Pulmonary Venous AR Velocity and Duration

When there is pseudonormalisation there is a moderate increase in the LAP as well as an elevation in the LVEDP. As described previously, an elevation of the LVEDP can be identified by: (1) an increase in the PV_{AR} velocity and/or (2) shortening of the duration of the mitral A wave compared with PV_{AR} duration. Therefore, a 'normal' transmitral inflow profile with an increased PV_{AR} velocity (> 35 cm/s) and/or an $AR_{dur} - A_{dur} \geq 30$ ms is suggestive of pseudonormalisation (Fig. 15.13). In addition, a decrease in the PV_S velocity and an increase in the PV_D velocity may also be seen when there is pseudonormalisation.

Decreased DTI e′ +/- Delayed Onset to DTI e′

As previously stated, the e´ is inversely related to LV relaxation; in particular, when LV relaxation is impaired, the e´ is also decreased. Therefore, a 'normal' transmitral inflow profile in conjunction with a reduced e´ velocity is indicative of pseudonormalisation.

Furthermore, with impaired LV relaxation, the onset of the e´ velocity is delayed relative to the onset of the transmitral E velocity (Fig. 15.14). Hence, measurement of the time interval between the onset of e´ and the onset of the transmitral E velocity ($T_{e'-E}$) may be useful in identifying patients with pseudonormalisation. This interval ($T_{e'-E}$) is derived as the difference between time intervals of: (1) the onset of the QRS complex or peak R wave on the ECG to the transmitral E velocity and (2) the onset of the QRS complex or peak R wave on the ECG to the DTI e´ velocity (Fig. 15.15).

Important limitations of the $T_{e'-E}$ measurement include: (1) the inability of most ultrasound systems to simultaneously measure each time interval and, therefore, variation in the cycle length may significantly affect the accuracy of this measurement, and (2) time intervals are numerically quite small so any error in measurement may prove significant.

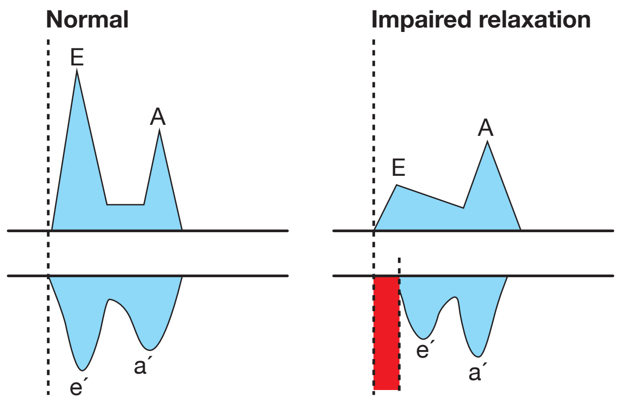

Figure 15.14 Normally, the transmitral E and DTI e´ velocities have a simultaneous onset (*left*). When there is delayed LV relaxation the onset of e´ is delayed (*right*).

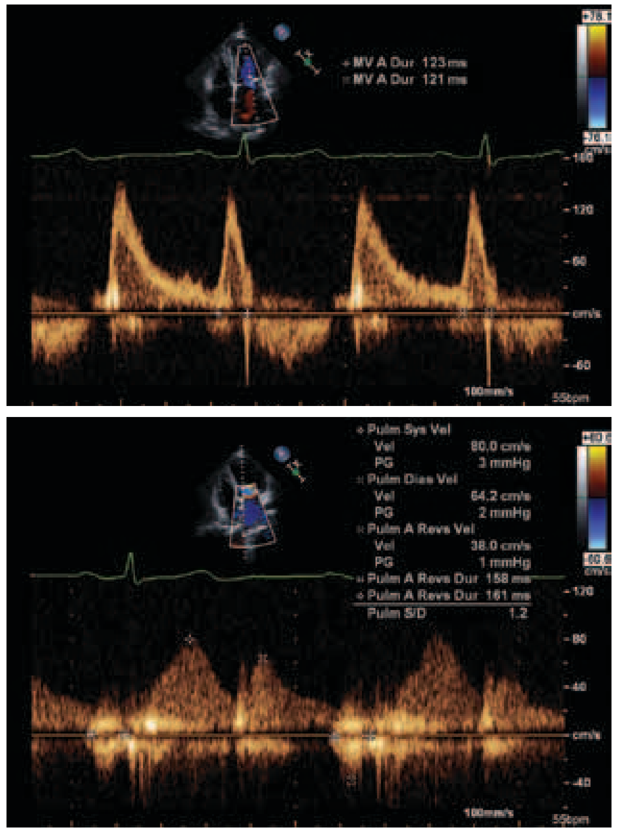

Figure 15.13 These two traces were recorded from the same patient. The transmitral inflow profile (*top*) and the pulmonary venous profile (*bottom*) are shown. Observe that the transmitral inflow profile appears normal with an averaged mitral A duration of 122 ms. However, on the pulmonary venous trace, the peak PV_{AR} velocity is 38 cm/s and the averaged PV_{AR} duration is 160 ms; the resultant AR_{dur}-A_{dur} is 160 ms – 122 ms = 38 ms. As the PV_{AR} velocity is > 35 cm/s and the AR_{dur}-$A_{dur} \geq 30$ ms, these profiles are consistent with pseudonormalisation.

