Echocardiographic Assessment of Diastolic Dysfunction in Special Situations

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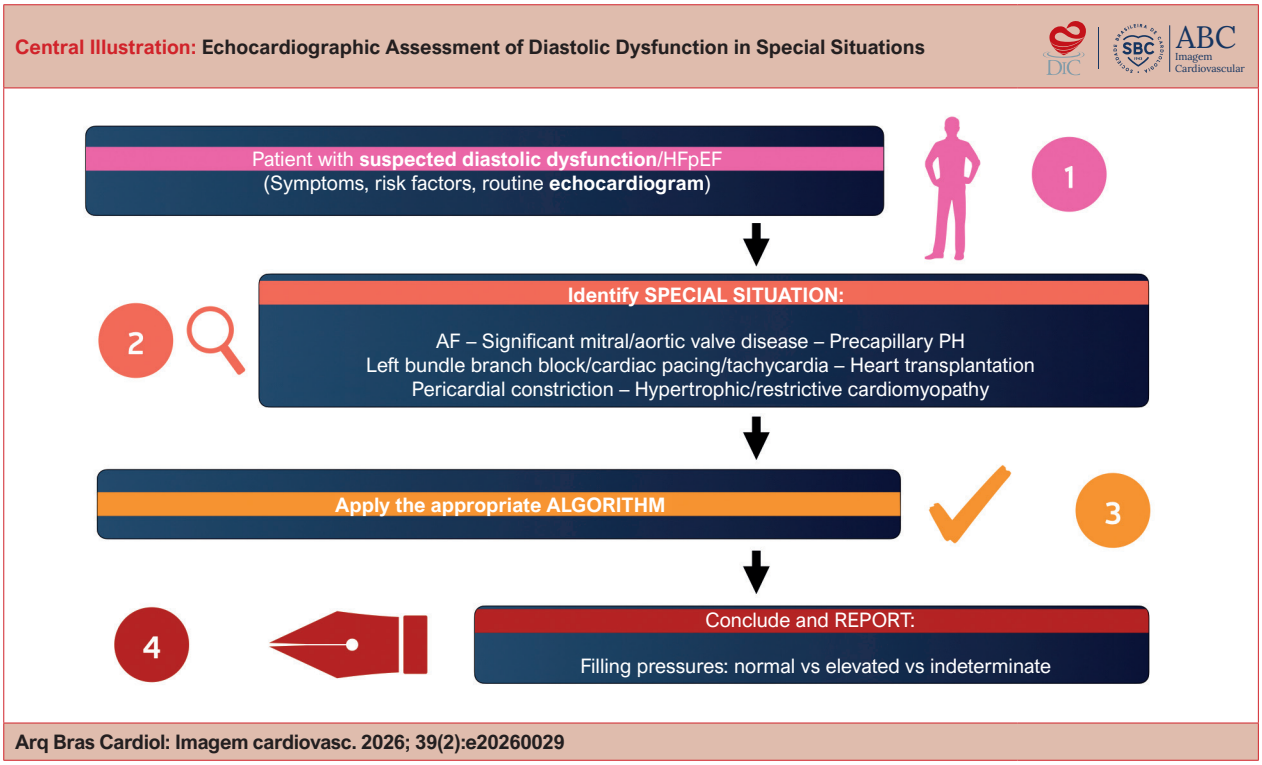

Proposed framework for the echocardiographic assessment of LV diastolic function in special clinical situations. The figure summarizes the main clinical scenarios in which conventional algorithms may be limited and highlights the adapted diagnostic approaches recommended for each context . AF: Atrial fibrillation; PH: pulmonary hypertension. HFpEF: heart faillure with preserved ejection fraction.

