology of strain imaging, and the clinical significance of RV free wall strain across a broad spectrum of cardiovascular conditions. Particular emphasis is placed on its application in diseases where RV dysfunction plays a pivotal role, including pulmonary artery hypertension, heart failure, congenital heart disease, acute pulmonary embolism, and valvular heart disorders. In addition to summarizing current evidence, this review also highlights the prognostic implications of RV strain analysis, demonstrating its value in risk stratification, disease monitoring, and therapeutic decision-making. Furthermore, potential limitations of the technique, including variability among imaging platforms, varies on image quality, and the influence of loading conditions, are discussed in detail. Future perspectives are also explored, focusing on emerging developments such as three-dimensional strain imaging, automated quantification, and the integration of artificial intelligence in echocardiographic analysis. Overall, RV free wall strain represents a significant advancement in the non-invasive assessment of RV function. By enabling earlier detection of myocardial dysfunction and providing deeper insights into RV mechanics, RV FWS has the potential to redefine conventional approaches to RV evaluation. Incorporating this parameter into routine echocardiographic assessment may enhance diagnostic accuracy, facilitate timely clinical intervention, and ultimately improve outcomes in patients with a wide range of cardiovascular diseases.

KEYWORDS

Right Ventricular Free Wall Strain, Right Ventricular Dysfunction, Speckle Tracking Echocardiography, RV Strain Imaging

1. INTRODUCTION

Assessment of ventricular function represents a fundamental component of cardiovascular evaluation and plays an important role in the diagnosis, prognosis, and management of numerous cardiac and pulmonary diseases. Ventricular performance determines the ability of the heart to maintain adequate circulation and tissue perfusion, making its accurate assessment essential in clinical cardiology. Historically, much of the emphasis in cardiac imaging and research has been placed on the assessment of left ventricular (LV) function. This focus is largely due to the left ventricle's primary role in systemic circulation and the relative ease with which its geometry and function can be assessed using conventional imaging techniques. As a result, parameters such as left ventricular ejection fraction (LVEF) have become well-established indicators of cardiac function and are routinely used in clinical practice to guide diagnosis and therapeutic decision-making.

In contrast, the right ventricle has traditionally received less attention in both clinical evaluation and research. For many years, the right ventricle was considered a passive chamber with a secondary role in maintaining cardiac output. However, accumulating evidence over the last two decades has demonstrated that RV function is a major determinant of clinical outcomes in a wide range of cardiovascular and pulmonary diseases. Conditions such as pulmonary hypertension, COPD, heart failure, congenital heart disease, and acute pulmonary embolism frequently involve impairment of right ventricular performance. In many of these conditions, the degree of RV dysfunction is closely associated with symptom severity, exercise intolerance, and overall prognosis. Consequently, there has been increasing recognition of the need for accurate and reliable methods to assess RV function in routine clinical practice.

The anatomical and physiological characteristics of the right ventricle make its assessment particularly challenging. Unlike the LV, which has a relatively symmetrical, ellipsoidal shape, the right ventricle exhibits a complex crescent-shaped geometry that wraps around the left ventricle. The RV is composed of distinct anatomical components including the inlet portion, the trabeculated apical region, and the outflow tract, each contributing to its unique contraction pattern. The RV wall is considerably thinner than that of the left ventricle and is composed predominantly of longitudinal myocardial fibers. As a result, right ventricular contraction is primarily driven by longitudinal shortening rather than circumferential contraction.

Furthermore, the right ventricle functions within the low-pressure pulmonary circulation, making it highly sensitive to alterations in preload and afterload. Even modest increases in pulmonary vascular resistance can significantly affect RV performance. These physiological characteristics, combined with the complex geometry of the chamber, limit the accuracy of conventional two-dimensional echocardiographic techniques for assessing right ventricular volumes and function. Unlike the left ventricle, standardized volumetric measurements for the RV are more difficult to obtain due to the lack of clear geometric assumptions that adequately represent its structure.

