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THE ROLE OF ECHOCARDIOGRAPHY IN HEART FAILURE

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Abstract:
Heart failure (HF) is a serious medical condition characterized by high mortality and morbidity rates, poor functional capacity, and reduced quality of life. It affects more than 64 million people globally and has become a significant public health concern due to its high economic and social burden. To address this challenge, echocardiography has emerged as a critical diagnostic and therapeutic tool in the evaluation and management of HF patients.
Echocardiography offers numerous advantages over other imaging modalities, including its non-invasive nature, ease of availability, and safety. It allows clinicians to obtain a comprehensive assessment of cardiac structure and function, including ventricular size, shape, and function. Echocardiography also plays a crucial role in risk stratification and the initial phenotype assessment of HF patients, providing essential data for guiding therapeutic decision-making and monitoring treatment efficacy.
Advances in echocardiography have expanded its applications in HF patient care, enabling more accurate assessment of systolic and diastolic function. This includes the use of novel echocardiographic techniques such as strain imaging, speckle tracking, and 3D echocardiography, which allow clinicians to evaluate ventricular deformation, regional wall motion abnormalities, and global cardiac function.
Moreover, RV evaluation is increasingly being recognized as a critical component of echocardiographic assessment in HF patients. RV dysfunction is prevalent in HF patients, and its assessment can provide important prognostic information and guide management decisions. Echocardiography provides a safe and practical means of assessing RV function, including RV size, shape, and systolic function.
In summary, echocardiography is an indispensable tool in the evaluation and management of HF patients. It allows for a comprehensive assessment of cardiac structure and function, risk stratification, and therapeutic decision-making. With advances in echocardiographic techniques, clinicians can obtain vital data on systolic and diastolic function, including RV evaluation, improving patient outcomes and reducing the economic and social burden of HF.
Keywords: *Systolic dysfunction, Diastolic dysfunction, Ejection fraction, Heart failure, Echocardiography.*

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INTRODUCTION:

Heart failure is a clinical pathological syndrome characterized by failure of the heart to generate enough cardiac output to meet the minimum metabolic needs of the body tissues in spite of normal or above normal filling pressure. Before we really delve into the details of heart failure, there are few terms that we should focus upon. Primarily the Cardiac output is calculated as:

CO = Heart rate × Stroke volume.

Now there's so many determinants of stroke volume but three most important determinants of stroke volume are intrinsic health of myocardium, preload (end diastolic volume) and afterload.
Some people's heart fail, when there is dangerously low cardiac output or even if there is a high cardiac output but body demands so much oxygen and other nutrients that heart may increase the cardiac output but still it cannot meet the body needs under those circumstances, heart will fail.

Moreover another situation occurs as when the heart is able to generate normal Cardiac output but peripheral tissues metabolism is so fast that the demands on the cardiac output is pathologically high and the tissues for example, hyperthyroidism, tissue has a very high metabolic rate so demand for the oxygen is very high and heart step up its cardiac output but still it is unable to meet the exaggerated demands of the body so in spite of increasing and stepping up its cardiac output heart failed to provide the exaggerated demands of the peripheral tissue this should also be considered heart failure but of course this is the high output heart failure.

Classification of Heart failure: Heart failure is categorised into 4 stages namely- A, B, C and D stages- which stretch from a high risk of evolving heart failure to heart failure fashion.

There is a difference between the four stages of heart failure and the four classes of heart failure symptoms which is also described in the New York Heart Association (NYHA), which shows the severity of symptoms, originating from class one (no symptoms) to the most severe, i.e. class four (with symptoms at rest). [1]

Stage A

Stage A is considered to be a pre-heart failure. It conveys the high risk of developing heart failure since the person has a family history of heart failure or has one or more of these medical conditions:

- hypertension
- coronary artery disease
- diabetes
- metabolic syndrome
- family history of cardiomyopathy
- history of rheumatic fever
- history of alcohol abuse
- history of consuming drugs that can damage the heart muscle (e.g. some cancer drugs).

Stage B

Stage B is marked as silent heart failure or asymptomatic. It says that the person has been diagnosed with systolic left ventricular dysfunction but has never had symptoms of heart failure. In Stage B heart failure, most people have an echocardiogram (echo) that shows an ejection fraction (EF) of 40% or less. This class includes people who have heart failure along with reduced EF (HFrEF) due to any cause.

Stage C

Patients with stage C heart failure have been diagnosed with heart failure and have/had signs and symptoms.

There would be many possible symptoms of heart failure, most commonly:

- fatigued
- less able to exercise
- oedema
- shortness of breath

Stage D

Patients suffering from Stage D have advanced symptoms and do not get better with treatment. This indicates the final stage of heart failure. They are likely to have NYHA class three to four symptoms and they show symptoms on mild or minimal exertion or at rest. [1]

METHODOLOGY:

A general overview of the methodology used in echocardiography studies for heart failure are:

Study design: The study design can vary, but echocardiography studies for heart failure often use a cross-sectional or longitudinal design.

Study population: The study population typically includes patients with heart failure who meet certain inclusion and exclusion criteria.

Echocardiography protocol: The echocardiography protocol includes a standard set of images and measurements that are obtained using a combination of two-dimensional, M-mode, Doppler, and tissue Doppler imaging.

Image acquisition: Echocardiographic images are acquired by trained technicians or sonographers, and are interpreted by experienced echocardiographers.

Echocardiographic measurements: A variety of echocardiographic measurements are obtained, including left ventricular ejection fraction, left ventricular end-diastolic and end-systolic volumes, left atrial volume, mitral and tricuspid regurgitation, and pulmonary artery systolic pressure.

Statistical analysis: Statistical analysis is used to examine the relationship between echocardiographic measurements and heart failure, and to identify predictors of adverse outcomes.

Ethical considerations: Ethical considerations include obtaining informed consent from study participants, protecting patient confidentiality, and ensuring that the study complies with local and national regulations.