Abstract

Echocardiographic assessment of diastolic function and left ventricular (LV) filling pressures is fundamental to the evaluation of dyspnea and the management of heart failure. However, conventional algorithms have limitations in several special clinical settings in which rhythm disturbances, valvular heart disease, pulmonary hypertension (PH), or structural cardiac abnormalities interfere with the interpretation of Doppler parameters. This article presents a practical approach to assessing diastolic function in conditions such as atrial fibrillation (AF), PH, mitral valve disease, mitral annular calcification, aortic valve disease, conduction disturbances, ventricular pacing, and restrictive cardiomyopathies. The main parameters applicable to each context, the technical aspects of image acquisition, and strategies for preparing a clear and clinically useful echocardiographic report are discussed.

Keywords

Doppler Echocardiography; Stroke Volume; Diastolic Heart Failure

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Manuscript received March 12, 2026, revised manuscript March 23, 2026, accepted March 25, 2026
Editor responsible for the review: Marcelo Tavares

DOI: https://doi.org/10.36660/abcimg.20260029i

Introduction

Left ventricular (LV) diastole is not a passive phase of the cardiac cycle. Relaxation, diastolic suction, and ventricular compliance, together with the interactions among the ventricle, left atrium, and pulmonary circulation, determine

symptoms, hemodynamics, and prognosis across a range of cardiac conditions.

In clinical practice, echocardiographic assessment of diastolic function is generally guided by two key questions: (1) Is diastolic dysfunction present? and (2) Are LV filling pressures elevated at the time of assessment?

The term "LV filling pressures" encompasses different invasive measurements that reflect LV pressure behavior during diastole. Right heart catheterization is used to estimate pulmonary artery wedge pressure (PAWP), whereas left heart catheterization allows measurement of mean left atrial pressure (mLAP), pre-A pressure, and LV end-diastolic pressure (LVEDP). Although these measurements reflect the same underlying pathophysiologic process, they may differ according to the stage and severity of diastolic dysfunction. LVEDP, for example, tends to rise earlier, which has implications for the interpretation of echocardiographic parameters, since some variables correlate better with LVEDP, such as E-wave velocity, whereas others more directly reflect PAWP or pre-A pressure.[1]

In special situations, the correlations between echocardiographic parameters and invasive measurements may be further influenced by factors specific to each clinical condition. A classic example is significant mitral stenosis, in which mLAP and, consequently, pulmonary capillary pressure are elevated without a corresponding increase in LV diastolic pressures. This example illustrates how certain conditions can dissociate atrial and ventricular pressures, reinforcing the need for specific assessment protocols tailored to each clinical context.

Special Situations and Diastolic Assessment

Atrial fibrillation (AF) is the best-known example of a special situation and probably the most widely debated, as beat-to-beat variability and the absence of the A wave affect the applicability of key echocardiographic measurements. In pulmonary hypertension (PH), tricuspid regurgitation (TR) and pulmonary artery systolic pressure (PASP) are no longer reliable indirect markers of left-sided filling pressure. In heart transplant recipients, atrial remodeling and anastomotic scarring may confound traditional indices. This article focuses on these scenarios and provides a practical framework for echocardiographers dealing with such situations.

Assessment Sequence

Diastolic function assessment is generally performed at the end of the echocardiographic examination, since special situations must first be excluded, a process that requires a comprehensive study (Central Illustration).[1-3] The checklist proposed in Table 1 outlines the most likely scenarios in sequence.

Which variables should be used in special situations

In both routine and special situations, isolated measurements should not be used for diagnosis; instead, integration of multiple echocardiographic variables is required. Table 2 summarizes the main clinical situations and the measurements most appropriate for each context.

Assessment of diastolic function in special situations encompasses multiple clinical scenarios, which may hinder the systematic application of diagnostic algorithms. It is therefore useful to recognize which parameters have specific limitations — such as left atrial dimensions in patients with AF — and which can be applied more consistently across different settings. Among the latter, peak TR velocity, except in cases of precapillary PH, and isovolumetric relaxation time (IVRT) stand out, as both have high feasibility and are relatively straightforward to interpret.