To overcome these challenges, several conventional echocardiographic assessment parameters have been developed to evaluate RV systolic function. Among the most widely used are tricuspid annular plane systolic excursion (TAPSE), right ventricular fractional area change (FAC), and tissue Doppler–derived systolic velocity of the tricuspid annulus (S′). These parameters are relatively easy to measure to obtain and have been incorporated into echocardiographic guidelines for the assessment of right ventricular function. TAPSE, for example, measures the longitudinal displacement of the tricuspid annulus during systole, reflecting the longitudinal contractile motion of the RV. Similarly, FAC estimates global RV systolic function by measuring the percentage change in RV area between diastole and systole, while tissue Doppler imaging provides information on myocardial velocity during contraction.

Although these parameters are widely adopted in clinical practice, they possess several inherent limitations. Many of these indices primarily reflect longitudinal motion of the basal segments of the RV rather than global myocardial performance. Additionally, measurements such as TAPSE and tissue Doppler velocities are angle dependent and may be influenced by loading conditions. These limitations reduce their sensitivity in detecting subtle or early myocardial abnormalities. Consequently, right ventricular dysfunction may remain undetected until structural and functional impairment becomes more advanced.

In recent years, significant technological advancements in echocardiographic imaging have led to the development of more sophisticated techniques capable of assessing myocardial mechanics in greater detail. Among these innovations, speckle tracking echocardiography (STE) has emerged as a powerful non-invasive method for evaluating myocardial deformation. STE analyzes the movement of natural acoustic reflections, known as speckles, within the myocardial tissue throughout the cardiac cycle. By tracking these speckles frame by frame, the technique allows quantitative assessment of myocardial strain and strain rate, which reflect the deformation and contractile properties of the myocardium.

Strain imaging provides valuable insights into myocardial mechanics that extend beyond conventional measurements of chamber motion or velocity. It allows for the detection of subtle changes in myocardial contractility before global functional parameters become abnormal. In the context of RV assessment, strain imaging has proven particularly beneficial due to the RV's predominantly longitudinal contraction pattern.

Among the various strain parameters derived from speckle tracking echocardiography, right ventricular free wall strain (RV FWS) has gained considerable attention. RV FWS specifically evaluates the longitudinal deformation of the RV free wall segments while excluding the interventricular septum, which may be influenced by left ventricular mechanics. By focusing on the intrinsic contractile function of the RV myocardium, this parameter provides a more accurate representation of right ventricular performance.

Recent studies have demonstrated that RV free wall strain is highly sensitive in detecting early or subclinical RV dysfunction in a variety of cardiovascular conditions. Reduced RV strain values have been associated with adverse clinical outcomes, increased disease severity, and poorer prognosis in patients with pulmonary hypertension, heart failure, and other cardiopulmonary disorders. Because of its ability to identify myocardial dysfunction before conventional parameters become abnormal, RV FWS is increasingly recognized as an important tool for early diagnosis, risk stratification, and disease monitoring.

In contemporary echocardiographic practice, the integration of advanced deformation imaging techniques has significantly enhanced the understanding of right ventricular mechanics. As research continues to expand, RV free wall strain is emerging as a key parameter that may redefine the approach to right ventricular functional assessment. Its incorporation into routine echocardiographic evaluation has the potential to improve diagnostic accuracy, facilitate earlier therapeutic interventions, and ultimately contribute to better clinical outcomes in patients with cardiovascular disease.

2. Anatomy and Physiology of the Right Ventricle

Understanding RV structure and mechanics is essential for accurate functional assessment. The right ventricle is composed of three main anatomical components:

1. Inlet portion containing the tricuspid valve apparatus
2. Trabeculated apical region
3. Outflow tract (infundibulum)

Unlike the thick-walled left ventricle, the RV has a relatively thin myocardial wall and relies predominantly on longitudinal fiber contraction for systolic function. The contraction pattern begins at the inlet and apex and progresses toward the outflow tract, producing a bellows-like motion that efficiently propels blood into the pulmonary circulation.

