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Diastolic dysfunction – What an anesthesiologist needs to know?

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Diastolic dysfunction (DD) is a common condition that is increasingly encountered in patients undergoing both cardiac and noncardiac surgery as the age profile of our patient population increases and the noninvasive diagnosis of DD becomes more accessible. There is a growing body of evidence demonstrating the significance of DD and adverse perioperative outcomes, and thus, it is becoming imperative for anesthesiologists to have an understanding of the pathophysiology, diagnosis, and management of patients with DD. Current guidelines are based on transthoracic echocardiogram (TTE) measurements in patients who are spontaneously breathing and in a euvolemic state and, consequently, not applicable to the perioperative period. In this review article, we discuss the grading of DD as well as introduce a practical approach to the diagnosis and management of patients with DD during the perioperative period.

Introduction

Whereas more than 50% of patients with congestive heart failure (CHF) have a normal ejection fraction, there is a presumption of a systolic etiology in these patients [1,2] and a diagnosis of diastolic

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dysfunction (DD) is often overlooked. Despite its adverse impact on postoperative outcomes, the presence of DD is not a risk stratification marker [3,4]. Our appreciation of DD as a possible etiology of CHF in patients with normal systolic function has evolved in recent years with the clinical use of Doppler echocardiography [5]. To date, the majority of work on DD has been undertaken on ambulatory patients, and as Doppler indices of left ventricular (LV) filling are impacted by loading conditions, current guidelines of diastolic function assessment acknowledge their inapplicability in the perioperative arena [6]. The current, possibly complex, algorithmic approach that is based on spontaneously breathing euvolemic patients is unsuitable for the dynamic perioperative loading conditions under positive pressure ventilation [4]. In addition, guidelines are based on Doppler signals obtained by transthoracic echocardiography (TTE), whereas intraoperative Doppler tracings are predominantly obtained by transesophageal echo (TEE). However, considering the outcome value of DD, it is imperative to devise a practical, quick, and simple approach for the perioperative assessment of DD [7].

Rationale for intraoperative assessment

The adverse impact of perioperative DD on outcome has been well demonstrated in cardiac surgery, vascular surgery, and in the intensive care units [8–11]. With advancing average age, it is likely that the age of patients and associated comorbidities presenting for surgery will increase [12–15]. Based on the left atrial (LA) pressure, the filling abnormalities of the LV range from impaired relaxation to the reduced compliance stage (Fig. 1). Precise knowledge of the stage of the filling abnormality can potentially help refine the intraoperative management [7] (Fig. 2). Whereas a detailed description of the technical aspects for the assessment of DD is beyond the scope of this article, a basic and practical understanding of the various stages of DD is essential for all anesthesiologists to interpret the echocardiography reports and accordingly make informed and evidence-based intraoperative management decisions.

Terminology

Impaired relaxation and reduced compliance

Impaired relaxation is the earliest filling abnormality characterized by the impairment of the LV active suction force during diastole. It has a characteristic appearance on pulsed wave Doppler (PWD)

