Relax: A practical approach to evaluate diastolic function in the operating room

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Introduction

Doppler Echocardiography has become the primary non-invasive clinical tool to evaluate diastolic performance. There is no evidence yet of its utility in the surgical patient. However, the knowledge and technology now being available in the operating theatre should help us identify patients with established diastolic dysfunction and adapt our haemodynamic management accordingly. The difficulty in studying diastolic function in surgical patients is related to the continuously changing loading conditions because preload changes have an independent effect on almost all echocardiographic variables currently used to quantify diastolic performance.

Basically there are four techniques to evaluate diastolic performance, i.e. analysis of

1. Transmitral flow patterns using pulsed wave Doppler
2. Pulmonary venous flow patterns with pulsed wave Doppler
3. Mitral annular motion using tissue Doppler imaging (either with pulsed or colour wave Doppler)
4. LV inflow propagation velocity using colour Doppler M-mode

Also atrial dimensions provide important information. An enlarged left atrium often is the signature of chronic diastolic dysfunction.

Transmitral flow

This flow pattern is easy to acquire and rapidly allows distinction between patients with normal diastolic function, delayed relaxation, or a restrictive filling pattern. It is important to position the sample volume correctly at the level of the mitral valvular (MV) tip using the 4-chamber midoesophageal view, with the Doppler beam slightly angulated to the lateral wall. Signal gain needs adjustment to obtain a clear spectral envelope and the ECG tracing must be displayed on the screen to properly relate the signal components to distinct phases in the cardiac cycle. Mitral inflow velocities reflect the instantaneous pressure gradient between left atrium and left ventricle. Velocities of the early diastolic inflow (E-wave) relate to the pressure drop occurring during isovolumetric relaxation and the subsequent rise in LV pressure due to progressive filling. In healthy adults peak E velocities are typically higher than the second component of the mitral inflow signal which relates to atrial contraction (A-wave) and prevailing pressures in the LV. With impaired isovolumetric relaxation, the magnitude of peak E-velocities decreases and a compensatory rise in atrial velocities occurs. Hence, early stage diastolic dysfunction typically is associated with a reduction of peak E velocities, a lower ratio between peak-E and peak-velocities and a prolonged deceleration time of the E wave component. The natural adaptive response to this condition is an elevation of atrial pressures which restores the early transmitral pressure gradient. As a result, transmitral flow variables (i.e. E and A velocities, E/A ratio and E deceleration time) will paradoxically return to near-normal levels, despite a further progression of disease. This stage is referred to as 'pseudonormalization' because the mitral inflow profile cannot be distinguished from the normal pattern, except for the fact that it is associated with elevated atrial pressures (the compensatory response). At

this stage, additional measurements are required, either by invasive assessment of filling pressures or by using one of the other echo-techniques described below which offer clues to discern normal from pseudonormal transmitral flow patterns. With further progression of diastolic dysfunction mitral flow analysis regains its diagnostic potential; further increases of filling pressures produce very high E-velocities, supranormal E/A ratios and a shortened E-deceleration time all of which indicate restrictive filling (Figure 1).

Pulmonary venous flow

These flow velocities reflect the instantaneous pressure differences between the pulmonary veins and the left atrium. The flow pattern consists of a systolic (Spv-often biphasic), a diastolic (Dpv) and an atrial (Apv) component. The diagnostic utility of the diastolic Dpv-wave is comparable with that of the mitral E-wave (Figure 2). The atrial component, however, increases both in magnitude and duration when atrial pressures rise. Hatle et al. showed that the difference in duration between the PV atrial wave and the Mitral atri-

al component is directly related to the prevailing atrial pressure (Rossvoll and Hatle JACC 1993). Hence, this variable adds useful information to the study of transmitral flow profiles in differentiating a normal from a pseudonormal MV flow signal. However, A-wave characteristics are also affected by atrial function (e.g. atrial stunning) and are unreliable in patients with non-sinus rhythm.