Echocardiographic Approach in Heart Failure

Classification of Heart Failure Patients Based on Left Ventricular Ejection Fraction (LVEF) and Prognostic Implications:

European Society of Cardiology (ESC) have classified the HF patients into three groups based on the LVEF values as follows:

1. Those with preserved LVEF [≥50%, HF with preserved ejection fraction (HFpEF)],
2. Mid-range LVEF [40 – 49%, HF with mid-range ejection fraction (HFmrEF)],
3. Reduced LVEF [<40%, HF with reduced ejection fraction (HFrEF)]. [2]

According to a meta-analysis conducted by the MAGGIC group, which included 39,372 patients from 30 studies, the prognosis of heart failure with reduced ejection fraction (HFrEF) can be stratified based on the left ventricular ejection fraction (LVEF). The analysis found that lower LVEF values are associated with a higher risk of mortality, both for all-cause and cardiovascular mortality. In comparison, heart failure with preserved ejection fraction (HFpEF) has a better prognosis than HFrEF, although once the LVEF is above 50%, there is no correlation between LVEF and mortality. This means that the risk of death is similar for LVEF values of 60% or 70%.

Studies have reported that HFpEF patients have an in-hospital mortality rate of 2.3-5%, a 1-year mortality rate of 22-29%, and a 5-year mortality rate of 65%. However, clinical trials have found that cardiovascular causes accounted for a higher percentage of deaths in HFrEF patients (83%) than in HFpEF patients (70%). These findings suggest that the underlying mechanisms and pathophysiology of HFrEF and HFpEF may differ and need to be considered in clinical practice.[3],[4]

Diagnosing HFpEF can be difficult, especially when the LVEF is within normal limits. To identify the underlying cause of clinical symptoms, the ESC guidelines recommend an extensive evaluation to confirm structural and/or functional abnormalities of the heart. The key indicators of structural alterations include an elevated left ventricular mass index and left atrial volume index, while increased E/e' ratio and e' are the main functional alterations. [2]

HFmrEF patients make up about one-fifth of the HF population.[5],[6] The pathogenesis is similar to HFrEF, but different from true HFpEF due to the higher prevalence of coronary artery disease.[7] However, the resemblance varies among studies and it's unclear if HFmrEF is a transitional status or an independent entity.[8] Improving LVEF from HFrEF to HFmrEF may indicate better prognosis, but observer variability in standard echocardiography can make identification of borderline patients inaccurate. [9]

The use of LVEF to distinguish between different categories of HF patients presents both benefits and drawbacks. One advantage is that LVEF can indicate changes in prognosis as it may vary across different HF categories. However, to fully account for these changes, it may be necessary to consider LVEF modifications over time and the underlying causes of HF.

Assessment of LV Systolic Function

Assessment of LV systolic function provides valuable prognostic information, plays an excellent role in selection of medical therapy and is instrumental in determining the timing of surgery for valvular heart disease.

Myocardial Excursion:
• Typically use eyeball method (proven reliable for broad categorisation).
• Maybe estimated using fractional shortening (M-mode measurement across mid-LV walls using PLAX or PSAX views.

Normal Value = 25 - 45%

Fractional Shortening (FS) = (LVIDd – LVIDs)/LVIDd

Indirect M-mode Markers of LV Function:

On M-mode echocardiography, various indirect signs of Left Ventricular systolic dysfunction can be analysed. These comprise an elevated E-point to septal separation and during systole, there will be gradual closure of the aortic valve. Usually, the mitral valve E-point (maximal early opening) is within 7mm of the left side of the ventricular septum in the presence of a decreased ejection fraction, this distance is increased.

Examination of the aortic valve opening pattern also allows indirect evidence with regard to the systolic function of the left ventricle. With the decrease in the left Ventricular forward stroke volume, there would be a gradual reduction in late systole of forward flow. This encourages a rounded appearance of aortic valve closure in late systole.

Two Dimensional Measurements:

2D Echocardiography provides innately superior spatial resolution for determining left ventricular function and size. The recommended normal ranges for commonly obtained measurements is given by the American Society of Echocardiography which is as follows:

	Women				Men			
	Reference Range	Mildly Abnormal	Moderately Abnormal	Severely Abnormal	Reference Range	Mildly Abnormal	Moderately Abnormal	Severely Abnormal
LV dimension								
LV diastolic diameter	3.9-5.3	5.4-5.7	5.8-6.1	≥ 6.2	4.2-5.9	6.0-6.3	6.0-6.8	≥ 6.9
LV diastolic diameter/BSA, cm/m^2	2.4-3.2	3.3-3.4	3.5-3.7	≥ 3.8	2.2-3.1	3.2-3.4	3.5-3.6	≥ 3.7
LV diastolic diameter/height, cm/m	2.5-3.2	3.3-3.4	3.5-3.6	≥ 3.7	2.4-3.3	3.4-3.5	3.6-3.7	≥ 3.8
LV volume								
LV diastolic volume	56-104	105-117	118-130	≥ 131	67-155	156-178	179-201	≥ 201
LV diastolic volume/BSA, mL/m^2	***35-75***	***76-86***	***87-96***	**≥ 97**	***35-75***	***76-86***	***87-96***	**≥ 97**
LV systolic volume, mL	19-49	50-59	60-69	≥ 70	22-58	59-70	71-82	≥ 83
LV systolic volume/BSA, mL/m^2	***12-30***	***31-36***	***37-42***	**≥ 43**	***12-30***	***31-36***	***37-42***	**≥ 43**

Table 1: Provides the American Society of Echocardiography- recommended normal ranges for commonly obtained measurements.

The Simpson's rule or the Rule of Disks is currently the most common method for determining ventricular volumes. This method needs recording an apical, four and/or two-chamber view from which the border of the endocardial in end-systole and end-diastole is outlined. The ventricle is mathematically divided across its long axis into a series of disks having equal height. The calculation of individual disk volume is measured as the product of the height and disk area where the height of disks is presumed to be the total left ventricular long axis length divided by the number of segments or disks. The surface area of every single disk is determined from the diameter of the ventricle at that point i.e. area, A=πr^2. The ventricular volume is calculated as the summation of the volume of the disks.