RV performance is strongly influenced by loading conditions. Increased pulmonary artery pressure, volume overload, or ventricular interdependence may significantly affect RV mechanics. Because of these complexities, accurate evaluation of RV function requires sensitive imaging modalities capable of detecting subtle changes in myocardial performance.

3. Conventional Echocardiographic Assessment of Right Ventricular Function

Echocardiography remains the most widely used non-invasive imaging modality for evaluating right ventricular (RV) structure and function in routine clinical practice. Due to its availability, safety, cost-effectiveness, and real-time imaging capability, transthoracic echocardiography plays a central role in the assessment of RV performance in patients with various cardiovascular and pulmonary diseases. However, because of the complex anatomy and contraction pattern of the right ventricle, accurate evaluation of its systolic function has historically been challenging.

The right ventricle demonstrates a complex contraction mechanism involving longitudinal shortening, inward movement of the free wall, and contribution from the interventricular septum. Unlike the left ventricle, whose contraction is largely circumferential and radial, RV systolic function is primarily dependent on longitudinal myocardial fibers extending from the base toward the apex. As a result, many conventional echocardiographic parameters for RV assessment focus on longitudinal motion of the tricuspid annulus.

Over time, several echocardiographic indices have been developed and recommended by professional societies for routine evaluation of RV function. Among the most commonly used parameters are Tricuspid Annular Plane Systolic Excursion (TAPSE), Right Ventricular Fractional Area Change (FAC), and Tissue Doppler–derived systolic velocity of the tricuspid annulus (S′ velocity)**.** These parameters are relatively simple to obtain and have demonstrated reasonable reproducibility in clinical practice. Nevertheless, each of these indices possesses certain limitations, particularly in detecting subtle or early myocardial dysfunction.

3.1 Tricuspid Annular Plane Systolic Excursion (TAPSE)

Tricuspid annular plane systolic excursion (TAPSE) is one of the most widely used and easily obtainable echocardiographic parameters for evaluating RV systolic function. TAPSE measures the longitudinal displacement of the lateral tricuspid annulus toward the apex during systole. This measurement is obtained using M-mode echocardiography from the apical four-chamber view by aligning the M-mode cursor through the lateral tricuspid annulus and measuring the vertical distance of annular movement between end-diastole and end-systole.

Because the right ventricle relies predominantly on longitudinal fiber shortening for its contraction, the motion of the tricuspid annulus provides a useful surrogate marker for RV systolic performance. TAPSE is widely favored due to its simplicity, rapid acquisition, and high reproducibility even in routine clinical settings. A TAPSE value of 17 mm or greater is generally considered indicative of normal RV systolic function according to established echocardiographic guidelines.

Despite these advantages, TAPSE has several limitations. It reflects only the longitudinal motion of the basal segment of the RV free wall and therefore does not provide a comprehensive assessment of global RV function. In addition, TAPSE may be influenced by translational motion of the heart and by overall cardiac movement within the thoracic cavity. It may also remain preserved in certain disease states where regional myocardial dysfunction is present but basal motion remains relatively intact. Consequently, relying solely on TAPSE may lead to underestimation of early or regional RV dysfunction.

3.2 Right Ventricular Fractional Area Change (FAC)

Right ventricular fractional area change (FAC) is another commonly used echocardiographic parameter that provides an estimate of global RV systolic function. FAC is calculated using two-dimensional echocardiographic images obtained from the apical four-chamber view. The endocardial borders of the right ventricle are manually traced at end-diastole and end-systole to determine the RV end-diastolic area (RVEDA) and RV end-systolic area (RVESA). The percentage change in area between these two phases represents the RV fractional area change.

FAC can be calculated using the following formula:

$$FAC = (RVEDA - RVESA) / RVEDA \times 100$$

A value of 35% or greater is generally considered indicative of normal RV systolic function.

Compared with TAPSE, FAC provides a more comprehensive assessment of RV contractility because it incorporates changes in the entire RV cavity area rather than focusing solely on annular displacement. This parameter therefore reflects both longitudinal and radial components of RV contraction, offering a better estimate of overall ventricular performance.

