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Left Ventricular Global Systolic Function Assessment by Echocardiography

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Abstract:

Background: Accurate assessment of left ventricular (LV) global systolic function is essential for the diagnosis, risk stratification, and management of a wide range of cardiovascular diseases. Echocardiography remains the cornerstone imaging modality for evaluating LV systolic performance due to its wide availability, non-invasive nature, and real-time functional assessment. Conventional parameters such as left ventricular ejection fraction (LVEF) have been extensively used; however, they are limited by load dependency, geometric assumptions, and inter-observer variability. Recent advances in echocardiographic techniques, including tissue Doppler imaging and speckle-tracking echocardiography, have enabled more sensitive and reproducible assessment of myocardial function, particularly through the evaluation of global longitudinal strain. Integrating conventional and advanced echocardiographic indices provides a more comprehensive and accurate assessment of LV global systolic function, allowing earlier detection of subclinical myocardial dysfunction and improved clinical decision-making.

Keywords: Left ventricular systolic function; Echocardiography; Ejection fraction; Global longitudinal strain; Speckle-tracking echocardiography; Tissue Doppler imaging.

Introduction:

Left ventricular (LV) systolic function represents a central component of overall cardiac performance and plays a pivotal role in determining clinical outcomes across a wide spectrum of cardiovascular diseases. Impairment of LV systolic function is associated with increased morbidity, hospitalization rates, and mortality in patients with heart failure, ischemic heart disease, cardiomyopathies, and valvular disorders. Consequently, accurate and reproducible assessment of LV systolic function is essential not only for diagnosis but also for risk stratification, therapeutic guidance, and monitoring of disease progression and response to treatment **(1).**

Echocardiography has long been established as the first-line imaging modality for the evaluation of LV systolic function owing to its wide availability, cost-effectiveness, non-invasive nature, and capability to provide real-time functional assessment at the bedside. Conventional echocardiographic parameters, particularly left ventricular ejection fraction (LVEF), remain widely used in daily clinical practice. However, growing evidence has highlighted important limitations of LVEF, including its dependence on loading conditions, limited sensitivity to subtle myocardial dysfunction, and variability related to image quality and geometric assumptions. These limitations have driven the development and adoption of advanced echocardiographic techniques aimed at providing a more comprehensive and sensitive assessment of global LV systolic performance **(2).**

The LV is characterized by its thick myocardial walls and its complex three-dimensional geometry. Although it approximates an elongated ellipsoid with a conical apex in normal physiological states, pathological remodeling due to ischemic or non-ischemic disease often alters its geometry regionally or globally. This lack of conformity to a simple geometric model represents a fundamental challenge in estimating LV volumes and contractile function using echocardiography. Despite these challenges, echocardiography has evolved into a primary modality for functional assessment due to its non-invasive nature, bedside availability, and ability to provide both qualitative and quantitative data **(3).**

Echocardiographic Modalities for LV Function

Multiple echocardiographic techniques are employed to evaluate LV systolic performance, including two-dimensional (2D) imaging, M-mode echocardiography, Doppler echocardiography, and, more recently, threedimensional (3D) echocardiography. Early validation studies relied primarily on transthoracic echocardiography (TTE); however, intraoperative and critical care settings have expanded the application of transesophageal echocardiography (TEE), which offers superior imaging quality in mechanically ventilated or anesthetized patients. These modalities provide different methods of assessing global LV systolic function, either by geometric measurements of chamber dimensions, analysis of volume surrogates, or more advanced deformation imaging such as speckle-tracking strain analysis **(4).**

Indices of Global LV Systolic Function

The gold standard invasive parameter for quantifying contractility is the maximum rate of LV pressure rise during systole (dP/dt max), obtained with high-fidelity intracavitary or intramyocardial micromanometers.