AF and PH have specific diagnostic algorithms in the most recent publications that are not based solely on the sequential application of the variables summarized in the

Table 1– Steps to be assessed before proceeding with echocardiographic evaluation of diastolic function

Clinical condition	Implications for diastolic function assessment
What is the presumed or confirmed rhythm (sinus rhythm, AF/flutter, pacemaker rhythm), and does the heart rate allow separation of the E and A waves?	In the presence of AF, specific algorithms should be prioritized. In sinus tachycardia with E–A wave fusion, the assessment should be adapted.
Is there significant mitral valve disease (stenosis, ≥ moderate failure, prosthesis) or ≥ moderate mitral annular calcification?	If so, the standard algorithm may not be applicable, and condition-specific algorithms should be used.[1]
Is there relevant PH or suspicion of precapillary PH?	If so, TR and PASP cannot be used as surrogates for left-sided filling pressure. A specific algorithm is available for assessment in the setting of concomitant precapillary PH.[1]
Do the two-dimensional findings suggest cardiac amyloidosis or hypertrophic cardiomyopathy? Has the structural analysis already provided a coherent overall picture (hypertrophy, LA size, valves, RV, pericardium)? The numerical findings must be consistent with the anatomy.	If so, a condition-specific algorithm should be used.[1]

LA: left atrium; AF: atrial fibrillation; PH: pulmonary hypertension; PASP: pulmonary artery systolic pressure; TR: tricuspid regurgitation; RV: right ventricle.

Table 2 – Main clinical situations and corresponding applicable measurements

Condition	Echocardiographic indicators of elevated filling pressure
AF	1. DT < 160 ms (reduced LVEF) 2. Peak acceleration rate of the E-wave velocity ≥ 1,900 cm/s² 3. IVRT ≤ 65 ms 4. DT of pulmonary venous diastolic flow velocity ≤ 220 ms 5. E/Vp ≥ 1.4 6. Septal E/e′ ≥ 11 7. Peak TR velocity > 2.8 m/s
Sinus tachycardia	1. Early filling pattern (reduced EF) 2. IVRT ≤ 70 ms 3. Pulmonary vein systolic fraction ≤ 40% 4. Mean E/e′ > 14 5. Use of compensatory beats to separate E and A waves
Hypertrophic cardiomyopathy (HCM)	1. Mean E/e′ > 14 2. Ar–A ≥ 30 ms 3. Peak TR velocity > 2.8 m/s 4. LAVI > 34 mL/m²
Restrictive cardiomyopathy	1. Mean E/e′ > 14 2. DT < 140 ms* 3. E/A > 2.5* 4. IVRT < 50 ms*
PH	1. E/A ≥ 2 → favors postcapillary PH 2. E/A ≤ 0.8 → favors precapillary PH 3. If E/A 0.8–2: Lateral E/e′ > 13, LAVI > 34 mL/m², and LA reservoir strain < 18% favor postcapillary PH
Mitral stenosis	1. IVRT < 60 ms* 2. Mitral A > 1.5 m/s 3. IVRT / TE–e′ < 4.2
Mitral regurgitation (MR)	1. IVRT < 60 ms* 2. Ar–A ≥ 30 ms 3. IVRT / TE–e′ < 5.6 4. Mean E/e′ > 14 (valid only if reduced EF)
Moderate to severe mitral annular calcification (MAC)	1. E/A < 0.8 → normal LAP 2. E/A > 1.8 → elevated LAP 3. E/A between 0.8–1.8: • IVRT ≥ 80 ms → normal LAP • IVRT < 80 ms → elevated LAP
Heart Transplant	1. E/e′ < 7 → normal LAP 2. E/e′ > 14 → elevated LAP 3. E/e′ 7–14: • E/SR_{IVRT} ≤ 200 cm → normal LAP • E/SR_{IVRT} > 200 cm → elevated LAP • If SR_{IVRT} is unavailable, use peak TR velocity: – ≤ 2.8 m/s → normal LAP – > 2.8 m/s → elevated LAP