However, FAC also has certain limitations. Accurate measurement requires optimal visualization of the RV endocardial borders, which may be difficult in patients with limited or poor acoustic windows or excessive trabeculation within the RV cavity. Additionally, the calculation assumes that the traced areas accurately represent the true ventricular geometry, which may not always be the case due to the irregular shape of the right ventricle. Inter-observer variability may also occur depending on the quality of image acquisition and manual tracing of the RV endocardium.

3.3 Tissue Doppler Imaging (S′ Velocity)

Tissue Doppler imaging (TDI) provides another useful method for assessing RV systolic function by measuring myocardial velocities during the cardiac cycle. Using pulsed-wave Doppler techniques, the systolic velocity of the lateral tricuspid annulus (S′ velocity) can be obtained from the apical four-chamber view. This measurement reflects the speed of longitudinal myocardial contraction of the right ventricle during systole.

The S′ velocity is typically measured by placing the sample volume at the lateral tricuspid annulus and recording the peak systolic velocity waveform. A peak systolic velocity of 9.5 cm/s or greater is generally considered normal and indicative of preserved RV systolic function.

One of the primary advantages of tissue Doppler imaging is its ability to provide quantitative assessment of myocardial motion with relatively high temporal resolution. It is also useful in situations where other measurements may be difficult to obtain, such as in critically ill patients or during bedside echocardiographic examinations.

However, the technique is not without limitations. Tissue Doppler measurements are highly angle dependent, meaning that the accuracy of velocity measurements depends on proper alignment of the ultrasound beam with the direction of myocardial motion. Any deviation from the optimal angle may result in underestimation of myocardial velocities. Additionally, TDI measurements can be influenced by overall cardiac motion and loading conditions, which may affect their reliability in certain clinical scenarios.

Limitations of Conventional RV Parameters

Although TAPSE, FAC, and tissue Doppler–derived S′ velocity remain essential components of routine echocardiographic evaluation, these conventional parameters have limited sensitivity for detecting early or subtle myocardial dysfunction. Most of these indices primarily reflect longitudinal motion or global chamber movement rather than intrinsic myocardial contractility.

Furthermore, these parameters are influenced by several physiological factors including preload, afterload, and ventricular interdependence. Changes in pulmonary artery pressure, intravascular volume status, or left ventricular function may significantly affect RV measurements without necessarily reflecting intrinsic myocardial impairment.

As a result, early stages of right ventricular dysfunction may remain undetected when relying solely on conventional echocardiographic indices. This limitation has driven the development of more advanced imaging techniques capable of assessing myocardial deformation and regional contractility with greater sensitivity.

Among these emerging techniques, speckle tracking echocardiography and strain imaging have gained considerable attention for their ability to provide detailed insights into myocardial mechanics. These methods allow for earlier identification of subclinical RV dysfunction, thereby enhancing the diagnostic and prognostic capabilities of modern echocardiography.

4. Speckle Tracking Echocardiography and Strain Imaging

Speckle tracking echocardiography represents a significant advancement in myocardial imaging. This technique tracks naturally occurring acoustic reflections within the myocardium across sequential frames of two-dimensional echocardiographic images.

By analyzing the motion of these speckles, STE calculates myocardial deformation parameters including:

- Strain
- Strain rate
- Myocardial displacement

Strain represents the percentage change in myocardial length relative to its original dimension. Negative strain values reflect myocardial shortening during systole, whereas positive values indicate myocardial lengthening.

Unlike tissue Doppler imaging, STE is largely angle independent and provides detailed regional myocardial analysis, making it particularly suitable for evaluating complex ventricular structures such as the RV.

5. Right Ventricular Free Wall Strain

Right ventricular free wall strain specifically evaluates the longitudinal deformation of the Right ventricular free wall segments. Typically, strain measurements are obtained from three segments:

- Basal Right ventricular free wall
- Mid Right ventricular free wall
- Apical Right ventricular free wall

The average of these three segments represents Right ventricular free wall strain.

