Inadequate Doppler Signal

Suboptimal Doppler signals of the MR and/or TR jet may occur when there is poor alignment of the Doppler beam with the regurgitant jet direction. This is particularly problematic with eccentric jets. Another problem which may affect the accuracy of this measurement is valve click artefact which may obscure the profile of the early regurgitant signal.

Significant Aortic Stenosis or Hypertension

Patients with significant aortic stenosis or systemic hypertension may have normal LV dP/dt even when there is impaired systolic performance. Pulmonary hypertension has also been found to cause underestimation the RV dP/dt.

This is because the dP/dt is not totally independent of afterload and the dP/dt may rise with increases in afterload as well as preload.

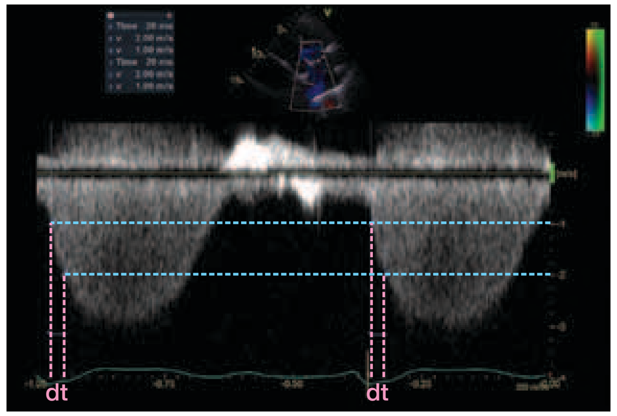

Figure 14.3 This image shows the measurement of the dP/dt from a tricuspid regurgitant (TR) signal. From velocity points at 1 m/s and 2 m/s, the time interval (dt) is measured as 26 ms (or 0.026 s). Using the simplified Bernoulli equation, $\Delta P = 4V^2$, the pressure difference between these 2 points can be derived:

$$\Delta P = [4 \times (2)^2] - [4 \times (1)^2] = [4 \times 4] - [4 \times 1] = 16 - 4 = 12 \text{ mm Hg}$$

The dP/dt is then derived as:

$$dP/dt = 12 \div \Delta t = 12 \div 0.026 = 462 \text{ mm Hg/s}$$

Systolic Myocardial Velocities

The arrangement of myocardial muscle fibres is very complex. Essentially, myocardial muscle layers can be divided into three layers which include fibres that are oblique, circumferential and longitudinal. All fibres act together to maintain a normal EF. In particular, without the longitudinal component of contraction, normal sarcomere shortening would lead to a LV fractional shortening of 12% and an LVEF of less than 30% [14.6].

Doppler Tissue Imaging (DTI), also known as Tissue Doppler Imaging (TDI), measures the myocardial velocities. By placing a PW Doppler sample volume within the ventricular myocardium at the mitral and/or tricuspid annulus, longitudinal myocardial velocities can be measured. As discussed in Chapter 6, the myocardial velocity profile obtained by DTI is characterised by three distinct waveforms: (1) an apically directed systolic myocardial velocity (s′), (2) an early diastolic atrially directed myocardial velocity (e′), and (3) a late diastolic atrially directed myocardial velocity (a′). In addition to these three distinct velocities, less prominent biphasic velocities may be seen between the s′ and e′ waves during the isovolumic relaxation period and between a′ and s′ waves during the isovolumic contraction period (Fig. 14.4).

The systolic velocities (s′) reflect systolic shortening of the ventricle in the longitudinal axis. Therefore, measurement of the peak s′ velocity of myocardial tissue can provide information regarding systolic function of the ventricle. In particular, the s′ velocities recorded at the mitral and tricuspid annuli have been found to have a reasonably good correlation with the left and right ventricular ejection fractions, respectively (see Appendix 14). Generally, an s′ velocity at the basal septal (medial) or lateral mitral annulus ≥ 9 cm/s is consistent with normal LV systolic function while an s′ velocity at the basal tricuspid annulus ≥ 9.5 cm/s is consistent with normal RV systolic function.