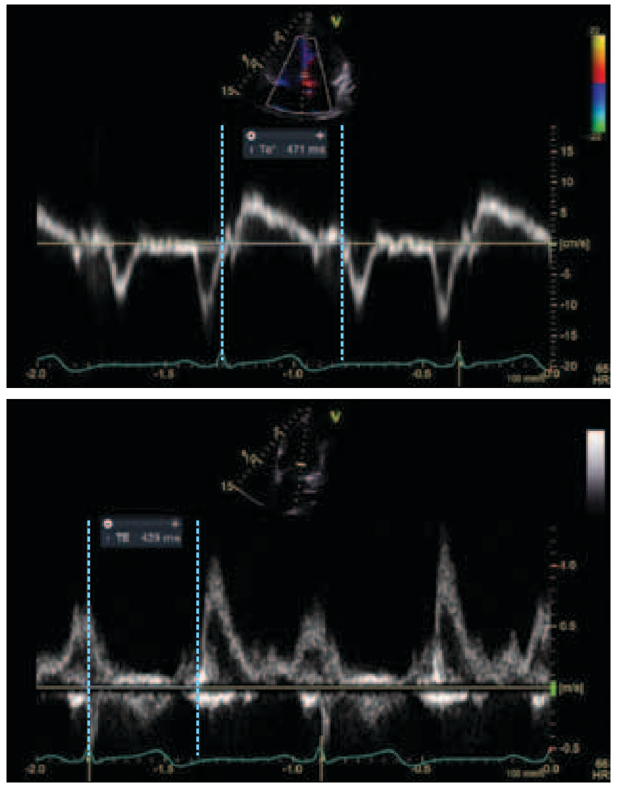

Figure 15.15 These two traces were recorded from the same patient. The septal DTI signal (*top*) and transmitral inflow profile (*bottom*) are shown. The time to onset of the early diastolic myocardial velocity (e´) is measured as the time interval from the peak R wave on the ECG to the commencement of the e´ signal (*top*). The time to onset of the transmitral inflow signal is measured as the time interval from the peak R wave on the ECG to the commencement of the transmitral E velocity (*bottom*). The $T_{e'-E}$ is calculated as the difference between these two intervals: $T_{e'-E}$ = 471 ms – 429 ms = 42 ms.

Increased E/e′ Ratio

As previously described, when the LAP is elevated, the transmitral E velocity is increased; however, the DTI e´velocity, which is inversely related to myocardial relaxation, remains reduced (and delayed) across all stages of diastolic dysfunction. Therefore, a high transmitral E and a low e´ (or an increased E/e´ ratio) indicates an elevation of LAP. Hence, a 'normal' transmitral inflow profile in conjunction with an elevated E/e´ ratio is indicative of pseudonormalisation.

In particular, the E/e´ ratio has been found to correlate with various LVFPs (see "Echocardiographic Parameters for Identifying Elevated LVFP" below).

Slow Flow Propagation Velocity (< 45 cm/s)

The flow propagation velocity (Vp) is a measurement of the velocity at which flow propagates within the ventricle. In particular, the Vp is indirectly related to the time constant of relaxation (tau) such that the longer it takes for the ventricle to relax, the slower the Vp. Therefore, a 'normal' transmitral inflow profile in conjunction with a slower than normal Vp is indicative of pseudonormalisation.

The Vp is measured from the apical 4-chamber view. From this view colour Doppler imaging of transmitral inflow is performed with an M-mode cursor is placed along the central path of transmitral inflow. Via this technique, the intraventricular pressure gradients over time can be measured as blood flow propagates from the mitral annulus toward the LV apex (Fig. 15.16). The Vp is then measured as the slope of the early transmitral wavefront.

While several methods have been described for the specific measurement of the Vp [15.4], the simplest method involves measurement of the early diastolic slope along the aliased velocity from the level of the mitral annulus to a distance of at least 4 cm into the LV cavity (Fig. 15.17). To enhance the early diastolic slope, the colour Nyquist limit is lowered by either decreasing the colour velocity scale or by moving the colour baseline upwards in the direction of flow; this creates aliasing and enhances the demarcation of the Vp slope. The normal Vp is > 50 cm/s; when there is prolongation of LV relaxation, the Vp is slowed (< 45 cm/s).