**Variables that are specific but not sensitive for detecting elevated filling pressures in the contexts in which they are presented. Ar–A: difference between the duration of the pulmonary venous atrial reversal wave and that of the transmitral A wave; AF: atrial fibrillation; PH: pulmonary hypertension; LAP: left atrial pressure; PASP: pulmonary artery systolic pressure; TR: tricuspid regurgitation; SR: strain rate; LARS: left atrial reservoir strain; DT: deceleration time; TE–e′: time interval between the E and e′ waves; IVRT: isovolumetric relaxation time; RV: right ventricle; LAVI: left atrial volume index; LVEF: left ventricular ejection fraction; EF: ejection fraction. Adapted from Nagueh et al.[1]*

table. In contrast, among heart transplant recipients and patients with mitral annular calcification, the algorithms presented in current publications are often presented visually but essentially correspond to the same recommendations summarized in the table. Constrictive pericarditis may also be considered a special situation in the assessment of diastolic function; however, because of its distinct pathophysiologic and diagnostic features, it is traditionally discussed separately and therefore will not be addressed in this review.

Atrial fibrillation

The absence of the A wave and cycle-length variability reduces the accuracy of echocardiographic measurements in AF. In a multicenter study involving 148 patients, no single parameter showed an adequate correlation with PAWP, prompting Khan et al. to propose a diagnostic algorithm integrating multiple hemodynamic and structural markers. This algorithm, subsequently incorporated into the 2024 British recommendations and the 2025 American guidelines, allows estimation of ventricular filling pressures even in the absence of the organized atrial contraction characteristic of AF.[1,3,4]

The main parameters include E-wave velocity ≥ 100 cm/s, septal E/e′ > 11, peak TR velocity > 2.8 m/s or PASP > 35 mmHg, E-wave deceleration time ≤ 160 ms, left atrial reservoir strain < 18%, pulmonary vein S/D ratio < 1, and body mass index > 30 kg/m². The interpretation of these criteria and their diagnostic sequence are illustrated in Figure 1.

The arrhythmic nature of AF requires additional care when acquiring echocardiographic measurements. To reduce the impact of beat-to-beat variability and improve reproducibility, recording 10 to 15 cardiac cycles at a high sweep speed and averaging multiple beats is recommended. Cycles should be selected with R–R intervals representative of the mean heart rate, ideally with similar preceding R–R intervals, while avoiding post-pause beats and very short cycles with wave fusion. The report should also explicitly state that the values represent averages obtained during AF and acknowledge the inherent beat-to-beat variability of this arrhythmia.

When the algorithm yields an indeterminate classification, the additional variables listed in Table 2 may be used as supportive elements in the interpretation. In addition, relatively low variability in E-wave velocity between consecutive cycles, despite irregular R–R intervals, may suggest elevated filling pressures. Although this finding is not formally included in diagnostic algorithms, it represents a qualitative sign that is often useful in the echocardiographic evaluation of patients with AF.

From a pathophysiologic standpoint, sustained elevation of left atrial pressure (LAP) tends to attenuate the impact of R–R interval variability on the transmitral gradient. Thus, despite rhythm irregularity, persistently elevated E-wave velocities with relatively little variation between consecutive cycles may provide an additional clue to increased filling pressures.