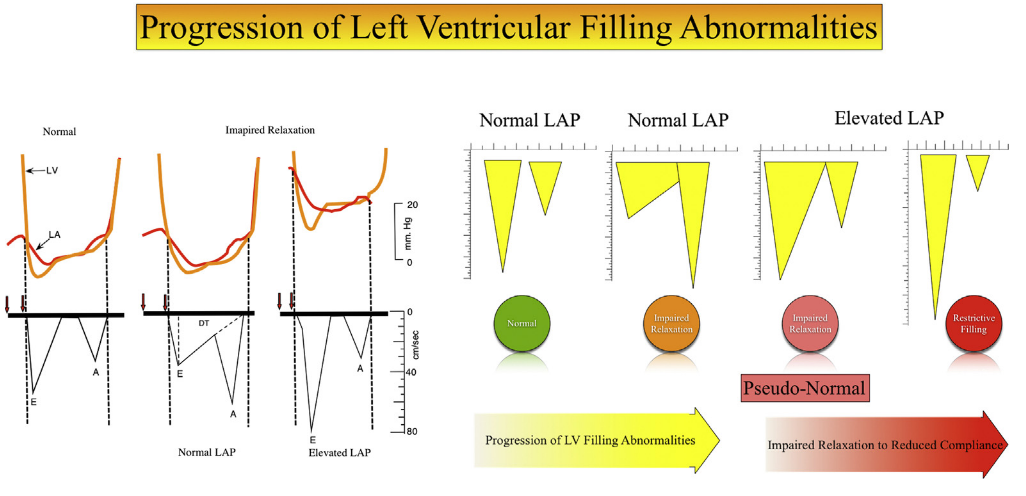

Fig. 1. Progression from normal diastolic function to worsening degrees of diastolic dysfunction (DD). The left side of the figure shows respective changes in the left atrium (LA) and the left ventricle (LV pressures with progression of DD). The right side shows the pattern of transmitral blood flow as DD progresses.

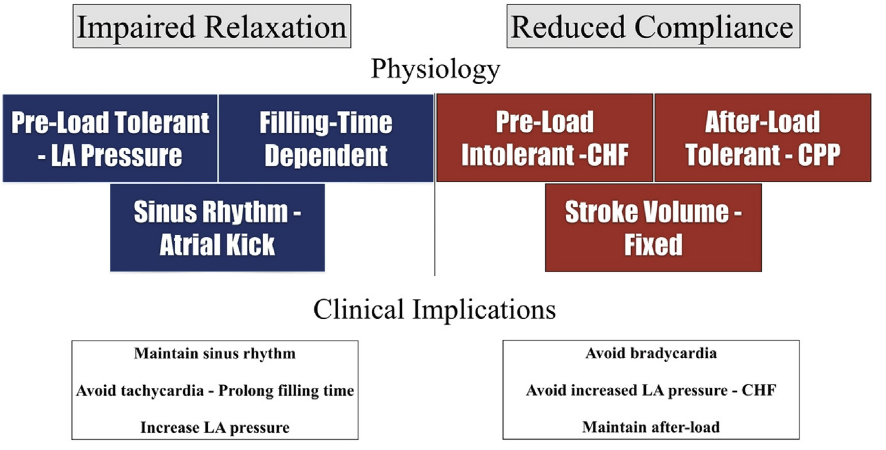

Fig. 2. Physiological differences between impaired relaxation and decreased compliance and proposed therapeutic options. CHF, congestive heart failure; LA, left atrium. (Reproduced with permission from Mahmood F et al. [7]).

of the LV inflow (Fig. 3). Continued impaired relaxation eventually leads to the stage of reduced compliance, with a permanently elevated LA pressure and, again, a characteristic filling pattern on PWD (Fig. 3). Based on the LA filling pressure, the filling pattern of the LV has a characteristic distribution from best to worst (Fig. 4).