For the determination of accurate volume, the transducer must be kept at the true apex and the ultrasonic beam must be through the centre of the left ventricle. Normally, the thinnest area of the LV is the true apex. For the determination of left ventricular volume, the endocardial border is traced with papillary muscle and trabeculae excluded from the cavity.

Intravenous contrast for LV opacification is also an important technique for enhancing endocardial border definition. If two or more segments are poorly visualised, the intravenous contrast for LV opacification both for regional wall motion assessment and for reproducibility of volume determination is used.

The use of 3D echocardiography for assessing left ventricular function:

3D echocardiography offers more comprehensive information on LV volume when compared to traditional techniques like cardiac magnetic resonance imaging. This imaging modality is particularly advantageous for irregularly shaped ventricles that do not conform to predictable geometric shapes. Similar to 2D echocardiography, the 3D volume can be divided into a 16 or 17 segment model, allowing for the extraction of various measures of global and regional ventricular function from a single volume. Although studies have indicated that real-time 3D echocardiography underestimates both end-diastolic and end-systolic volumes, this is likely due to the inclusion of LV trabeculae and papillary muscles within the cavity, which can pose challenges for analysis.

Myocardial Performance Index/ Tei index

MPI or Tei index can also be defined as the sum of isovolumic contraction and relaxation times divided by the ejection time. [10],[11]

$$MPI = (ICT + IRT) / ET$$

$$\text{Normal } MPI <= 0.40$$

Where,

IVCT: Isovolumic Contraction Time; IVRT: Isovolumic Relaxation Time; ET: Ejection Time

This index, combines features of both systolic and diastolic function. It may be applied to the LV and the RV. Normal MPI is <0.40 for LV and <0.3 for RV with progressively greater values implying progressively worse ventricular function.

Assessing LV function using dP/dt: If the patient has mitral regurgitation, using the LV function can also be quantified using dP/dt.

During systole, the LV cavity pressure rises. dP/dt refers to the rate of change in pressure (dP) in the LV with time (dt). If LV systolic function is impaired, dP/dt becomes reduced.

dP/dt is determined from the slope of velocity between 1 and 3 m/sec. While measuring the slope between 1 and 3 m/sec (i.e. the difference between the two analogous pressures P2 - P1 which is 36 - 4 mmHg), the simplified formula came out to be:

$$dP/dt = 32/t$$

dP/dt is generally >1200 mmHg/s with normal LV systolic function. Usually, dP/dt < 800 mmHg/s indicates a severely impaired LV.

dP/dt isn't reliable if the mitral regurgitation is acute, also if there is significantly increases afterload (e.g. aortic stenosis or systemic hypertension).

Global Longitudinal Strain:

Assessing left ventricular (LV) systolic function is central to the evaluation of cardiac disease, playing an essential role in guiding management and predicting outcomes.

Yet the echo community has long understood the variability and accuracy limitation of the traditional measurement techniques for LV ejection fraction (LVEF), regional strain and global longitudinal strain (GLS).

Speckle tracking echocardiography (STE) have suggested that strain, which assess deformation directly in the myocardium, could be more useful marker of LV systolic function. It can identify subclinical LV dysfunction before declines in LVEF becomes apparent and it can predict mortality and morbidity in numerous cardiac conditions, including heart failure.

The American Society of Echocardiography (ASE) and the European Association of Cardiovascular Imaging (EACVI) both encourage more clinical use of strain because of its ability to detect disease sooner than LVEF but despite this advice and GLS' proven ability to offer additional prognostic value, practical considerations have proven to be a barrier to wide-scale adoption. In the presence of impaired LV systolic function, LVEF can be normal as it does not reflect intrinsic myocardial contractility. LVEF is highly load-dependent and suffers from a high degree of intra-observer and inter-observer variability.

In essence, GLS is a direct measurement of myocardial changes, rather than the indirect measurement of LVEF (which is based on volume calculations) and is the most frequent type of strain used to characterise LV systolic function. Previously, EF is used to measure LV function. But changes detected by LVEF lags much behind the progression of subclinical disease. Currently there is a growing number of people, out of which more than half of all HF patients are diagnosed with heart failure with preserved ejection fraction (HFpEF).

Comprehensive evaluation of global longitudinal strain (GLS) in heart failure (HF) patients provides additive prognostic information and can play a significant role in improving risk stratification in chronic systolic heart failure.

During the early days of the pandemic, healthcare teams became painfully aware of cardiac injury in hospitalized patients, almost a quarter were diagnosed with cardiovascular complications which contributed to around 40% of all COVID related death.

A study of 148 patients from six acute hospitals in London found half of those admitted with COVID-19 has raised troponin levels a month after discharge. MRI showed myocarditis, infection, ischemia, or a combination of the three. [12]

Another paper, published in JAMA cardiology, found cardiac abnormalities in 78% of the MRIs taken from 100 people who had recovered from the disease in the previous two to three months. Ongoing myocardial inflammation was identified in 60% of the scans, and 76% of participants had elevated troponin levels.[13]

Echocardiography has played a major role in the response to COVID, both its acute and chronic manifestation.

A systemic review and meta-analysis, published in January 2021, concluded that lower LV GLS and right ventricular free wall longitudinal strain were independently associated with poor outcome in patients with COVID. [14]

Patients, especially those with diabetes, obesity, hypertension, have reduced basal LV strain.
A subgroup analysis indicated that for every 1% decreased in LV-GLS, mortality increased by 1.3x.