Velocities of the atrioventricular annulus

Motion of the AV annulus reflects global long axis LV performance. The velocity tracings obtained with tissue Doppler show a systolic component (S' or Sm) during motion of the MV annulus towards the apex (away from the transducer in TOE imaging – towards the TTE transducer) and two diastolic components (E' or Em and A' or Am) that relate to early and atrial diastolic filling respectively (Figure 3). The maximum E' velocity was demonstrated to be inversely related to the time constant of isovolumetric relaxation tau (Am J Cardiol 1997;79:928), almost linearly decrease with the progress of diastolic disease (does not
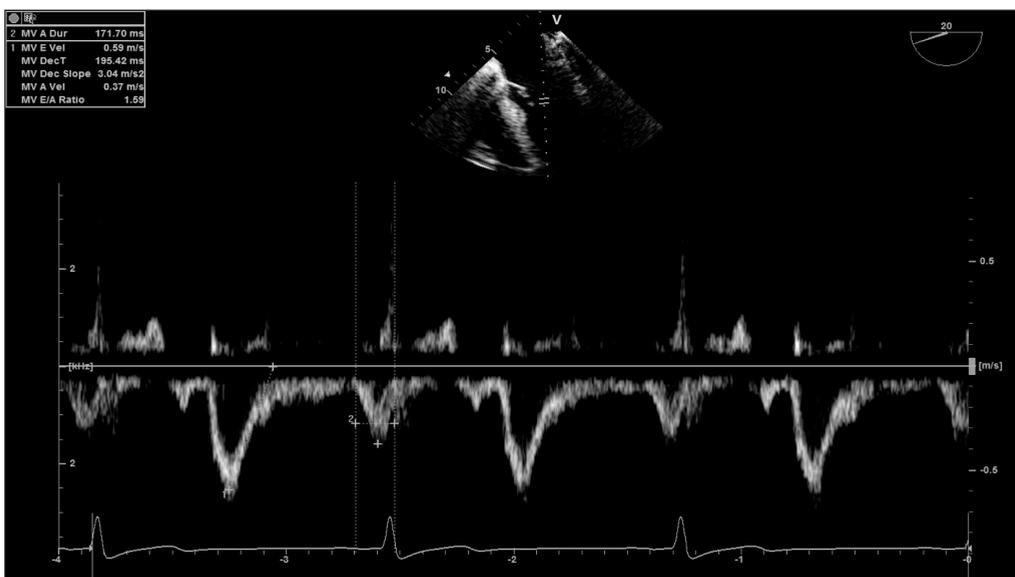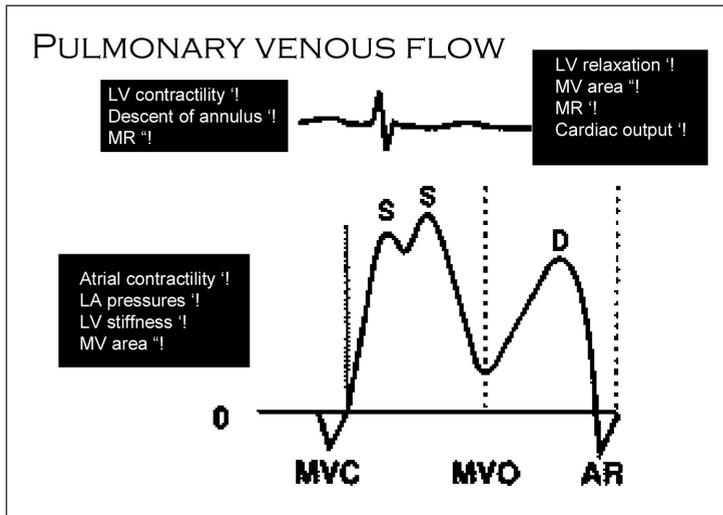

Figure 1

Figure 2

PULMONARY VENOUS FLOW

LV contractility '!
Descent of annulus '!
MR "!

LV relaxation '!
MV area "!
MR '!
Cardiac output '!

Atrial contractility '!
LA pressures '!
LV stiffness '!
MV area "!