Normal RV FWS values generally range from approximately **−20% to −25%**, though slight variations may occur depending on imaging software and population characteristics. Reduced strain values indicate impaired myocardial contractility and may signal early RV dysfunction even when conventional echocardiographic parameters remain normal.

By focusing exclusively on the free wall and excluding the interventricular septum, RV FWS provides a more accurate representation of intrinsic RV myocardial performance.

6. Clinical Applications of RV Free Wall Strain

6.1 Pulmonary Hypertension

Pulmonary hypertension imposes increased afterload on the right ventricle, leading to progressive RV remodeling and dysfunction. RV FWS has been shown to correlate strongly with disease severity, pulmonary artery pressures, and clinical outcomes. Reduced RV strain values are associated with worse prognosis and higher mortality.

6.2 Heart Failure
Right ventricular (RV) dysfunction frequently accompanies advanced left-sided heart failure and contributes significantly to adverse clinical outcomes. RV FWS enables early identification of subclinical RV involvement, thereby assisting in risk stratification and management decisions.

6.3 Pulmonary Embolism
Acute pulmonary embolism can cause sudden increases in RV afterload, resulting in RV dilation and dysfunction. Strain imaging can detect early myocardial impairment before conventional indices become abnormal, facilitating rapid diagnosis and appropriate therapeutic intervention.

6.4 Congenital Heart Disease
Patients with congenital heart diseases such as atrial septal defect (ASD), Tetralogy of Fallot (TOF), or repaired congenital anomalies often develop progressive RV dysfunction over time. RV strain imaging provides valuable insights into myocardial performance and long-term ventricular remodeling.

6.5 Valvular Heart Disease
Conditions such as severe tricuspid regurgitation or pulmonary valve disorders may significantly affect RV function. RV FWS allows clinicians to assess myocardial performance more accurately and determine the optimal timing for intervention.

Table 1. Comparison of Conventional Echocardiographic Assessment for Right Ventricular Function

Parameter	Measurement Method	Normal Reference Value	Advantages	Limitations
TAPSE (Tricuspid Annular Plane Systolic Excursion)	M-mode echocardiography measuring longitudinal movement of the tricuspid annulus	≥17 mm	Simple, quick, widely available, reproducible	Evaluates only longitudinal motion; does not represent global RV function; angle dependent
FAC (Fractional Area Change)	2D echocardiographic measurement of RV end-diastolic and end-systolic area	≥35%	Reflects global RV systolic function better than TAPSE	Dependent on image quality and geometric assumptions
S′ Velocity (Tissue Doppler)	Tissue Doppler imaging measuring systolic velocity of the tricuspid annulus	≥9.5 cm/s	Easy to obtain; useful bedside parameter	Angle dependent; influenced by loading conditions
RV Free Wall Strain	Speckle tracking echocardiography measuring myocardial deformation of RV free wall	≤ −20% (approx.)	Detects early myocardial dysfunction; angle independent; sensitive marker	Requires good image quality; software dependent

7. Prognostic Significance of RV Free Wall Strain
Multiple studies have demonstrated that RV strain parameters possess significant prognostic value across a range of cardiovascular diseases. Reduced RV FWS is associated with:

- Increased hospitalization rates
- Higher mortality risk
- Poor exercise tolerance
- Adverse remodeling

Compared with conventional parameters, RV strain often identifies high-risk patients earlier, allowing timely therapeutic interventions.