Method for calculating the dP/dt

Step 1: Optimise the CW Doppler signal of the MR or TR signal:
- obtain complete CW Doppler spectrum of the regurgitant signal
- ensure alignment is parallel with the regurgitant jet
- increase sweep speed to 150 mm/s or higher

For MR:

Step 2: Maximise the MR jet:
- move zero baseline upward
- reduce velocity scale to 4 m/s

Step 3: Calculate the dP/dt:
- mark the MR velocity at 1 m/s
- mark the MR velocity at 3 m/s
- measure the time interval (Δt) between these two points in seconds
- calculate the dP/dt:
  dP/dt (mm Hg/s) = 32 ÷ Δt

For TR:

Step 2: Maximise the TR jet:
- move zero baseline upward
- reduce velocity scale to 3 m/s

Step 3: Calculate the dP/dt:
- mark the TR velocity at 1 m/s
- mark the TR velocity at 2 m/s
- measure the time interval (Δt) between these two points in seconds
- calculate the dP/dt:
  dP/dt (mm Hg/s) = 12 ÷ Δt

[14.6] Henein MY, Gibson DG. Normal long axis function. *Heart*. 1999 Feb;81(2):111-3.

Limitations of s´ in the Assessment of Ventricular Systolic Function

Pulsed DTI versus Colour DTI

The absolute myocardial velocities obtained via colour DTI are lower than those obtained via pulsed-wave DTI (see Appendix 17). This is because colour DTI values represent the mean instantaneous velocities (Fig. 14.5). Furthermore, as for pulsed-wave DTI the values for the s′ velocities for colour DTI also vary according to: (1) the wall sampled, (2) the sampling site along each wall, and (3) the patient age (see Appendix 17).

Localised Velocities

DTI is a PW Doppler technique which measures localised velocities within one segment of the ventricular wall as indicated by the sample volume position. Measurement of the s′ velocity at this localised segment is then assumed to reflect the systolic function of the entire ventricle. This is one of the primary disadvantages of DTI in the evaluation of systolic ventricular function.

It is important to note that DTI velocities are influenced not only by myocardial function, but also by myocardial tethering and cardiac translational motion. In particular, DTI is not able to distinguish between actively contracting myocardium and passive myocardial motion. For example, normal s′ velocities may be detected when a hypocontractile or akinetic myocardial segment is being 'pulled on' by normally contracting myocardium; this effect is referred to as myocardial tethering. Likewise, s′ velocities can be affected by the normal translational motion of the heart within the thoracic cavity during the cardiac cycle.

It is also important to remember that normally the s′ velocities progressively decrease from the base to the apex (see Appendices 15-17); thus, sample volume positioning is important when using this variable in the assessment of systolic function.

> *i* The normal values for the s´ velocities of the LV vary according to: (1) the wall sampled (the s´ velocities being generally lower at the septum), (2) the sampling site along each wall (the s´ velocities progressively decrease from the base to the apex), (3) the patient age (the s´ velocity decreases with advancing age), and (4) gender (the s´ velocity is higher in men than in women). The normal values for the RV s´ velocities vary according to the sampling site along the RV lateral wall (the s´ velocities progressively decrease from the base to the apex). However, unlike the LV s´ velocities, the RV s´ velocities are less affected by patient age. See Appendices 15-17 and Tables 6.3 and 6.6 for further details.