Owing to its invasive nature, however, it has limited clinical applicability. Instead, echocardiography provides indirect but clinically robust alternatives by measuring changes in LV dimensions and volumes across the cardiac cycle. Parameters commonly derived include fractional shortening (FS), fractional area change (FAC), ejection fraction (EF), stroke volume (SV), cardiac output (CO), and, more recently, global longitudinal strain (GLS) using speckle-tracking echocardiography (STE) **(5).**

Changes in LV Dimensions and Volumes

LV dimensions and derived indices are central to routine assessment. While the irregularity of LV geometry introduces some limitations, dimension-based calculations provide practical surrogates of global LV systolic function. According to the 2015 ASE/EACVI chamber quantification guidelines, the same reference values apply for both TEE and TTE, thereby standardizing interpretation across clinical contexts **(6).**

Fractional Shortening (FS)

Fractional shortening is derived from left ventricular (LV) internal dimensions measured at end-diastole (LVIDd) and at end-systole (LVIDs), usually obtained from the parasternal long-axis view in transthoracic echocardiography or from the trans-gastric two-chamber or short-axis views in transesophageal echocardiography. It is expressed as the difference between end-diastolic and end-systolic diameters, divided by the end-diastolic diameter, and multiplied by one hundred **(7).**

In other words, FS is calculated as: "end-diastolic LV internal diameter minus end-systolic LV internal diameter, divided by the enddiastolic diameter, and expressed as a percentage." A normal fractional shortening is generally greater than 25%. While FS is simple, rapid, and reproducible, it reflects contractility of only two opposing myocardial walls and is therefore limited in the presence of regional wall motion abnormalities. Furthermore, FS is preload- and afterload-dependent, which reduces its reliability in hemodynamically unstable patients **(8).**

Fractional Area Change (FAC)

Fractional area change is determined from planimetry of the LV endocardial borders in a trans-gastric mid-papillary short-axis view. The LV end-diastolic area (LVEDA) and LV end-systolic area (LVESA) are traced, and the difference between the two areas is divided by the enddiastolic area, then expressed as a percentage. Put simply, FAC is calculated as: "end-diastolic LV cavity area minus end-systolic LV cavity area, divided by the end-diastolic area, multiplied by one hundred." A normal FAC is greater than 35%, whereas values of 15% or less are consistent with severe LV systolic dysfunction **(9).**

FAC correlates well with radionuclide ejection fraction measurements, particularly when ejection fraction is below 45%, and is frequently used intraoperatively as a surrogate for LV preload and systolic performance. However, FAC is also influenced by loading conditions and is limited by being a single-plane measurement, which may underestimate or overestimate global function in patients with extensive regional wall motion abnormalities, especially in the apical segments **(9).**

Left Ventricular Ejection Fraction

Left ventricular ejection fraction (LVEF) is the percentage of the stroke volume (SV) relative to the left ventricular end-diastolic volume (LVEDV). It is calculated by measuring the difference between the left ventricular end-diastolic volume (LVEDV) and the left ventricular endsystolic volume (LVESV), divided by the LVEDV, and then multiplying by 100% **(10).**

In 2D echocardiography, images are captured in a single plane, and volume calculations, which are three-dimensional, require mathematical models based on geometric shapes. Several geometric shapes have been used in LV volume calculations, such as prolate ellipsoid, truncated ellipsoid, and area-length methods. These methods performed well for normally shaped ventricles but failed in clinical settings with abnormal ventricles. The biplane method of multiple discs (Simpson's method) is the only technique recommended in the 2015 ASE/EACVI guidelines, as it is more accurate, even in abnormal ventricles **(11).**

3D echocardiography, which measures LV volumes in less geometry-dependent ways, provides more accurate estimates of ejection fraction. Some methods for LV volume calculation, like the Teichholz and prolate ellipsoid methods, use a single linear measurement of the LV cavity **(12).**

The area-length method assumes the LV shape is similar to a bullet. This method multiplies the cross-sectional area (CSA) of the LV in the transgastric mid-papillary short axis (TG MP SAX) view by the length of the LV cavity as measured in the modified 4-chamber or 2-chamber views. This volume is then adjusted by a correction factor. However, this method is discouraged due to its limitations **(13).**

Biplane Simpson's Method of Multiple Discs

This method is the only recommended approach for calculating LV volumes and ejection fraction with 2D echocardiography. It divides the LV cavity into twenty cylindrical discs of equal height, and the volume of each disc is calculated and summed. The method requires imaging the LV in long-axis views, including the base and apex, in two orthogonal planes. The endocardial border is traced, and the software of most echocardiography machines automatically divides the LV area into equal sections. The volumes of the discs are summed separately in both planes, and the average gives the LV volume. Measurements are made at enddiastole and end-systole **(14).**