8. Limitations of RV Free Wall Strain
1. Although right ventricular free wall strain (RV FWS) derived from speckle tracking echocardiography has emerged as a promising and sensitive parameter for evaluating right ventricular function, it is not without limitations. Despite its ability to detect subtle or early myocardial dysfunction and provide valuable prognostic information, several technical and physiological factors may influence the accuracy, reproducibility, and clinical interpretation of RV strain measurements. Understanding these limitations is essential for proper application of the technique in routine echocardiographic practice.
2. One of the primary limitations of RV free wall strain analysis is its strong dependence on image quality. Accurate strain measurement requires clear visualization of the right ventricular endocardial border, particularly along the free wall segments. In patients with poor acoustic windows, such as those with obesity, chronic lung disease, or chest wall deformities, obtaining optimal images can be challenging. Inadequate image quality may interfere with proper tracking of myocardial speckles, leading to inaccurate or unreliable strain measurements. Additionally, excessive trabeculation of the right ventricle and its thin myocardial wall can sometimes make endocardial border delineation difficult, further affecting the reliability of strain analysis.
3. Another important limitation involves variability among different echocardiographic vendors and software platforms. Speckle tracking algorithms are not yet fully standardized across imaging systems, and different software packages may use distinct tracking methods, smoothing techniques, and strain calculation formulas. As a result, strain values obtained from one platform may not always be directly comparable with those derived from another system. This inter-vendor variability may lead to inconsistencies in reported RV strain values and complicate the establishment of universal reference ranges. Efforts by international echocardiographic societies are ongoing to standardize strain measurement methodologies and improve consistency across platforms.
4. RV free wall strain measurements are also influenced by loading conditions, particularly changes in preload and afterload. The right ventricle is highly sensitive to alterations in pulmonary vascular resistance and intravascular volume status. Conditions such as pulmonary hypertension, fluid overload, or sudden increases in pulmonary artery pressure may significantly affect RV myocardial deformation without necessarily reflecting intrinsic myocardial contractility. Similarly, acute hemodynamic changes may temporarily alter strain values, making interpretation more complex in certain clinical settings. Therefore, strain measurements should always be interpreted within the broader clinical and hemodynamic context.
5. Another challenge associated with RV strain analysis is the complex geometry and contraction pattern of the right ventricle. Unlike the left ventricle, which has a relatively symmetrical shape, the right ventricle demonstrates a crescent-like structure and involves multiple contraction components including longitudinal shortening, radial motion, and septal interaction. While RV free wall strain focuses on longitudinal deformation, it may not fully capture the multidirectional nature of RV mechanics. In addition, the interventricular septum contributes significantly to overall RV contraction, and exclusion of septal segments in RV free wall strain analysis may sometimes underestimate global ventricular performance in certain disease conditions.
6. Operator expertise and experience also play an important role in the reliability of RV strain measurements. Proper acquisition of the apical four-chamber view focused on the right ventricle is essential for accurate strain analysis. Incorrect imaging planes, inadequate frame rates, or poor tracking of myocardial segments can introduce measurement errors. Furthermore, manual adjustments during endocardial border tracing may contribute to inter-observer variability, particularly when performed by less experienced operators.
7. Time consumption and additional post-processing requirements represent another practical limitation. Compared with conventional echocardiographic parameters such as TAPSE or tissue Doppler velocities, strain analysis requires dedicated software and additional processing time. In busy clinical environments, this may limit its routine use unless automated analysis tools become more widely available.
8. Despite these limitations, ongoing technological advancements continue to improve the feasibility and reliability of RV strain

analysis. Developments in automated border detection, artificial intelligence–based tracking algorithms, and three-dimensional strain imaging may help overcome many of the current challenges associated with speckle tracking techniques.

9. To facilitate broader clinical adoption of RV free wall strain, further efforts are needed to establish standardized imaging protocols, uniform reference values, and consensus guidelines for strain measurement and interpretation. With continued refinement and validation, RV strain imaging has the potential to become an integral component of comprehensive right ventricular assessment in modern echocardiography.

9. Future Perspectives

Advancements in echocardiographic technology are expected to further enhance RV strain analysis. Emerging developments include:

- Three-dimensional strain imaging
- Automated strain quantification using artificial intelligence
- Integration with cardiac magnetic resonance imaging for multimodal assessment

Artificial intelligence–driven analysis may significantly reduce operator dependency and improve reproducibility, making RV strain evaluation more accessible in routine clinical practice.