It is expected from healthy adults to have a peak LV global longitudinal strain (GLS) of around -20% , which decreases normally with age. [15],[16]

Evaluation of LV Diastolic Function:

The most common cause of left heart failure and a powerful predictor of cardiovascular events is Diastolic dysfunction. Diastolic dysfunction is the primary cause of approximately 50% of heart failure cases and is present in over 25% of adults over 40 years of age. Though there are several parameters for evaluation of LV diastolic function by echocardiography, the most commonly used are the pulsed Doppler mitral E/A ratio and tissue Doppler mitral E/e' ratio. Few more useful parameters are changes in mitral inflow with Valsalva maneuver, mitral E velocity deceleration time, isovolumic relaxation time, left atrial maximum volume index, mitral L velocity, colour M-mode Vp and E/Vp ratio, pulmonary vein systolic/diastolic velocity ratio.

Pulmonary regurgitation end diastolic velocity and Tricuspid regurgitation jet velocity showing pulmonary hypertension are also taken as substitutes of left atrial (LA) pressure in the absence of pulmonary disease.

In diastolic dysfunction, when the ventricular relaxation is impaired, the atrial contribution to ventricular filling gradually increases and the height of A wave increases therefore there is an equalization of the E and A waves.

As the severity of diastolic dysfunction increase, A wave becomes taller than E wave. This phase is known as E/A reversal. Furthermore, due to elevated left atrial pressure the E wave becomes taller, mimicking the restrictive filling pattern. This is a type of pseudo normalization of the mitral flow pattern.

A triphasic LV filling pattern with an additional mid diastolic L wave can occur in situation of LV diastolic dysfunction, especially in hypertrophic cardiomyopathy but may also be seen rarely in normal individual with bradycardia.[17]

The normal ratio between the amplitudes of E and A waves (E/A ratio) is 0.8 to 1.5, DT is 140– 240 ms and IVRT 70 – 100 ms.

The mitral flow doppler patterns in LV diastolic dysfunction has been divided into four stages;

Stage I: In mild diastolic dysfunction, E/A ratio is revered and < 0.8. The reversal is due to the increase in A wave due to the more forceful atrial contraction to overcome the LV diastolic dysfunction. The deceleration time of the early diastolic filling (DT) is normally 140 - 240 ms. In diastolic dysfunction DT is prolonged. These patients are generally asymptomatic.

Stage II: In this, the E wave becomes taller due to elevated LA pressure. This is called pseudonormalization of the filling pattern. In this stage E/A reversal can still be demonstrated during Valsalva maneuver.

Stage III: The E wave becomes very high so that E/A ratio is more than > 2 and a significantly reduced DT < 160 ms and IVRT <50 ms . This is also called restrictive filling pattern.

Stage IV: In this, restrictive filling pattern remains fixed even during Valsalva maneuver. Initial stages (I to III) are considered reversible with treatment. Stage IV is considered as advanced. Use of drugs producing bradycardia like beta blockers in stages III and IV may precipitate low output state.

Tissue Doppler; If e' septal is < 7 cm/sec then it's pathological, the e' lateral < 10 cm/sec is pathological and the ratio of the E wave and the e' wave 14, so the cutoff is 14 or everything above 14 abnormal or pathological. If E/e' septal > 15 is pathological and E/e' lateral > 13 is pathological.

For calculation of PCWP Nagueh formula can be used from the Doppler derived mitral E/e' ratio. PCWP is usually equal to the LA pressure and hence the LV filling pressure. E' (Ea) has been considered as a preload independent index of relaxation of LV.

Nagueh formula : PCWP = 1.24 × {(E/e') + 1.9}

Another calculation of PCWP is simply ,

E/e' + 4 = PCWP (often used in emergency department)

If the E/ Vp ratio is >2.5 the LV end diastolic pressures are >15 mmHg in patients with reduced EF

E/ Velocity propagation = LVEDP

There is another measurement can include the velocity propagation and the IVRT

4.5 × [10/(2×IVRT+Vp)-9] = LVEDP

Receiver operating characteristic (ROC) showed that the combination of abnormal e' <= 8 and elevated E/A had high diagnostic accuracy compared with E/E' in both HFpEF and HFrEF. Cut off values of E/A was 1.81 in HFpEF and 1.16 in HFrEF for predicting mean PCWP > 18 mmHg. Septal e' is slightly lower than lateral e'. E/e' at lateral mitral annulus > 10 and E/e' at septal mitral annulus > 15 indicates LV diastolic dysfunction.

The indeterminate patients of LV feeling pressures, diastolic dysfunction was introduced in the 2016 guidelines of the Society of Echocardiography where there was a differentiate in healthy LV and sick LV and the resulting diastolic dysfunction. In patients with normal LVEF, average E/e' > 14, Septal e' velocity < 7 cm/s or Lateral e' velocity < 10 cm/s, TR velocity > 2.8 ms, LA volume Index > 34 ml/m2; if < 50% positive indicates normal diastolic function, if 50% positive, Indeterminate diastolic function and > 50% positive diastolic dysfunction is present, fig 4. [18]

Another measurement is perform called Left Atrial Volume index (LAVI), the normal value of LAVI is 16 – 34 ml/m2. The pathological value is > 34 ml/m2.

Similarly, Ar- A duration > 30 ms and reduction of S/D (<<1) also suggested Pathological.

Aging can cause reduced mitral E/A, annular e' velocity and mitral E DT, these can be confound with the evaluation of diastolic dysfunction. In elderly: E/e' > 14, Ar- A > 30 ms, mitral inflow changes with Valsalva maneuver, elevated resting pulmonary artery systolic pressure (PASP), LA dilatation or hypertrophy. These are the definite indices which indicates diastolic dysfunction. [19]