Limitations of the Method

Suboptimal image quality, particularly in patients with obesity, pulmonary hyperinflation, or in mechanically ventilated settings, may hinder accurate tracing of the endocardial border and lead to errors in volume estimation. In patients with electrical or mechanical dyssynchrony, defining true end-systolic and end-diastolic frames becomes challenging, which may compromise reproducibility. The presence of regional wall motion abnormalities (RWMA) in myocardial segments not well visualized in standard imaging planes may result in underestimation or misinterpretation of global LV function. Furthermore, in arrhythmic conditions such as atrial fibrillation, beat-to-beat variability in ejection fraction requires multiple cardiac cycles to be averaged, adding complexity and potential variability to measurements **(15).**

Reference Values for LV Function

Quantitative thresholds for LV systolic performance are well established. Normal LV systolic function is defined as an ejection fraction greater than 55%. Mild LV dysfunction is classified as an ejection fraction between 45% and 54%, moderate dysfunction as 30% to 44%, and severe dysfunction as less than 30%. These ranges provide clinically relevant stratification and are widely used for prognostication and therapeutic decision-making in patients with coronary artery disease and other cardiomyopathies **(16).**

Cardiac Output and Cardiac Index

Cardiac output (CO) represents the volume of blood ejected by the LV per minute and is calculated as the product of stroke volume (SV) and heart rate (HR). Stroke volume itself is obtained by multiplying the crosssectional area (CSA) of the left ventricular outflow tract (LVOT) by the velocity–time integral (VTI) of flow through the LVOT. In practice, CSA is derived from LVOT diameter measured in the parasternal long-axis view, while pulsed-wave Doppler at the LVOT just beneath the aortic valve provides VTI. Cardiac index (CI) is the cardiac output normalized to body surface area, providing a patient-size–adjusted measure of cardiac performance. Both CO and CI are influenced by preload, afterload, heart rate, and intrinsic LV contractility, and therefore must be interpreted in the context of overall hemodynamic status **(17).**

Systolic Index of Contractility (dP/dt)

The maximal rate of rise in LV pressure during isovolumic contraction (dP/dt max) is a load-sensitive but valuable index of LV contractility. Although the gold standard measurement requires invasive micromanometers, echocardiographic estimation can be obtained from the continuous-wave Doppler envelope of a central mitral regurgitation jet. The steepest slope of the MR signal corresponds to the pressure gradient between the LV and left atrium during early systole and allows calculation of dP/dt. This approach, however, requires the presence of a well-defined MR jet and is not applicable in patients without mitral regurgitation **(18).**

Tissue Doppler Imaging (TDI)

Tissue Doppler imaging evaluates myocardial velocities by applying Doppler principles to myocardial motion rather than blood flow. Peak systolic myocardial velocity (S′), typically measured at the mitral annulus, correlates with global LV systolic function. TDI provides quantitative and reproducible indices of both systolic and diastolic performance, but its measurements are angle-dependent. Nevertheless, S′ velocity has been shown to be a useful surrogate marker of LV systolic function in various disease states, including coronary artery disease and heart failure **(19).**

Speckle-Tracking Echocardiography and Global Longitudinal Strain (GLS)

Speckle-tracking echocardiography (STE) is an angle-independent imaging modality that tracks acoustic markers (“speckles”) in the myocardium frame by frame, allowing assessment of myocardial deformation. Global longitudinal strain (GLS), defined as the percentage change in myocardial length from end-diastole to end-systole, is the most widely validated strain parameter. Normal GLS is approximately −18% with an acceptable variation of ±2%, with more negative values reflecting better systolic performance. GLS is highly reproducible, less loaddependent than traditional measures, and provides incremental prognostic value in the detection of subclinical systolic dysfunction, particularly in patients with coronary artery disease where ischemia first impairs subendocardial longitudinal fibers **(20).**

Mitral Annular Plane Systolic Excursion (MAPSE)

Mitral annular plane systolic excursion quantifies the longitudinal displacement of the mitral annulus toward the LV apex during systole, representing global longitudinal LV function. Normal MAPSE values exceed 8 mm, with typical averages of 12 ± 2 mm. MAPSE is simple to measure, reproducible, and particularly useful in situations where advanced imaging techniques are not feasible. However, as it reflects longitudinal motion alone, it may underestimate LV performance in conditions with preserved longitudinal function but impaired circumferential or radial contraction **(21).**

Left Ventricular Outflow Tract Ejection Acceleration (LVOT ACC)