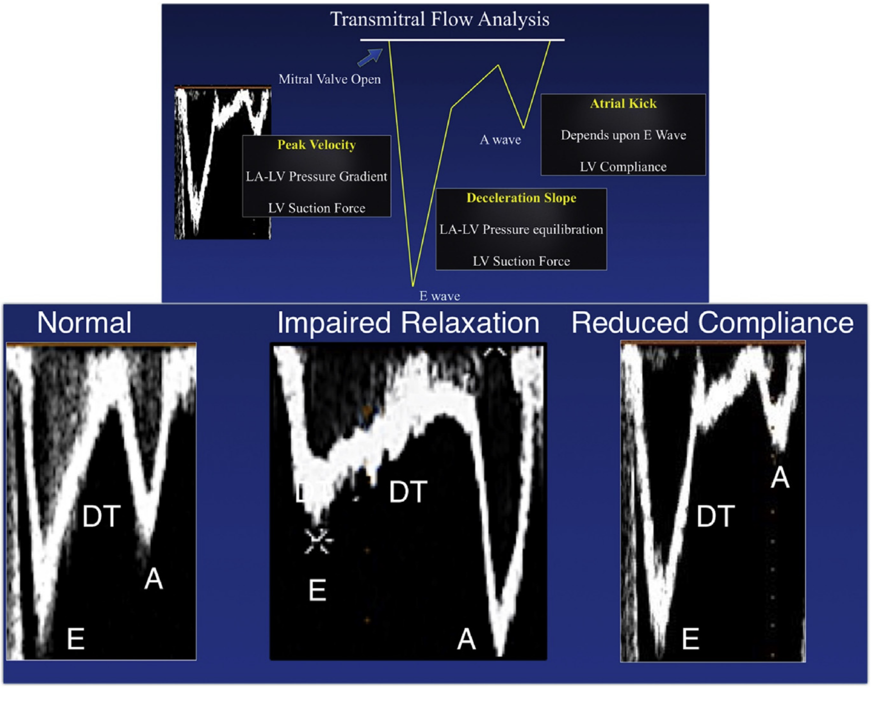

Fig. 3. Typical transmitral pulsed wave Doppler pattern. Top panel, Graphical description of the measurement of peak velocities and gradients. Bottom panel, Actual pulsed wave pattern in normal, impaired compliance, and reduced compliance. E wave = rapid filling phase, A wave = atrial kick, DT = Deceleration time.

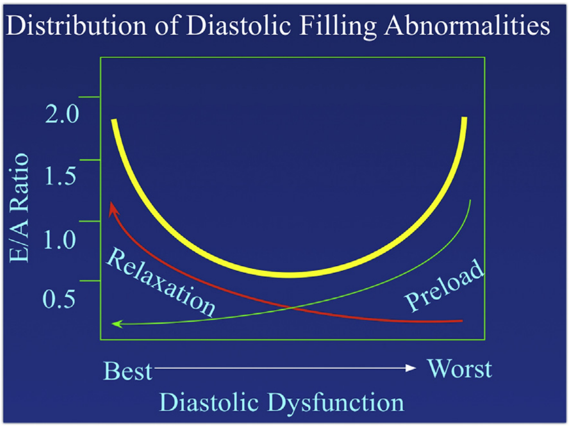

Fig. 4. Distribution of diastolic filling abnormalities from best to worst, with their relationship with the filling pattern of the left ventricle and also the relationship with the E/A ratio as obtained by pulsed wave Doppler (PWD).

Pseudo-normalization

Pseudo-normalization is the intermediate stage between the early impaired relaxation and later reduced compliance stage [4] (Fig. 3). This occurs when the elevated LA pressure accounts for the impaired relaxation and the LV filling assumes a “normal appearance.” Maneuvers to reduce LA pressure (e.g., Valsalva maneuver) are often performed in the outpatient clinics to unmask the underlying relaxation abnormality and reveal the true underlying pathology.

Diastolic dysfunction and diastolic heart failure

Although often used synonymously, DD and diastolic heart failure (DHF) are different entities [16,17]. Echocardiographic evidence of various stages of LV filling abnormalities is referred to as DD, and the addition of the clinical presence of shortness of breath is classified as DHF. All patients with DHF have DD, but not all patients with DD have DHF [7].

Intraoperative assessment

It is currently known that intraoperative application of DD assessment guidelines is not practical in the perioperative arena [3,4]. In contrast to the hemodynamics and spontaneous ventilation seen in the awake state, patients undergoing general anesthesia (GA) demonstrate altered loading conditions secondary to the effects of dehydration and positive pressure ventilation. Doppler-derived indices of flow (E and A waves, deceleration time (DT)) vary considerably with loading conditions with indeterminate filling patterns that cannot be satisfactorily classified into the guidelines-based subgroups. It is recommended to use a more mechanistic approach to assess the stage of LV relaxation abnormality rather than classification into a specific subgroup (6). It is important to use Doppler modalities that are relatively load independent. In addition, a combination of various Doppler modalities can be used to assess the LV end-diastolic pressure (LVEDP) with a relative degree of reliability.

