Doppler Tissue Imaging

Conventional PW and CW Doppler modalities are used to determine the velocity and direction of blood flow through the heart and great vessels over the cardiac cycle. However, Doppler Tissue Imaging (DTI) or Tissue Doppler Imaging (TDI) is used to record the velocities within the myocardium and at the corners of the mitral and tricuspid annuli.

While the principles of DTI are essentially the same as conventional PW Doppler, there are importance differences between these techniques. Conventional PW Doppler assesses the velocity of blood flow by measuring high-velocity, low-amplitude signals from moving RBCs; therefore, when using this modality filters are set to detect velocities between 15 to 100 cm/s and amplitudes between 0 to 15 dB. Conversely, myocardial velocities are much slower and amplitudes are much higher; therefore, when using DTI filters are set to detect low velocities (< 20 cm/s) and high amplitudes (> 40 dB).

DTI velocities may be displayed as spectral Doppler with signals recorded from a specific sample volume site, as colour-encoded M-mode and/or as colour-encoded 2D mode (Fig 5.13). Most commonly, the DTI examination is performed via spectral Doppler as this modality readily displays quantitative velocity information.

Display Differences between PW and CW Doppler

PW Doppler signals are described by the degree of spectral broadening and by the presence or absence of a spectral window. As such, the appearance of the PW Doppler spectrum can be used to distinguish laminar and turbulent flow (Fig. 5.14).

Spectral broadening is defined by the spectral width or 'thickness' of the Doppler spectrum. In the presence of laminar flow, the majority of RBCs are moving at similar velocities. Therefore, a small range of Doppler shifts are represented resulting in a narrow band of spectral signals being displayed. As flow becomes turbulent, there is a greater variation in blood flow velocities which produces a larger range of Doppler shifts. This results in increased spectral broadening on the spectral display. Spectral broadening may also be increased by using excessive Doppler gain and by widening of the sample gate such that a wider range of velocities are displayed.

Spectral window refers to the 'clear' area under the spectral trace. In the presence of laminar flow, there is a large spectral window because the majority of RBCs are moving at similar velocities. As flow becomes turbulent, spectral broadening occurs and the spectral window size is diminished or eliminated. Importantly, with CW Doppler, there is no spectral window and spectral broadening occurs even in the presence of laminar flow (Fig. 5.15). This occurs because a large range of velocities are encountered along the entire path of the ultrasound beam.

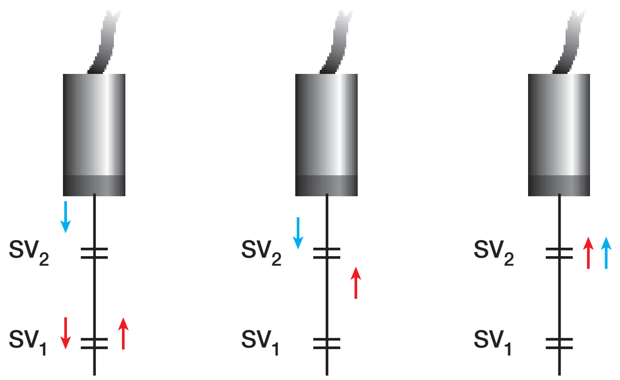

Figure 5.12 This schematic illustrates how high PRF increases the maximum detectable velocity by using more than one sample volume. Observe that two sample volumes are used (SV_1 and SV_2) so that two pulses are sent out one after the other (*left*). The returning signal from SV_1 and the second transmitted signal both reach SV_2 at the same time (*middle*). As a result, the returning signals from both SV_1 and SV_2 return to the transducer at the same time (*right*). The ultrasound machine assumes that all signals have originated from SV_1 and this results in range ambiguity as the true origin of the signal is not apparent; that is, the signal could have originated from SV_1 or SV_2 or from both SV_1 and SV_2.