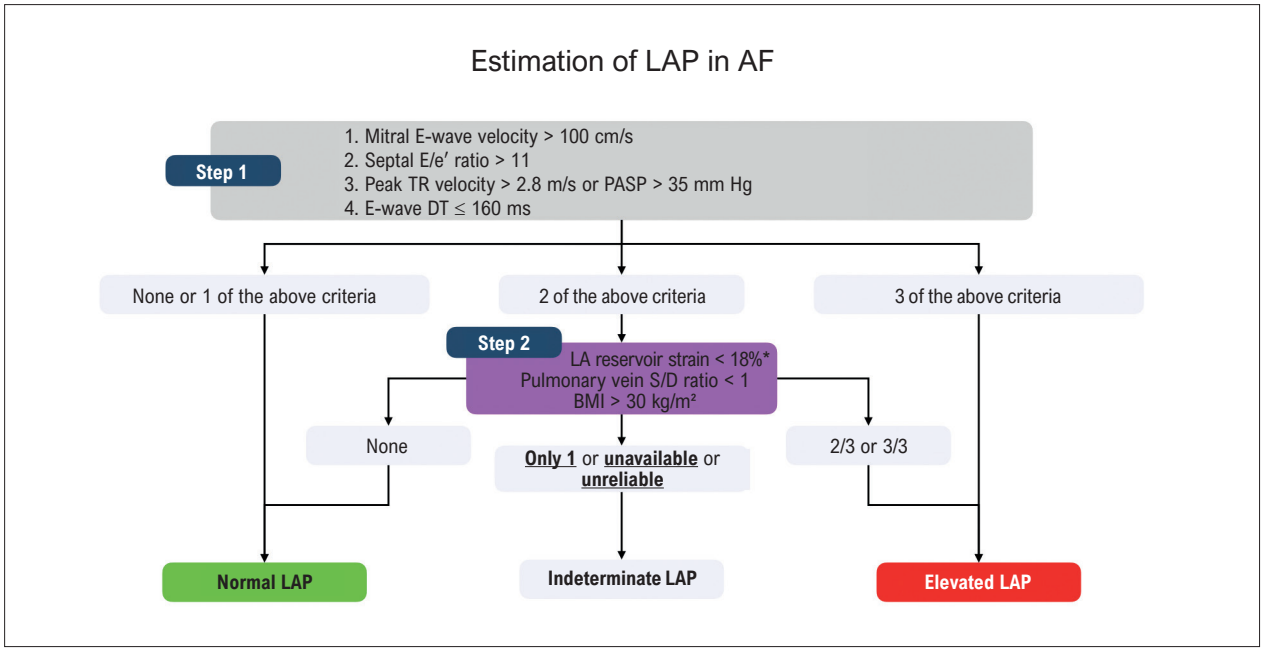

Figure 1 – *Algorithm for estimating LAP in patients with AF. Diagnostic algorithm integrating Doppler parameters and clinical variables to estimate LAP in patients with AF. The approach combines immediate hemodynamic markers with structural or functional consequences of chronically elevated filling pressures. Adapted from Khan et al.[4] AF: Atrial fibrillation; BMI: body mass index; LAP: left atrial pressure; TR: tricuspid regurgitation; LA: left atrial; LARS: left atrial reservoir strain; DT: deceleration time; PASP: pulmonary artery systolic pressure. *Cutoff value in the original study = 16% (Khan et al.[4]), modified to 18% in the 2025 American recommendations for diastolic function assessment (Nagueh et al.[1]).*

Although AF is one of the most common settings in which conventional algorithms for assessing diastolic function have limitations, other clinical scenarios also require specific adaptations in the interpretation of echocardiographic parameters, as discussed in the following sections.

PH with preserved EF: suspected noncardiac (precapillary) PH

In precapillary PH, peak TR velocity and PASP are elevated by definition and therefore cannot be used to infer LV filling pressure. The variables presented in Table 2 are essentially the same as those used in Figure 2, but organized as a flowchart based on the work of Inoue et al. and later incorporated into the 2025 American recommendations and the 2024 British recommendations.[1, 3, 5]

Mitral valve disease and annular calcification

In mitral valve disease, estimation of filling pressures should rely on integration of the variables presented in Table 2, as hemodynamic and structural alterations may affect the interpretation of individual parameters.

Among these conditions, moderate or severe mitral annular calcification deserves particular attention, as reduced annular motion may limit the interpretation of parameters that depend on mitral annular velocity, such as e′. In such cases, use of a specific, easy-to-remember, and clinically applicable algorithm is recommended, allowing direct, dichotomous determination of filling pressures and avoiding the undesirable outcome of an indeterminate classification.[1,6]

Aortic valve disease (aortic stenosis and aortic regurgitation)

In aortic valve disease, estimation of filling pressures is usually feasible, and the standard algorithm can generally be applied. However, it should be recognized that ventricular hypertrophy and myocardial remodeling, which are frequently associated with these conditions, may reduce left atrial reservoir strain and e′ before overt elevation of filling pressures occurs. Therefore, interpretation of these parameters should always take into account the clinical context, the severity of the valvular disease, and the presence of symptoms or signs of congestion.[1, 7]