Flow propagation velocity

Transmitral flow propagation velocity (V_p) is obtained using a combination of color flow Doppler and M-mode imaging (Fig. 5) [18]. With appropriate Nyquist limit adjustment and M mode beam alignment, a wave front of flow propagation can be appreciated from the mitral valve toward the LV apex (Fig. 5). The slope of the first aliasing velocity is traced from the mitral valve to almost 4 cm into the LV cavity. Whereas the PWD at the mitral valve tips represents the filling at the point of assessment,

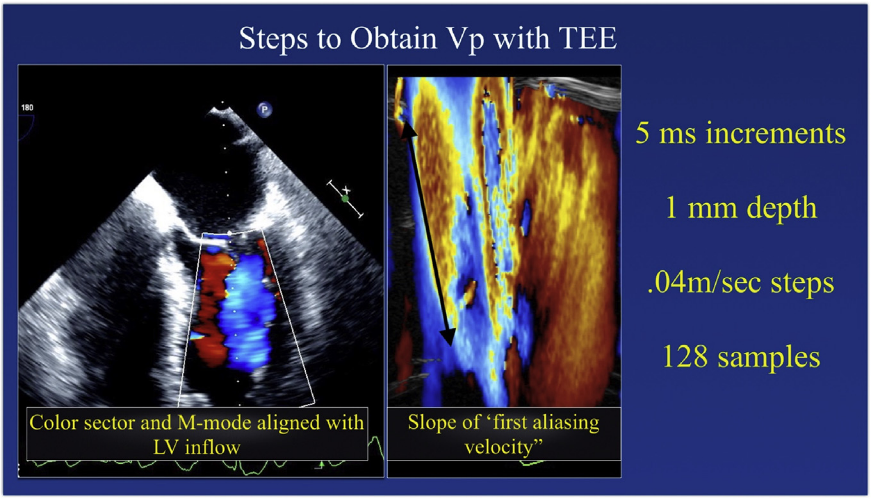

Fig. 5. Transmitral flow propagation velocity (V_p). Left panel, Mid-esophageal 4-chamber view showing the color flow Doppler sector and M-mode cursor aligned with the left ventricular (LV) inflow. Right panel, measuring the slope of the first aliasing velocity to obtain the transmitral flow propagation velocity.

V_p represents the filling characteristics of the entire LV cavity [18]. It is relatively load independent and can be used with other Doppler indices for the estimation of LVEDP [19]. Intraoperative use of V_p and its association with postoperative outcome has been demonstrated in high-risk noncardiac surgery [8,10].

Doppler tissue imaging

As PWD interrogation of the LV represents the flow of blood, Doppler tissue imaging (DTI) is used to assess tissue velocity (lateral mitral annulus) and the obtained waveforms are extrapolated to assess the LV filling. The tissue signals are of low velocity and high amplitude and mimic the transmitral inflow PWD (Fig. 6). Mitral annular motion is contrary to the blood flow, and the signals are above the