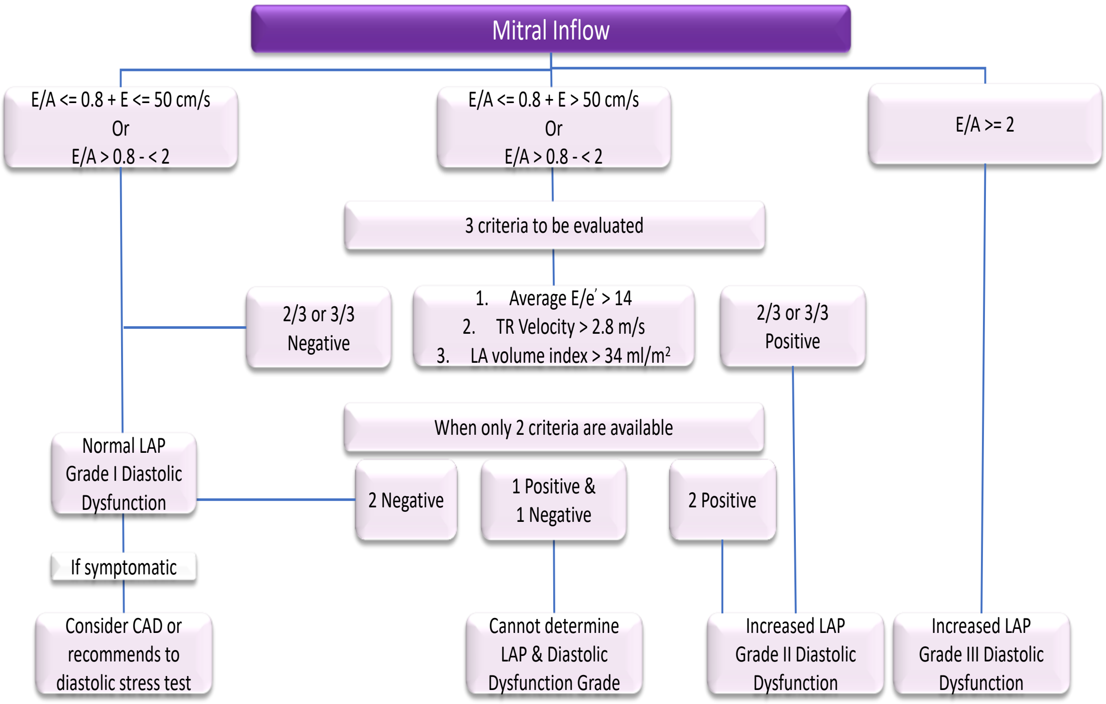

Figure 1: Algorithm to grade left ventricle diastolic dysfunction.[58] CAD, coronary artery disease; LAP, left atrial pressure; S/D, systolic/diastolic; TR, tricuspid regurgitation; LA, Left atrium

Colour M- mode flow propagation is another important measurement and can use it for several formula.[47] Measure from the mitral valve to 4 cm distally into the LV > 50 cm/s is considered normal, if its below 50 cm/s there might be elevated filling pressures. (E/Vp = PCWP)

Diastolic stress testing is like the LV stress testing. The E/e' ratio has to be elevated > 14 and TR velocity has to be above > 2.8 m/sec during the stress test, also the hand grip stress test is quite nice when the E/e' ratio is rising and the TR is rising that points towards that there's really a diastolic problem so possibly a heart failure with preserved ejection fraction (HFpEF).

According to new literature still we can measure left atrial (LA) strain. In left atrial strain, there are several phases and functions and have to differentiate (fig-5). PALS normal value is around 39% and PACS normal value approximately 17%. It help to identify also the situations where it might be indeterminate with the prior known markers. LA strain + LVI equals better detection of diastolic dysfunction, if PALS < 23% show that more hospitalizations in these patients even double amount of hospitalizations and the patient will be more symptomatic, patient will experience dyspnoea.

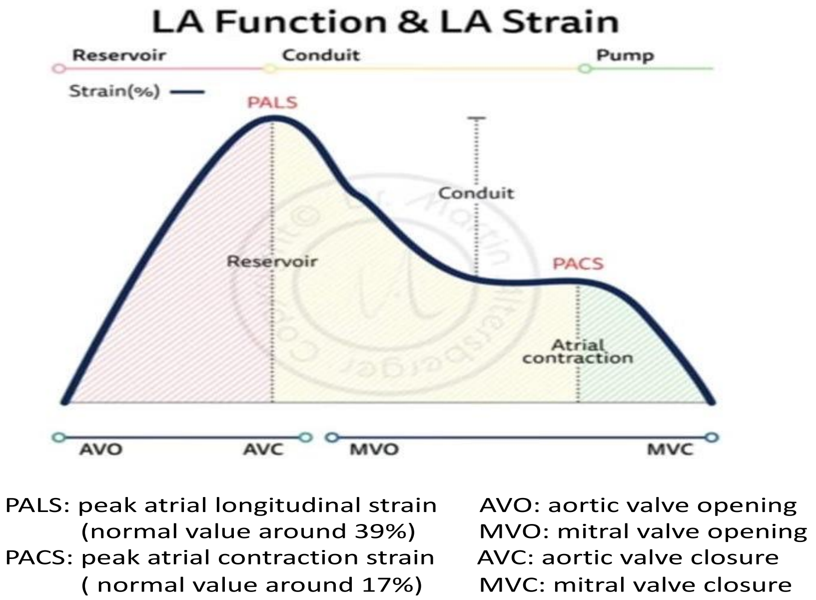

Figure 2: LA strain phases and function- Diastolic dysfunction in the elevation of feeling pressures, PALS < 18% is very likely to have PCWP > 12 mmHg, PALS < 16% the PCWP is most likely to be > 15 mmHg. So, the PACS above > 14% identifies normal feeling pressures (< 12 mmHg). PACS < 8% denote elevated feeling pressures.

LV strain in diastolic dysfunction while in HFrEF in correlates with the nutrientic peptides the BNP also with the fibrosis of heart with survival hospitalizations and of course with diastolic dysfunction as well. The lower the LV strain the worse diastolic dysfunction and elevated feeling pressures are more likely. Furthermore in HFpEF , have a reduction in left ventricular strain in the early stage, where good EF but the bad strain (- 15% cutoff).