Conduction disorders and ventricular pacing (left bundle branch block, ventricular pacing, and cardiac resynchronization therapy)

Ventricular dyssynchrony alters regional relaxation and the temporal relationship between transmitral flow and tissue Doppler signals, reducing the accuracy of e′ and E/e′. In first-degree AV block, these variables remain valid only in the absence of E–A fusion. In advanced AV block, when isolated A waves are present, a peak TR velocity > 2.8 m/s may suggest elevated filling pressures.[1]

Restrictive cardiomyopathies and amyloidosis

When a suggestive structural phenotype is identified—including increased ventricular wall thickness, characteristic abnormalities in longitudinal strain, LA enlargement, RV involvement, and PH—a condition-specific assessment is recommended. In these situations, the cutoff values

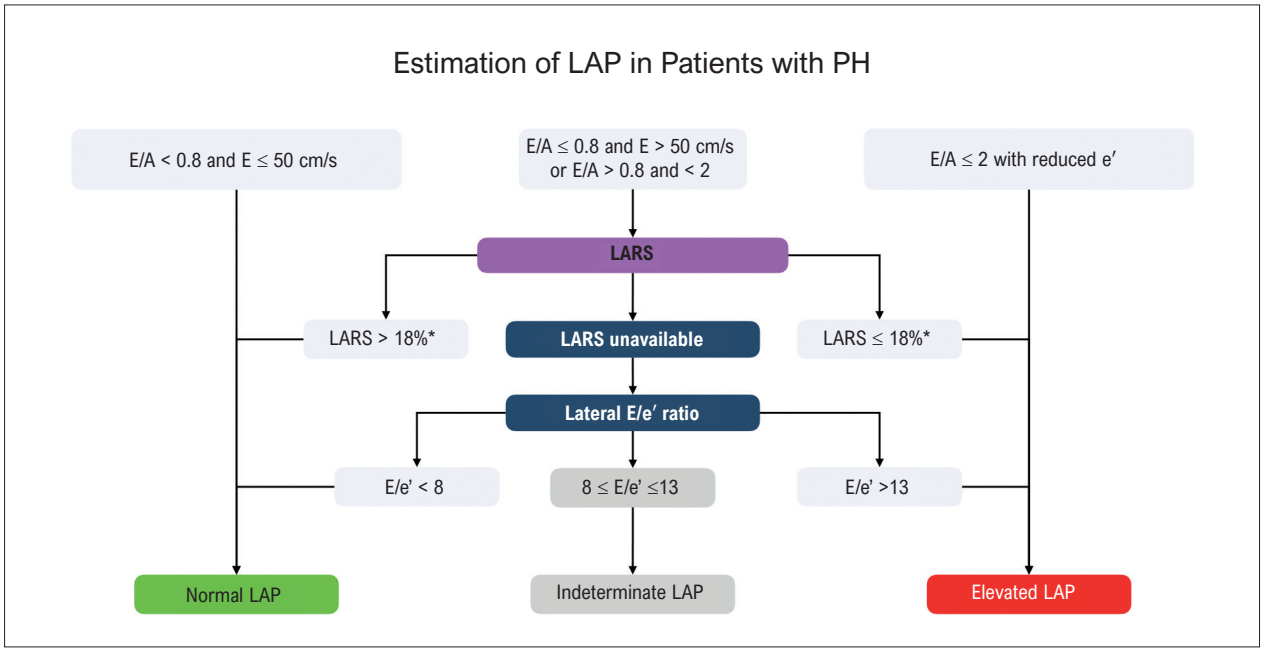

Figure 2 – *Echocardiographic approach to the assessment of diastolic function in PH. Interpretive strategy for echocardiographic parameters of diastolic function in patients with PH, highlighting variables that are useful for differentiating elevated left-sided filling pressures from primarily pulmonary vascular disease. Adapted from Inoue et al.[5] LAP: left atrial pressure; LARS: left atrial reservoir strain; PH: pulmonary hypertension. *Cutoff value in the original study = 16% (Inoue et al.[5]), modified to 18% in the 2025 American recommendations for diastolic function assessment (Nagueh et al.[1]).*

presented in Table 2 differ from those used in other conditions and are more stringent for characterizing elevated filling pressures.