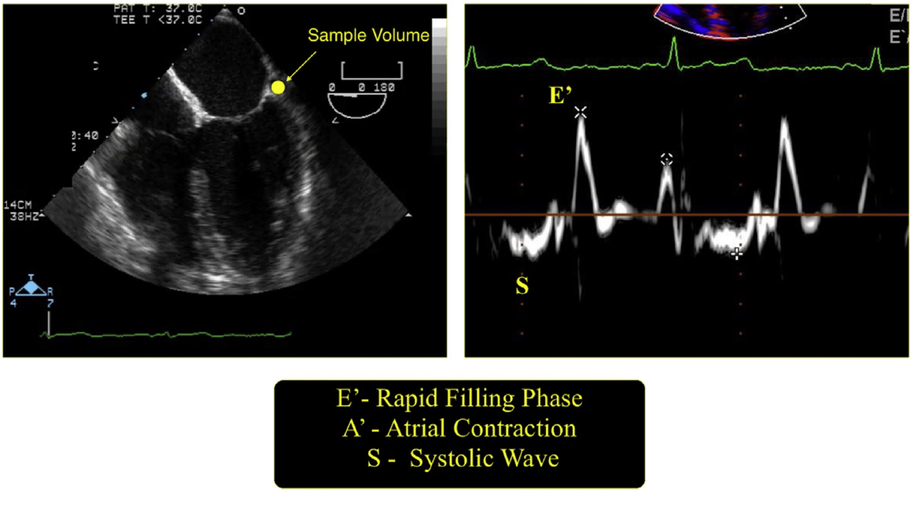

Fig. 6. Spectral tissue Doppler display. Left panel, Mid-esophageal 4-chamber view showing the correct placement of the pulsed wave Doppler. Right panel, actual wave pattern of TDI showing measured velocities. E' = rapid relaxation wave, A' = atrial systolic wave, S' = ventricular systolic wave.

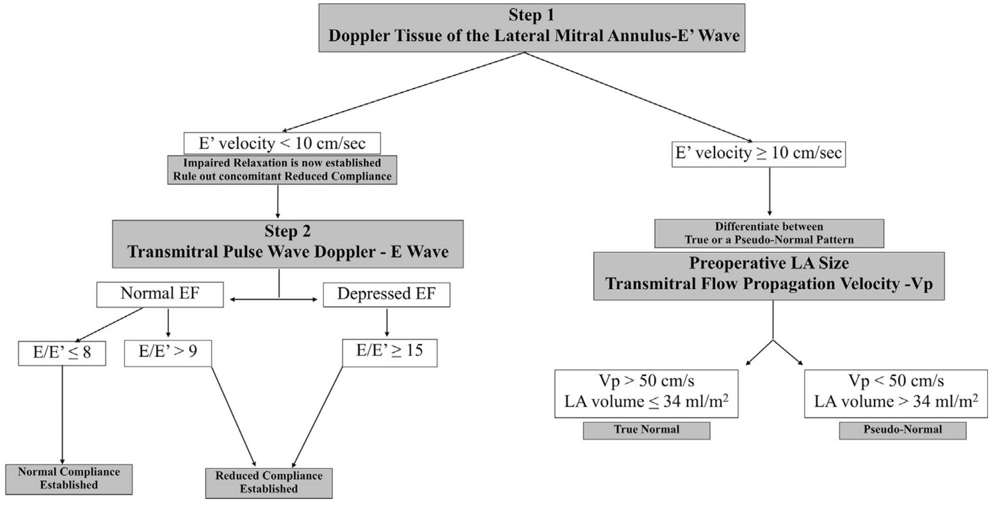

Fig. 7. Proposed diastolic dysfunction algorithm based on the ASE guidelines. Step 1: Left atrial (LA) volumes should be obtained with transthoracic echocardiography before surgery. Lateral mitral annular peak velocity (E =) and transmitral pulsed wave Doppler-derived peak velocity (E) are obtained or calculated after induction. Impaired relaxation is established with lateral mitral annular Doppler tissue imaging. E= <10 cm/s is the cutoff value for impaired relaxation. Step 2 (a): After establishing impaired relaxation, the presence of concomitant decreased compliance needs to be diagnosed. The assessment of decreased compliance or an increased left atrial pressure needs to be performed in the context of the patient's systolic function. Step 2(b): When the age-corrected peak Doppler tissue imaging E = velocity is within the normal range, corroborative evidence should be obtained to confirm this finding as a “true normal” value and exclude pseudonormalization. Left atrial volume measurement and propagation velocity (Vp) will aid in distinguishing pseudonormalization from true normal. This algorithm, derived from within the published guidelines, has the possibility to differentiate patients with impaired relaxation from those with decreased compliance, allowing care providers to act accordingly. EF, ejection fraction (Reproduced with permission from Mahmood F et al. [7]).

baseline (Fig. 6). Most modern ultrasound systems have DTI automated presets to optimize the signals to represent the high amplitude and low velocity nature of the DTI signals. In addition to the peak velocities, isovolumetric contraction and relaxation times can also be measured from the DTI tracing. Because of its shared anatomical location, the medial mitral annulus does not exclusively represent the LV [4]. With transesophageal echocardiography (TEE), the DTI signals are obtained from the mid-esophageal 4-chamber view, with the sample volume located at the lateral mitral annulus (Fig. 6).