LVOT acceleration time and peak systolic velocity can be combined to calculate LVOT ejection acceleration, which provides an indirect index of LV contractility. The physiologic principle is that a steeper and faster acceleration of blood through the LVOT reflects stronger contractile force. Normal LVOT acceleration values range between 8 and 14 m/s^2. While less commonly used in routine clinical practice, this index can be useful in intraoperative or critical care settings where continuous monitoring of LV performance is necessary **(22).**

The Left Ventricular Global Function Index (LVGFI)

The Left Ventricular Global Function Index (LVGFI) is an integrated measure used to assess left ventricular (LV) function, combining multiple echocardiographic parameters into a single index. This index provides a comprehensive evaluation of LV performance and plays a critical role in diagnosing and managing various cardiovascular conditions. LVGFI was calculated as (LVSV/LVGV) × 100% **(23).**

Integration into the LVGFI

The LV Global Function Index (LVGFI) represents an effort to combine these diverse echocardiographic parameters into a single, comprehensive measure of LV function. This composite index incorporates multiple factors, such as LVEF, and TDI-derived velocities, offering a more nuanced understanding of LV function than any single parameter alone. By combining these measures, LVGFI can provide a more accurate assessment of both systolic and diastolic function, as well as myocardial deformation, offering better prognostic information for patients with a variety of cardiac conditions **(24).**

Challenges and Limitations

Despite its advantages, the use of LVGFI presents several challenges. The accuracy of the LVGFI is dependent on the quality of the echocardiographic images and the techniques used to measure the parameters. Variability in imaging equipment, software, and operators can lead to discrepancies in measurements, which may affect the reproducibility of LVGFI across different clinical settings. In addition, factors such as poor image quality due to obesity, lung disease, or mechanical ventilation can affect the accuracy of key parameters like TDI velocities. As a result, the reliability of LVGFI may be limited in some patient populations **(25).**

The Left Ventricular Global Function Index in coronary artery disease Patients

Assessment of Left Ventricular Function in ACS:

Echocardiography is the gold standard for evaluating LV function in ACS patients due to its non-invasive nature, wide availability, and real time imaging capabilities. Traditional methods to assess LV function include ejection fraction (EF), stroke volume (SV), and systolic/diastolic measurements. However, these parameters may not always accurately reflect overall LV function, particularly in patients with complex and heterogeneous myocardial conditions like those seen in ACS. Consequently, more comprehensive metrics, such as the LVGFI, have been developed to provide a broader assessment of LV function **(26).**

The LVGFI is derived from a formula that incorporates LV stroke volume, LV cavity volume, and LV myocardial volume. It reflects both the hemodynamic performance of the heart and the intrinsic contractile ability of the myocardium, offering a more holistic evaluation of LV function. The LVGFI has been proposed as a potentially valuable prognostic tool for identifying high-risk ACS patients and guiding therapeutic interventions **(27).**

Prognostic Value of LVGFI in ACS:

Recent studies have investigated the potential of LVGFI as a prognostic marker for adverse outcomes in ACS patients. It has been shown that LVGFI is correlated with clinical outcomes such as mortality, heart failure progression, and the occurrence of MACEs **(28).**

the prognostic value of the Left Ventricular Global Function Index (LVGFI) in predicting major adverse cardiovascular events (MACEs) in acute coronary syndrome (ACS) patients over a long-term follow-up. Previous study **Doganay and Celebi (29)** included 718 patients with ST-elevated myocardial infarction (STEMI) and 781 with non-ST-elevated myocardial infarction (NSTEMI). LVGFI, calculated using echocardiography, was found to be significantly lower in the STEMI group compared to the NSTEMI group, with decreased LVGFI levels identified as independent predictors of MACEs in both groups. The findings suggest that assessing LVGFI through echocardiography can effectively identify high-risk patients following a heart attack, potentially guiding treatment strategies and improving long-term outcomes **(29).**

One key advantage of LVGFI over traditional parameters is its ability to integrate both functional and structural aspects of the left ventricle. Unlike ejection fraction, which solely reflects the percentage of blood ejected from the LV, LVGFI provides a more nuanced view of the myocardial performance, taking into account changes in LV volume and myocardial tissue. This feature makes LVGFI particularly useful in patients with myocardial remodeling, which is common following ACS **(25)**.

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