s   S

D

0

MVC   MVO   AR

Figure 3

TDI : MITRAL ANNULAR PLANE EXCURSION
PULSED DOPPLER SPECTRAL DISPLAY

Systolic
shortening

Diastolic
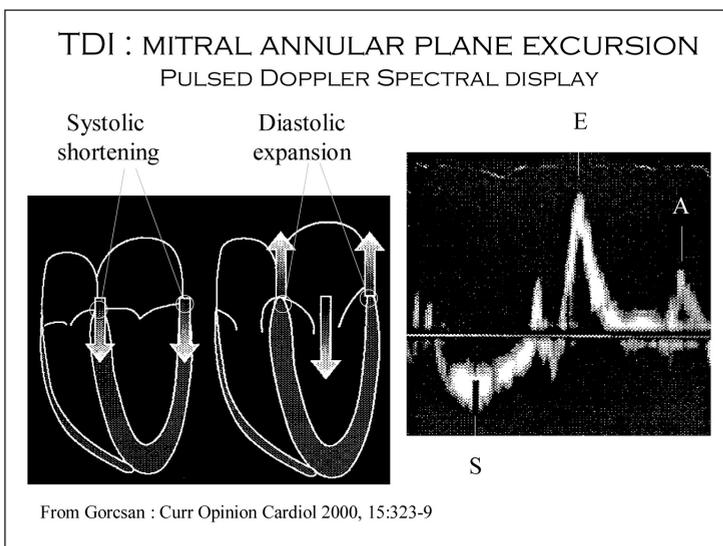expansion

E

A

S

From Gorcsan : Curr Opinion Cardiol 2000, 15:323-9

show pseudonormalization) and found less dependent on loading conditions than the corresponding transmitral E flow component. Consequently, the ratio of maximum transmitral velocity (E) to AV-ring velocity (E') corresponds to left ventricular end-diastolic pressure. Of all echocardiographic parameters investigated, the LV filling index E/E'lateral was reported the best index to detect diastolic dysfunction in HFNEF patients, in whom the diagnosis of diastolic dysfunction was confirmed by conductance catheter analysis. (Circulation 2007;116:637-647). Further work is required to find out if other determinants, such as the ratio of E' to A', have incremental clinical value. A consensus document by the Heart Failure and Echocardiography Associations of the European Society of Cardiology included the ratio of E to E' as an essential tool for non-invasive diagnostics of diastolic function in patients with HFNEF (Eur Heart J. 2007 Oct;28(20):2539-50) and remains valid in the presence of atrial fibrillation.

Quantification is meaningless unless the technique being used to measure AV annular velocities and the exact location where measurements were obtained are clearly specified. Tissue velocities can be measured with colour Doppler as well as pulsed Doppler, the latter being the reference. Colour Doppler provides an average value of maximum velocities within a range gated sample. When compared to the pulsed Doppler technique, which provides the complete spectrum including peak velocity within a sample, values obtained with colour Doppler are always about 20 % lower.

The standard view for TTE to quantify AV annular motion is the apical 4 chamber view with the pulsed Doppler sample located in the lateral wall immediately below the AV ring: long axis motion of the ventricle(s) is parallel to the Doppler line of interrogation and the excursion at the free wall is higher than the septum in a normally shaped heart. When regional wall motion abnormalities are present in the lateral wall, the alternative location would be the anterior part of the AV annulus in a 2 chamber apical view.

An important limitation of Doppler-based measurements, however, is the measurement error associated with improper alignment of the interrogating Doppler beam. This is a particular problem for transoesophageal echocardiography where space constraints may render parallel alignment of the Doppler beam with respect to MV annular motion nearly impossible. It is a major reason why there is still controversy on the accuracy of TDI to assess diastolic function in the intraoperative setting. Motion of the lateral wall deviates significantly from the line of interrogation and conventional TDI measurements made with TOE on the lateral wall will, by definition, always underestimate true velocities. Unfortunately, this major limitation for TOE has not received much attention, neither in clinical studies, nor in clinical practice, and unless a clear framework for the specific setting of intraoperative TOE has been developed, it is premature to base important clinical decisions solely on such data. Speckle tracking offers a potential solution to this problem but awaits confirmation.

Propagation velocity of mitral inflow

The propagation velocity of early mitral inflow (VpE) has also been shown to correlate with diastolic function in a load-independent way (for healthy and diseased subjects – see JACC 2000; 36: 1664-9). This variable can be assessed and quantified using the colour Doppler M-mode application (Figure 4). Several techniques have been published which
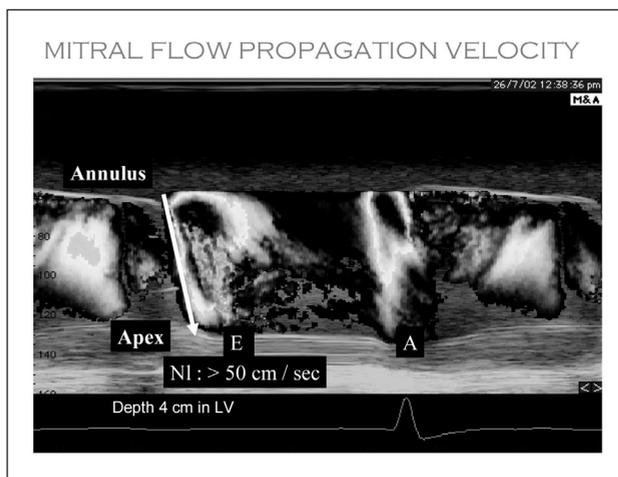
Figure 4

MITRAL FLOW PROPAGATION VELOCITY

Annulus

Apex   E   A

Nl : > 50 cm / sec

Depth 4 cm in LV

differ with regard to the identification and choice of the isovelocity line – see JASE 2002; 15: 339-48. Although experimental data appear promising, a consensus is clearly needed to stratify the current published data and to objectively assess the clinical value of this method.

Conclusion

A combination of methods is advocated to assess diastolic performance in the clinical setting – JASE 1999; 12:609-17. A complete study of mitral flow, mitral annular motion and pulmonary venous flow can be performed in a few minutes by any trained echocardiographer. However, a fair understanding of the pathophysiology of diastolic dysfunction and much attention to detail for the proper application of these techniques remains essential.

More advanced methods such as the analysis of global LV strain rate during the isovolumetric relaxation phase and measurement of LV untwisting rate are currently being validated.