	Functional	Morphological	Biomarkers (SR)	Biomarkers (AF)
Major	**Septal e' < 7 cm/s or Lateral e' < 10 cm/s or Average E/e' ≥ 15 or TR velocity > 2.8 m/s (PASP > 35 mmHg)**	**LAVI > 34 ml/m² or LVMI ≥ 149/122 g/m²(m/w) and RWT > 0.42**	**NT-proBNP > 220 pg/ml or BNP > 80 pg/ml**	**NT-proBNP > 660 pg/ml or BNP > 240 pg/ml**
Minor	Average E/e' 9-14 or GLS < 16%	LAVI 29-34 ml/m² or LVMI > 115/95 g/m² (m/w) or RWT > 0.42 or LV free wall thickness ≥ 12 mm	NT-proBNP 125-220 pg/ml or BNP 35-80 pg/ml	NT-proBNP 365-660 pg/m or BNP 105-240 pg/ml

Major criteria: 2 points	**≥ 5 points: HFpEF**
Minor criteria: 1 point	2-4 points: Diastolic Stress Test or Invasive Hemodynamic Measurements

Table 2: Echocardiographic and natriuretic peptide heart failure with preserved ejection fraction (HFpEF) work and scoring system (diagnostic workup). AF, atrial fibrillation; BNP, brain natriuretic peptide; LAVI, left atrial volume index; LVMI, left ventricular mass index; LV, left ventricle; RWT, relative wall thickness; TR, tricuspid regurgitation; NT-proBNP, N-terminal pro-brain natriuretic peptide; PASP, pulmonary artery pressure; SR, sinus rhythm.

A scoring for heart failure with preserved ejection fraction where diastolic dysfunction plays an essential role, as listed below (fig6). HFA PEFF score > 5 points in considered to be diagnostic of HEpEF, while a score of < 1 point is considered to make a diagnosis of HFpEF very unlikely and to mandate investigations for alternative causes.[20],[21],[22] Patients need further evaluation if they have an intermediate score of 2 - 4 points.

Evaluation of LV diastolic dysfunction in special clinical scenario (Echo parameters)

- Atrial fibrillation: In AF, Peak acceleration rate of mitral E velocity > 1900 cm/s2, DT of pulmonary venous diastolic velocity < 220 ms, septal E/e' > 11, IVRT is < 65 ms, E/Vp ratio is > 1.4 . To ensure accuracy, several beats must be measured (average of five or more beats).
- Mitral regurgitation: Ar- A will be >30 ms, IVRT < 60 ms, with normal EF IVRT/$T_{E\text{-}e'}$ < 5.6, with depressed EF average E/e' > 14
- Mitral regurgitation: Ar- A will be >30 ms, IVRT < 60 ms, with normal EF IVRT/T E-e' < 5.6, with depressed EF average E/e' > 14
- Mitral stenosis: Mitral A velocity above > 1.5 ms, IVRT < 60 ms, IVRT/TE-e' < 4.2.
- Hypertrophic cardiomyopathy: Ar- A > 30 ms, average E/e' is > 14, LAVI >> 34 mL/m2 and TR peak velocity is > 2.8 m/s.
- Restrictive cardiomyopathy: Mitral E/A > 2.5, IVRT < 50 ms, Mitral E DT < 140 ms, average E/e' > 14.
- Constrictive pericarditis: Septal e' is often higher than lateral e' (annular reversus), therefore E/e' should not be used to estimate LV filling pressure.
- Noncardiac pulmonary hypertension: Lateral E/e' > 13 suggests cardiac etiology.

Right ventricular dysfunction:

Right ventricular dysfunction and pulmonary hypertension are most frequent in HFpEF.[15],[23]

Right ventricular systolic function can be evaluated in terms of right fractional area change (FAC).

FAC= End diastolic area – End systolic area / End-diastolic area, < 35% is pathological.

Calculation of dp/dt from TR jet usually > 400 mmHg is normal systolic function. Tricuspid annular plane systolic excursion (TAPSE) is another measurement of RV systolic function. TAPSE is a measure of RV longitudinal function, If TAPSE < 1.7 mm indicates systolic dysfunction of RV. As discussed previously, In RV systolic dysfunction the RV Tei index is > 0.4 by PW doppler or by TDI is > 0.5. TDI derive Tricuspid lateral anulus systolic velocity wave (S') <9.5 cm/s. 3D echocardiography EF is < 45% than RV systolic dysfunction present. RV free wall GLS numerically > -20%.

The presence of right ventricular diastolic dysfunction has been linked to a range of conditions, including congenital heart diseases, cardiomyopathies, left-sided valvular heart disease, and systemic disorders such as diabetes mellitus, rheumatoid arthritis, and vasculitis. Assessment of right atrium (RA), right ventricle (RV), inferior vena cava (IVC) by 2D echocardiography gives indirect evidence on right ventricular diastolic function because significant elevation of right sided feeling pressures would alter the right heart dimensions, size of IVC and its inspiratory collapse. When using the inferior vena cava (IVC) to assess right atrial (RA) pressure, it is crucial to be aware that factors such as positive-pressure ventilation and athletic conditioning can cause the IVC to become dilated. Thus, it is important to consider these potential influences and interpret the IVC size within the appropriate clinical context to ensure accurate assessment of RA pressure.[21] As in the case of mitral valve assessment of tricuspid inflow velocities is a simple way to assess RV diastolic function. RV diastolic dysfunction may be implies by RV e' is < 7.8, RV E/A ratio is <0.8 or >2.0, RV E/e' > 6.0 and RA pressure >5 mmHg.

RESULTS:

The study by Butler et al. aimed to review the current state of therapies for heart failure with preserved ejection fraction (HFpEF) and provide direction for future developments. HFpEF is a type of heart failure where the heart still pumps normally but has difficulty relaxing and filling with blood. The researchers found that HFpEF is a complex syndrome with multiple underlying causes and comorbidities, including hypertension, obesity, diabetes, and aging. There is currently no specific therapy that has been shown to improve outcomes in HFpEF, and the management primarily involves addressing the underlying conditions and comorbidities. The study suggests that there is a need for better understanding of the underlying mechanisms of HFpEF and development of targeted therapies. These may include drugs that improve diastolic function, reduce inflammation, or address specific comorbidities. The study also highlights the importance of personalized medicine in the management of HFpEF, as the underlying causes and comorbidities may vary widely among patients. In summary, the study by Butler et al. found that there is currently no specific therapy for HFpEF and highlights the need for better understanding of the underlying mechanisms and development of targeted therapies. Personalized medicine may also play an important role in the management of HFpEF.