10. CONCLUSION

Right ventricular function plays a fundamental role in maintaining efficient cardiopulmonary circulation and overall cardiovascular stability. In recent years, increasing clinical evidence has highlighted the importance of the right ventricle not only in pulmonary diseases but also in a wide range of cardiovascular conditions. Impairment of RV function has been associated with adverse clinical outcomes, increased morbidity, and higher mortality in diseases such as pulmonary hypertension, heart failure, pulmonary embolism, and congenital heart disorders. Therefore, accurate and timely assessment of right ventricular performance is essential for appropriate diagnosis, therapeutic planning, and long-term patient management.

Conventional echocardiographic parameters, including tricuspid annular plane systolic excursion (TAPSE), right ventricular fractional area change (FAC), and tissue Doppler–derived systolic velocity (S′), have long served as practical tools for evaluating RV systolic function in routine clinical settings. These parameters are simple, readily available, and widely recommended in echocardiographic guidelines. However, despite their clinical usefulness, these conventional indices possess several inherent limitations. Many of them primarily reflect longitudinal basal motion of the right ventricle and may not adequately represent the complex global and regional myocardial mechanics of the RV. Furthermore, these measurements may be influenced by geometric assumptions, loading conditions, and technical factors, which can reduce their sensitivity in detecting early or subtle myocardial dysfunction.

The introduction of advanced echocardiographic techniques has significantly improved the ability to assess myocardial function beyond conventional parameters. Among these innovations, speckle tracking echocardiography has emerged as a powerful and non-invasive imaging modality capable of providing detailed insights into myocardial deformation and contractility. By tracking natural acoustic markers within the myocardium, speckle tracking technology allows for quantitative assessment of strain, offering a more direct evaluation of myocardial mechanics.

Within this framework, right ventricular free wall strain has gained increasing recognition as a highly sensitive and reproducible parameter for assessing intrinsic RV myocardial function. Unlike traditional indices that rely on annular displacement or global chamber motion, RV FWS evaluates the deformation of the right ventricular free wall itself, thereby providing a more accurate representation of myocardial contractility. Numerous studies have demonstrated that reductions in RV free wall strain can be detected earlier than abnormalities in conventional echocardiographic parameters, making it particularly valuable for identifying subclinical RV dysfunction.

The clinical relevance of RV free wall strain extends across a broad spectrum of cardiovascular and pulmonary conditions. In pulmonary hypertension, RV strain parameters have shown strong correlations with disease severity and patient prognosis. In patients with heart failure, RV FWS provides important information regarding ventricular interaction and disease progression. Similarly, in acute pulmonary embolism and congenital heart disease, strain imaging has proven useful for detecting early myocardial impairment and guiding clinical management. By identifying subtle alterations in myocardial function, RV strain analysis contributes to improved risk stratification and more personalized treatment strategies.

As echocardiographic technology continues to advance, the role of deformation imaging in clinical cardiology is expected to expand further. Improvements in image resolution, automated strain analysis, and integration with artificial intelligence are likely to enhance the feasibility, accuracy, and reproducibility of RV strain measurements. Additionally, ongoing research efforts and international consensus initiatives aim to standardize measurement techniques and establish universally accepted reference values, which will further support the widespread adoption of RV strain analysis in routine practice.

Incorporating right ventricular free wall strain into comprehensive echocardiographic evaluation has the potential to significantly improve the early detection of right ventricular dysfunction. By providing a more sensitive assessment of myocardial mechanics, RV FWS can aid clinicians in identifying high-risk patients at an earlier stage of disease, facilitating timely intervention and improved therapeutic outcomes. Ultimately, the integration of advanced strain imaging into standard echocardiographic protocols represents an important step toward more precise and effective cardiovascular care.

Keywords: Right ventricular free wall strain, Right ventricular dysfunction, Speckle tracking echocardiography, RV strain imaging, Early detection, Right ventricular mechanics, Myocardial deformation, Echocardiographic assessment, Subclinical RV dysfunction, Cardiac imaging, Global longitudinal strain (RV GLS),Free wall longitudinal strain, Right heart function, Pulmonary hypertension, Right ventricular failure.

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