Recommendations for the Evaluation of Left Ventricular Diastolic Function by Echocardiography: An Update from the American Society of Echocardiography and the European Association of Cardiovascular Imaging

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Abbreviations

2D = Two-dimensional

AR = Aortic regurgitation

ASE = American Society of Echocardiography

AV = Atrioventricular

CW = Continuous-wave

DT = Deceleration time

EACVI = European Association of Cardiovascular Imaging

EF = Ejection fraction

GLS = Global longitudinal strain

HCM = Hypertrophic cardiomyopathy

HFpEF = Heart failure with preserved ejection fraction

HFrEF = Heart failure with reduced ejection fraction

IVRT = Isovolumic relaxation time

LA = Left atrial

LAP = Left atrial pressure

LV = Left ventricular

LVEDP = Left ventricular end-diastolic pressure

LVEF = Left ventricular ejection fraction

MAC = Mitral annular calcification

MR = Mitral regurgitation

PASP = Pulmonary artery systolic pressure

PCWP = Pulmonary capillary wedge pressure

RV = Right ventricular

STE = Speckle-tracking echocardiography

TR = Tricuspid regurgitation

Vp = Flow propagation velocity

Echocardiographic assessment of left ventricular (LV) diastolic function is an integral part of the routine evaluation of patients presenting with symptoms of dyspnea or heart failure. The 2009 American Society of Echocardiography (ASE) and European Association of Echocardiography (now European Association of Cardiovascular Imaging [EACVI]) guidelines for diastolic function assessment were comprehensive, including several two-dimensional (2D) and Doppler parameters to grade diastolic dysfunction and to estimate LV filling pressures.[1] Notwithstanding, the inclusion of many parameters in the guidelines was perceived to render diastolic function assessment too complex, because several readers have interpreted the guidelines as mandating all the listed parameters in the document to fall within specified values before assigning a specific grade. The primary goal of this update is to simplify the approach and thus increase the utility of the guidelines in daily clinical practice.

LV diastolic dysfunction is usually the result of impaired LV relaxation with or without reduced restoring forces (and early diastolic suction), and increased LV chamber stiffness, which increase cardiac filling pressures. Thus, when performing an echocardiographic study in patients with potential diastolic dysfunction, one should search for signs of impaired LV relaxation, reduced restoring forces and increased diastolic stiffness. More important, LV filling pressure should be estimated because elevated LV diastolic pressure in the absence of increased LV end-diastolic volume is strong evidence in favor of well-developed diastolic dysfunction. In the majority of clinical studies, LV filling pressures and diastolic function grade can be determined reliably by a few simple echocardiographic parameters with a high feasibility. In addition, technical developments have emerged that provide new indices that appear promising for studying LV diastolic function. This update places more emphasis on applying the most useful, reproducible, and feasible 2D and Doppler measurements from the 2009 guidelines.

Before applying the guidelines, it is essential to consider what the term *LV filling pressures* refers to. The term *LV filling pressures* can refer to mean pulmonary capillary wedge pressure (PCWP) (which is an indirect estimate of LV diastolic pressures), mean left atrial (LA) pressure (LAP), LV pre-A pressure, mean LV diastolic pressure, and LV end-diastolic pressure (LVEDP). The different LV and LA diastolic pressures mentioned above (Figure 1) have different correlates with Doppler signals. For example, in the early stages of diastolic dysfunction, LVEDP is the only abnormally elevated pressure because of a large atrial pressure wave, while mean PCWP and LAP remain normal. With tachycardia and/or increased LV afterload, mean PCWP and LAP increase which provides the basis for the diastolic stress test. Thus, it is important that one is clear on which pressure is being estimated as there are different Doppler variables that correlate with an increase in LVEDP only versus those that reflect an increase in both LAP and LVEDP. Although the current recommendations are focused on echocardiographic techniques, it should be noted that both nuclear scans and cardiac magnetic resonance can be used to evaluate LV filling rates and volumes. Notably, measurements derived by both techniques are affected by LV relaxation and LV filling pressures and are quite similar to measurements and derivatives obtained from mitral inflow velocities.

Tables 1 and 2 summarize the technical aspects, hemodynamic determinants, and clinical applications including limitations of each of the Doppler and 2D parameters.[2-50] Doppler signals that occur at end-diastole correlate best with LVEDP. These include mitral peak A velocity at tips level, A-wave duration at the annulus, A velocity deceleration time (DT), pulmonary vein peak Ar velocity, Ar velocity duration, Ar-A duration, and tissue Doppler–derived mitral annular a′ velocity. Mitral peak E-wave velocity, E/A ratio, E velocity DT, E/e′ ratio, pulmonary vein systolic-to-diastolic velocity ratio, and peak velocity of tricuspid regurgitation (TR) by continuous-wave (CW) Doppler relate best with earlier occurring LV diastolic pressures (mean PCWP, pre-A pressure, and mean LV diastolic pressure).

I. GENERAL PRINCIPLES FOR ECHOCARDIOGRAPHIC ASSESSMENT OF LV DIASTOLIC FUNCTION

The application of the guidelines starts with taking note of the clinical data, heart rate, blood pressure, 2D and Doppler findings with respect to LV volumes/wall thickness, ejection fraction (EF), LA volume, presence and severity of mitral valve disease as well as the underlying rhythm. The guidelines are not necessarily applicable to children or in the perioperative setting. This is an important first step because there may be recommendations that are specific to the underlying pathology. Second, the quality of the Doppler signal as well as the limitations for each parameter should be carefully examined. If a Doppler signal is suboptimal, that signal should not be used in formulating conclusions about LV diastolic function (Figures 2 and 3). Third, the presence of a single measurement that falls within the normal range for a given age group does not necessarily indicate normal diastolic function (see below). Given the several hemodynamic factors that affect each signal, some measurements may fall in the normal range despite the presence of diastolic dysfunction, and none of the indices should be used in isolation. Therefore, consistency between two or more of the indices should be relied upon in an individual patient. The echocardiographic indices of diastolic function