Other special situations

The remaining conditions listed in Table 2 are generally self-explanatory and do not require additional visual algorithms for interpretation. In these settings, Table 2 may serve as a practical guide for selecting the most appropriate variables for each clinical context, thereby facilitating the application of general principles for assessing diastolic function.

Minimum acquisition and report writing (essential elements)

The 2025 ASE recommendations emphasize that the essential parameters must be included in the report, especially when assessment of filling pressures is requested.[1] To avoid confusion for the referring clinician and to maintain internal consistency of the report, the echocardiographer should specify which protocol was used and should primarily report the variables involved in determining filling pressures in that specific context.

In certain special situations, certain variables traditionally used to assess diastolic function should not be considered when estimating filling pressures. One example is significant mitral annular calcification, in which e' velocity loses accuracy; reporting it with the same emphasis given in routine settings may mislead the treating physician, particularly because widely used clinical scores for the diagnosis of heart failure with preserved ejection fraction incorporate this measurement.[8, 9]

On the other hand, some variables may not be used to determine filling pressures in specific contexts, but should still be reported for their diagnostic or prognostic value. Left atrial dimensions, for example, do not reflect filling pressures in patients with AF but retain prognostic value. Similarly, PASP remains an important variable in the evaluation of patients with suspected precapillary PH.

Although the most recent recommendations still propose a diagnostic framework that first addresses the presence or absence of diastolic dysfunction and then determines filling pressures, the algorithms for special situations are essentially focused on estimating these pressures. In practice, this may create the impression that diastolic dysfunction is always present in such settings, which is not necessarily the case. Moreover, although undesirable, some algorithms applied to special situations may result in an indeterminate classification of filling pressures.

Therefore, meticulous measurement acquisition and appropriate contextualization of the variables used make the echocardiographic report clearer, help prevent misinterpretation, and allow a more reliable estimation of filling pressures across different clinical scenarios.

Conclusions

The most recent updates have introduced important advances in the echocardiographic assessment of filling pressures, including the incorporation of newly validated markers, such as left atrial reservoir strain, and the development of dedicated algorithms for conditions such as AF, PH, and heart transplantation. Taken together, these changes reflect a shift from a purely checklist-based approach to a more contextualized, pathophysiology-based evaluation, with the potential to reduce the frequency of indeterminate results.[1, 3, 4, 7, 10]

In practice, three approaches are particularly helpful: recognizing early when the standard algorithm does not apply; obtaining high-quality measurements from representative cardiac cycles; and reporting the findings clearly and in context, explicitly acknowledging the limitations of the method and recommending complementary testing when appropriate. In this way, echocardiography retains its central role in assessing filling pressures, even in the face of the complexity of special clinical situations.

Ultimately, the echocardiographer must recognize that, in special situations, the value of the examination lies not only in the application of algorithms, but also in the interpretation of hemodynamic signals in light of the clinical context.

Author Contributions

Conception and design of the research, acquisition of data, analysis and interpretation of the data, writing of the manuscript and critical revision of the manuscript for intellectual content: Calvilho-Júnior A.

Potential Conflict of Interest

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

Sources of Funding

There were no external funding sources for this study.

Study Association

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

Ethics Approval and Consent to Participate

This article does not contain any studies with human participants or animals performed by any of the authors.

Use of Artificial Intelligence

During the preparation of this work, the author(s) used Chat GPT - Open AI for text formatting (grammar and spelling check). After using this tool/service, the author(s) reviewed and edited the content as needed and take full responsibility for the content of the published article.

Availability of Research Data

The underlying content of the research text is contained within the manuscript.

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