The study by Marwick aimed to evaluate the various methods used for the assessment of left ventricular (LV) systolic function in clinical practice and research and to identify whether there is a common language or significant variability in their interpretation. The author found that there are several imaging modalities available for the assessment of LV systolic function, including echocardiography, radionuclide imaging, magnetic resonance imaging (MRI), and computed tomography (CT). Each modality has its advantages and limitations, and the choice of modality depends on the clinical question being asked, availability, and patient factors. Despite the availability of multiple modalities for LV systolic function assessment, the author found that there is significant variability in the interpretation and reporting of results. This variability can be attributed to differences in terminology, normal reference ranges, and interpretation criteria. The author suggests that there is a need for standardization of LV systolic function assessment to facilitate communication between clinicians, improve comparability between studies, and facilitate the development of evidence-based guidelines. In summary, the study by Marwick found that there are multiple imaging modalities available for the assessment of LV systolic function, each with its advantages and limitations. However, there is significant variability in the interpretation and reporting of results, highlighting the need for standardization in LV systolic function assessment.

The study by Priori et al. aimed to provide guidelines for the management of patients with ventricular arrhythmias and the prevention of sudden cardiac death. The guidelines were developed by a task force of the European Society of Cardiology and were based on a comprehensive review of the available evidence and expert consensus. The guidelines provide recommendations for the diagnosis, risk stratification, and treatment of ventricular arrhythmias, including both pharmacological and non-pharmacological therapies such as implantable cardioverter-defibrillators (ICDs) and catheter ablation. The guidelines also highlight the importance of addressing underlying conditions that may contribute to the development of ventricular arrhythmias, such as ischemic heart disease, heart failure, and genetic disorders. Overall, the study provides a comprehensive set of guidelines for the management of patients with ventricular arrhythmias and highlights the importance of personalized management based on individual patient characteristics and risk factors. The guidelines may be useful for clinicians in improving outcomes and reducing the risk of sudden cardiac death in this patient population.

The study by Mele et al. aimed to investigate the impact of tissue harmonic imaging (THI) on the accuracy and reproducibility of visual, manual, and automated echocardiographic assessment of left ventricular ejection fraction (LVEF) in patients with distorted left ventricles. THI is a technique that improves image quality by reducing image artifacts and enhancing the signal-to-noise ratio. The researchers found that THI significantly improved the accuracy and reproducibility of LVEF assessment compared to conventional echocardiography in patients with distorted left ventricles. THI also reduced interobserver variability in LVEF measurements. These findings suggest that THI may have clinical utility in patients with distorted left ventricles and could improve the accuracy of LVEF assessment in this population.

The study by Tei et al. aimed to evaluate the correlation between a non-invasive Doppler-derived myocardial performance index (MPI) and invasive measurements obtained during cardiac catheterization. The MPI is a parameter that reflects both systolic and diastolic function of the myocardium. The researchers found a strong correlation between the non-invasive MPI and invasive measurements of left ventricular (LV) function obtained during cardiac catheterization. The correlation was strongest for LV end-diastolic pressure, a measure of diastolic function, and LV ejection fraction, a measure of systolic function. The study concluded that the non-invasive MPI is a reliable and useful parameter for assessing global LV function, and may be particularly useful in patients with impaired systolic and diastolic function.

The study by Tsang et al. aimed to evaluate left atrial (LA) size as a risk marker for the development of atrial fibrillation (AF) in older men and women. The researchers followed 1655 individuals over a median of 3.1 years and found that those with larger LA volumes had a higher risk of developing AF. Specifically, each 10 mL/m^2 increase in LA volume was associated with a 39% increase in the risk of developing AF. The study also found that LA volume was a stronger predictor of AF than other commonly used clinical risk factors, such as hypertension and left ventricular hypertrophy. The researchers concluded that LA volume is an important risk marker for the development of AF in older individuals and may help identify those at increased risk for this condition.

The study by Wang et al. aimed to investigate the natural history of asymptomatic left ventricular systolic dysfunction (LVSD) in the general population. The researchers followed 1,869 participants without clinical heart failure for an average of 4.4 years and assessed their left ventricular function using echocardiography. The study found that the prevalence of LVSD increased with age, from 1.6% in those younger than 50 years to 6.4% in those older than 70 years. Among those with LVSD at baseline, the incidence of clinical heart failure was 12.9% per year, and the mortality rate was 9.1% per year. However, the majority of participants with LVSD remained asymptomatic throughout the study, and the risk of developing heart failure or dying was significantly lower for those with asymptomatic LVSD compared to those with symptomatic LVSD.

The study by Omar et al. aimed to review the advances in echocardiographic imaging in heart failure with reduced and preserved ejection fraction (HFrEF and HFpEF). The researchers found that echocardiography plays a critical role in the diagnosis and management of heart failure, and has evolved significantly over the years with the development of new techniques and technologies. In HFrEF, echocardiography is used to assess left ventricular size and function, as well as other parameters such as mitral regurgitation and pulmonary artery pressure. The study highlights the importance of newer techniques such as speckle tracking imaging and three-dimensional echocardiography in the evaluation of HFrEF, as they can provide more detailed information on cardiac mechanics and function. In HFpEF, echocardiography is used to assess left ventricular diastolic function, which is often impaired in this type of heart failure. The study suggests that newer techniques such as strain imaging and tissue Doppler imaging can provide more accurate assessment of diastolic function in HFpEF.