Increased PA Pressures

Elevated LAP is usually associated with some degree of pulmonary hypertension due to the backward transmission of the elevated LAP to the lungs. Hence, in the absence of pulmonary disease, an elevation in the pulmonary artery systolic pressure (PASP) suggests an elevation in the LAP.

In particular, it has been noted that a PASP of 30 mm Hg or less indicates a normal PCWP while a PASP > 40 mm Hg is associated with elevated PCWP. To simplify this further, a TR velocity > 2.8 m/s is also suggestive of an elevated LAP (see Information Box below). Therefore, a 'normal' transmitral inflow profile and a TR velocity > 2.8 m/s (or an RVSP/PASP > 40 mm Hg), in the absence of pulmonary disease, is suggestive of pseudonormalisation.

> If a PASP of 40 mm Hg is consistent with an elevated PCWP/LAP then a TR velocity of > 2.8 m/s is also consistent with a PASP > 40 mm Hg and an elevated PCWP/LAP. This is based on the assumption that: (1) the RAP is 8 mm Hg and (2) the RVSP is equal to the PASP. As detailed in Chapter 11, the RVSP is calculated from the peak TR velocity and the RAP so if the RVSP = 40 mm Hg and the RAP is 8 mm Hg, then:
>
> $RVSP/PASP = 4V_{TR}^2 + RAP$
> $4V_{TR}^2 = RVSP/PASP - RAP$
> $= 40 - 8$
> $= 32$
> $V_{TR}^2 = 32 \div 4$
> $= 8$
> $V_{TR} = \sqrt{8}$
> $= 2.8$ m/s

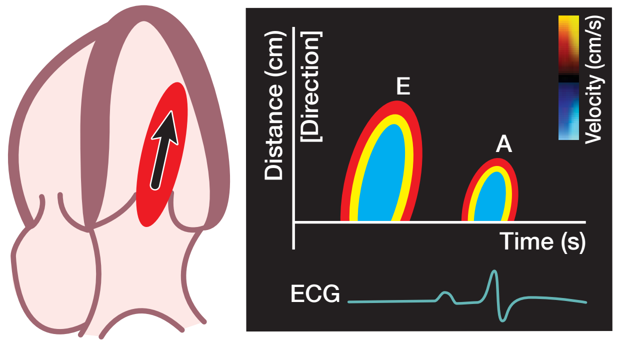

Figure 15.16 This schematic illustrates the information displayed via colour Doppler M-mode of transmitral inflow. The 2D colour Doppler image (*left*) displays the maximum mean velocity of blood flow into the LV during diastole. The colour Doppler M-mode trace (*right*) displays time along the X-axis, spatial distance (and direction of flow) along the Y-axis and velocity which is represented by a colour Doppler bar. When the patient is in sinus rhythm, two distinct waves are seen during diastole: (1) an early filling wave (E) as blood propagates from the LA to the LV apex and (2) a second wave which follows atrial contraction (A).

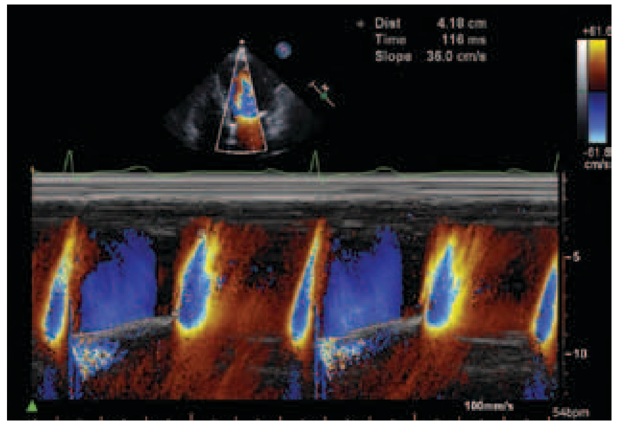

Figure 15.17 On the colour Doppler image of transmitral inflow as acquired from the apical 4-chamber view, the M-mode cursor is positioned along the transmitral inflow path (*top*). Vp is measured along the early diastolic slope of the first aliased velocity (red-blue interface) from the level of the mitral annulus to 4 cm into the LV cavity (*bottom*). The Vp is derived from the distance (Dist) and the time interval (Time) between the two points; in this example, the Vp is 36 cm/s:

Vp (slope) = Dist (cm) ÷ Time (s)
= 4.18 ÷ 0.116
= 36 cm/s

[15.4] De Mey S, De Sutter J, Vierendeels J, Verdonck P. Diastolic filling and pressure imaging: taking advantage of the information in a colour M-mode Doppler image. *Eur J Echocardiogr.* 2001 Dec;2(4):219-33.