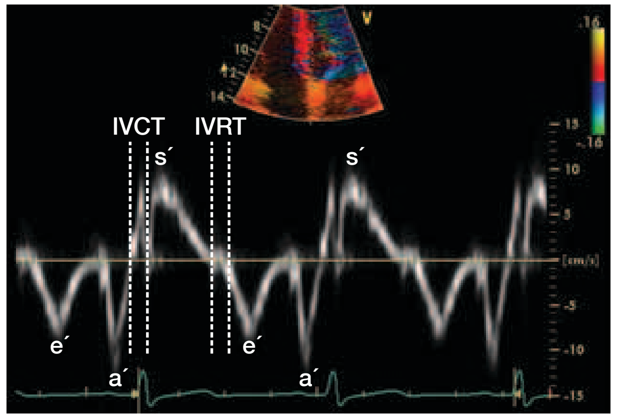

Figure 14.4 This trace shows the characteristic myocardial velocity profile recorded by Doppler Tissue Imaging (DTI) at the septal (medial) mitral annulus. From the apical views, the systolic myocardial velocity (s´) is apically directed and is, therefore, displayed above the zero baseline. The early diastolic myocardial velocity (e´) and the late diastolic myocardial velocity (a´) are both atrially directed velocities and are therefore displayed below the zero baseline. The time interval between the end of the s´ velocity and the beginning of the next e´velocity is the isovolumic relaxation time (IVRT) while the interval between the end of the a´velocity and the beginning of the next s´ velocity is the isovolumic contraction time (IVCT).

Angle of Intercept

As a Doppler technique, the accuracy of DTI velocity measurements is dependent upon the incident angle between the sampling site and myocardial motion. This can be a particular limitation for the evaluation of the lateral RV wall especially when the RV is significantly dilated. In this instance, parallel alignment of the ultrasound beam with the base of the lateral RV wall may prove difficult.

Furthermore, radial and circumferential myocardial motion, which also significantly contribute to overall systolic function, are not detected from the apical views as radial and circumferential motions are at 90 degrees to the ultrasound beam from these views.

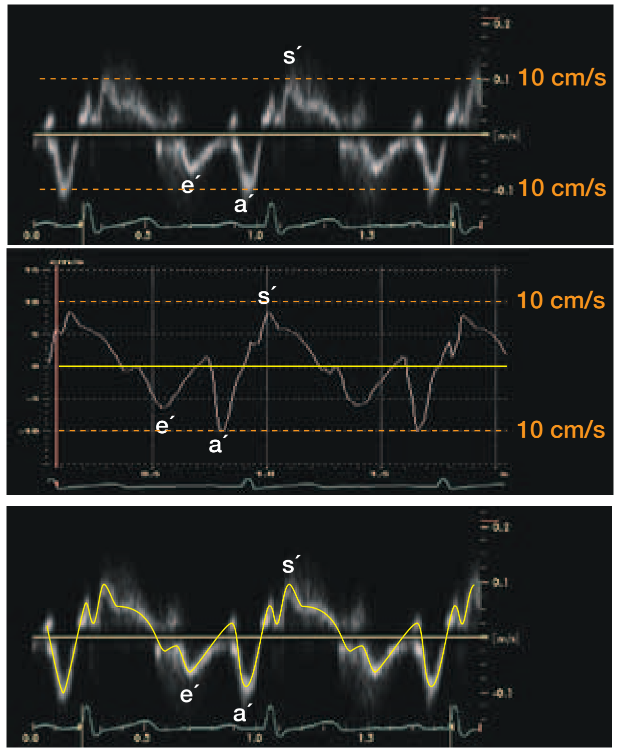

Figure 14.5 These Doppler Tissue Imaging (DTI) traces illustrate the difference between pulsed-wave DTI [PW-DTI] (*top*) and colour DTI [c-DTI] (*middle*). Observe that the profiles on both traces appear very similar; however, the velocities obtained via c-DTI are slightly lower than those derived by PW-DTI and the c-DTI signal appears "smoother" than the PW-DTI signal. The differences between c-DTI and PW-DTI occur because c-DTI measures the mean velocity while PW-DTI measures the peak velocity. The c-DTI signal, therefore, correlates with the centre of the PW-DTI spectrum (*bottom*).