The article by Kumar et al. describes a case report of a patient with dilated cardiomyopathy and a unique Doppler echocardiographic finding known as the "L wave." The L wave is a rare, low frequency wave that occurs during diastole and is thought to represent a delayed and prolonged left ventricular relaxation phase. The authors suggest that the L wave may be a useful marker for assessing diastolic function and for predicting adverse outcomes in patients with heart failure. However, further research is needed to validate this finding and to determine its clinical significance.

The study by Moller et al. aimed to investigate the prognostic and clinical implications of the ratio of left ventricular peak E-wave velocity to flow propagation velocity (E/Vp) in patients with first myocardial infarction (MI). The researchers found that a higher E/Vp ratio was associated with a worse prognosis and an increased risk of developing heart failure and cardiac death. The E/Vp ratio was also found to be a better predictor of adverse outcomes compared to other echocardiographic parameters such as left ventricular ejection fraction and mitral regurgitation. The study suggests that the E/Vp ratio measured by color M-mode Doppler echocardiography can provide important prognostic information in patients with first MI.

The study by Suzuki S et al. aimed to develop and validate the H2 FPEF score for predicting future heart failure with preserved ejection fraction (HFpEF) in stable outpatients with cardiovascular risk factors. The H2 FPEF score included the following variables: hypertension, age ≥ 60 years, diabetes mellitus, body mass index ≥30 kg/m2, and left atrial volume index ≥34 mL/m2. The score was developed using data from 2,405 patients and validated in an independent cohort of 2,516 patients. The results showed that the H2 FPEF score was significantly associated with the risk of future HFpEF. The score had good discrimination and calibration performance in both the development and validation cohorts. The study concluded that the H2 FPEF score is a simple and effective tool for predicting future HFpEF in stable outpatients with cardiovascular risk factors, and could be used to identify patients who would benefit from early interventions to prevent or delay the onset of HFpEF.

The study by Chung n, et al. aimed to determine the feasibility and accuracy of Doppler echocardiography in measuring left ventricular dP/dt compared to simultaneous invasive cardiac catheterization. The study included 22 patients who underwent both Doppler echocardiography and cardiac catheterization, and the results were compared. The study found a good correlation between Doppler echocardiography and cardiac catheterization in measuring left ventricular dP/dt, with a correlation coefficient of 0.84. The study concluded that Doppler echocardiography is a feasible and accurate method for measuring left ventricular dP/dt and can be used as an alternative to invasive cardiac catheterization.

The study conducted by Narayanan et al. in 2009, aimed to evaluate cardiac mechanics in patients with mild hypertensive heart disease using speckle-strain imaging.

The researchers found that the hypertensive heart disease patients had impaired left ventricular systolic and diastolic function compared to the healthy controls. The peak global longitudinal strain, a measure of myocardial deformation, was significantly reduced in the hypertensive group.

Additionally, the hypertensive group had a significantly higher left ventricular mass index and left atrial volume index, indicating left ventricular hypertrophy and left atrial enlargement, respectively.

Overall, the study suggests that speckle-strain imaging can detect early changes in cardiac mechanics in patients with mild hypertensive heart disease, even before the development of significant structural changes.

DISCUSSION:

The discussion in the provided articles covers a wide range of topics related to cardiology, offering insights into the diagnosis, treatment, and management of various cardiac conditions. One such condition is heart failure, which is characterized by the heart's inability to pump blood effectively. The 2016 ESC Guidelines for the diagnosis and treatment of acute and chronic heart failure provide recommendations for the management of heart failure, including lifestyle modifications, medication therapy, and device therapy. The guidelines also emphasize the importance of accurate diagnosis, as misdiagnosis can lead to inappropriate treatment and poor outcomes.

Another topic covered in the articles is ventricular arrhythmias, which are abnormal heart rhythms that originate in the ventricles. Risk assessment for ventricular arrhythmias is discussed, with one study providing a risk score based on 39,372 heart failure patients from 30 studies. This risk score can help healthcare professionals identify patients who are at higher risk of ventricular arrhythmias and provide appropriate treatment.

The articles also cover various assessment methods for cardiac conditions, such as echocardiography and cardiovascular magnetic resonance imaging. Echocardiography is a non-invasive imaging technique that uses ultrasound waves to produce images of the heart, while cardiovascular magnetic resonance imaging uses magnetic fields and radio waves to create detailed images of the heart. These assessment methods can provide valuable information about cardiac structure and function, helping healthcare professionals make accurate diagnoses and develop effective treatment plans.
The MOGE(S) classification is another topic discussed in the articles, providing a phenotype-genotype nomenclature of cardiomyopathy. This classification system can help healthcare professionals better understand the underlying causes of cardiomyopathy and develop personalized treatment plans based on the specific genetic and phenotypic characteristics of each patient.

Finally, the association between chronic kidney disease and heart failure is explored in the articles, highlighting the need for close monitoring and management of both conditions in patients who have both conditions. The articles emphasize the importance of multidisciplinary care for patients with complex medical conditions, such as those with heart failure and chronic kidney disease.

Overall, the discussion in the provided articles highlights the importance of accurate diagnosis, effective treatment, and ongoing research and development in the field of cardiology. The articles provide a valuable resource for healthcare professionals and researchers working in this area, offering insights into the latest developments in the diagnosis, treatment, and management of cardiac conditions.

CONCLUSION:

Echocardiography has proven to be a highly effective tool for the precise diagnosis and prognosis of heart failure (HF). It is currently considered the most convenient diagnostic procedure for evaluating both HF with reduced ejection fraction (HFrEF) and HF with preserved ejection fraction (HFpEF). By identifying the different stages and subtypes of HF and their etiology and complications, echocardiography can guide medical and device-based therapies. However, further research is still needed to gain a deeper understanding of the role of echocardiography in the management of HF and to explore new ways of utilizing this technology to improve clinical outcomes. Such efforts could lead to important advances in the diagnosis, monitoring, and treatment of HF, ultimately benefiting patients and healthcare systems alike.

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