Tissue signals from the lateral mitral annulus are relatively load-independent and represent the filling characteristics of the LV. DTI signals are less reliable in patients with mitral annular calcification, prosthetic valves and rings, and lateral wall motion abnormalities [4]. The ratio of the lateral mitral E′ velocity that represents the rapid filling phase is routinely used with the transmitral PWD-derived E wave to estimate the LVEDP [6]. When LVEDP is elevated, there will be an increase in the early filling velocity on transmitral Doppler (E) and a reduction in the early relaxation velocity on tissue Doppler (E′), and by calculating the E/E′ ratio, we can estimate LVEDP with an E/E' ratio >15, indicating an increase in LVEDP.

Left atrial size

As chronically elevated LVEDP is transmitted to the LA, the size of the LA is often referred to as the barometer of LVEDP [5,20,21]. Unlike the Doppler indices of the LV filling, LA size does not change acutely and represents long-term LVEDP. Analogous to hemoglobin A1C, which tracks blood glucose control for an extended period of time, LA size represents the long-term LVEDP and is used as a risk stratification marker in patients with cardiovascular disease [22]. In the absence of significant mitral regurgitation or stenosis, an enlarged LA is an indirect marker of chronically elevated LVEDP.

Practice Points

- A simplified and practical approach to the assessment of DD should be quick and simple without requiring any post-acquisition data manipulation. Because of the variable physiology in different stages of DD, the anesthesiologist should be able to classify the patient in the impaired relaxation or reduced compliance phases of the disease [3,7]. It is also important to incorporate Doppler indices that are least likely to be affected by loading conditions and are within the scope of the guideline recommendations such as DTI of the lateral mitral annulus and flow propagation velocity [6]. A simplified algorithm has been proposed that is based on initially acquiring the DTI of the lateral mitral annulus and establishing the presence of an impaired relaxation abnormality (Fig. 7). The next step is to exclude pseudo-normalization and presence of reduced compliance and elevated LVEDP (Fig. 7). Based on the specific filling abnormality, the perioperative management strategy can be accordingly adjusted (Fig. 2).
- Most geriatric patients presenting for cardiac and high-risk noncardiac surgery have some form of LV filling abnormalities. It is clinically important to establish the stage (impaired relaxation or reduced compliance) for optimal perioperative management. It is imperative for the anesthesiologists to have a basic understanding of DD to interpret the Doppler evaluation and appropriately risk stratify the patient for optimal perioperative management.

Research Agenda

As our understanding of the pathophysiology and adverse consequences of DD in the perioperative period is becoming more apparent, the need for future research in this area is clearly warranted. Such research should focus on the following:

- Development of a simple algorithm to classify perioperative diastolic function.
- Definitely establishing the outcome value of DD.
- Developing intraoperative management protocols based on the presence and stage of DD.
- Developing of risk stratification models based on DD.
- Developing load-independent Doppler indices for the diagnosis of DD.

Summary

DD is a common entity encountered in patients undergoing both cardiac and noncardiac surgery and has an important prognostic value in the perioperative period. The diagnosis and staging of DD are complex and performed using multiple indices, but it is mainly focused around Doppler, which allows us to define events during the cardiac cycle with precision. Although there is currently no specific therapy to improve diastolic function, it is important for the anesthesiologists caring for these patients to be able to appreciate the severity stage of the DD to optimize clinical management. For example, in patients with impaired relaxation, augmentation of LA pressure by optimizing volume status and avoiding tachycardia and arrhythmias can promote optimal LV filling by increasing the LA–LV pressure gradient and prolonging the filling time. This is in contrast to patients with more advanced DD where fluid restriction and judicious use of diuretics would be the optimal therapeutic strategy.

Conflicts of interest

None.

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