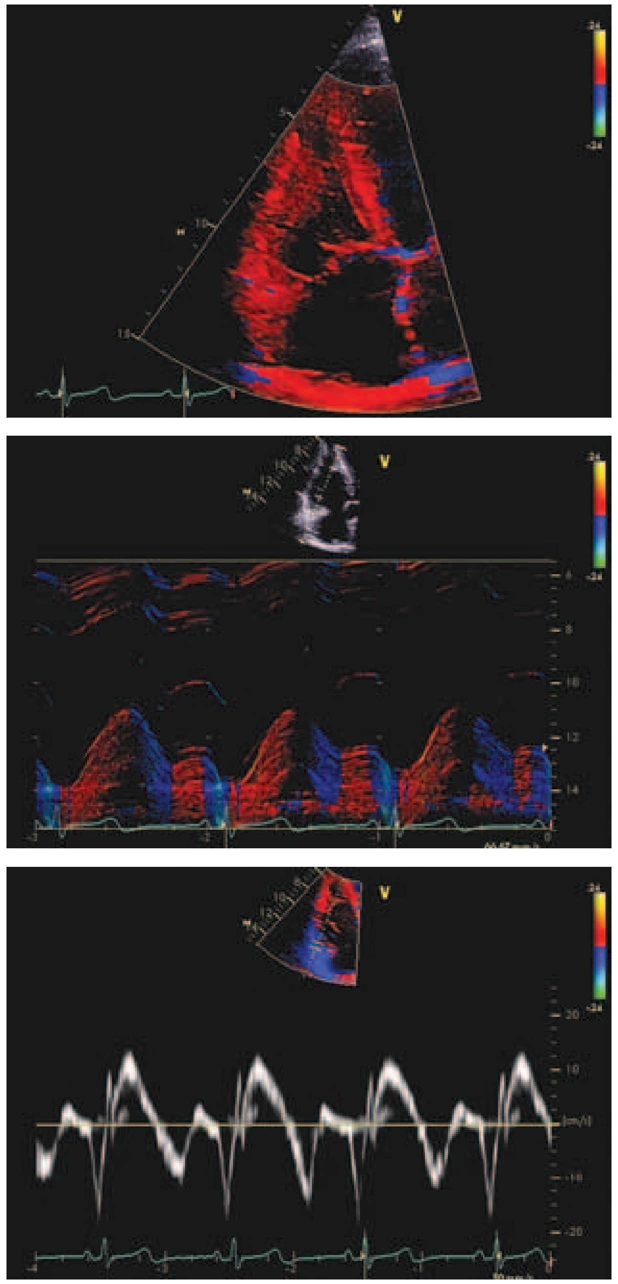

Figure 5.13 These images display the various display modes for Doppler tissue imaging. 2D colour DTI (*top*) and colour M-mode DTI (*middle*) both colour-encode myocardial velocities; as such the myocardium is colour encoded based on the velocity and direction of motion. For example, motion towards the transducer is coloured red while motion away from the transducer is coloured blue. Pulsed-wave DTI (*bottom*) is displayed the same as conventional Doppler in that the velocity, timing and direction of velocities are displayed; the notable difference is that the myocardial velocity scale is set quite low.

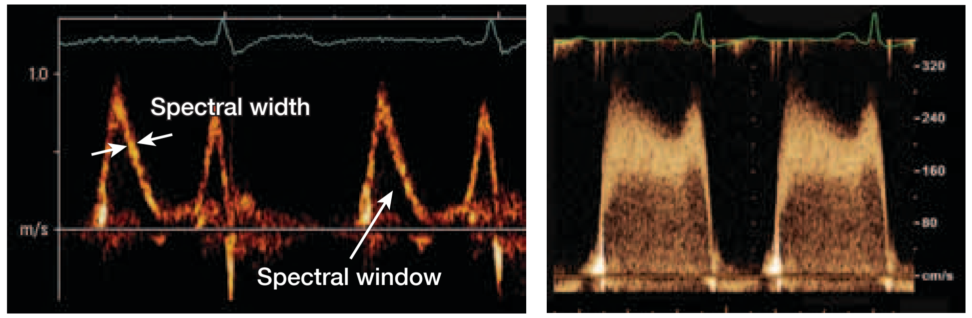

Figure 5.14 These two traces acquired from two different patients illustrate the difference between laminar and turbulent flow as seen via PW Doppler. The trace on the left is an example of laminar flow across a normal mitral valve. Note that there is minimal spectral broadening (narrow spectral width) and an obvious spectral window (dark area under the spectral Doppler curve). The trace on the right is an example of spectral broadening through a stenotic mitral valve. Observe the marked spectral broadening and an absence of a clear spectral window; this PW Doppler appearance is characteristic of turbulent flow.

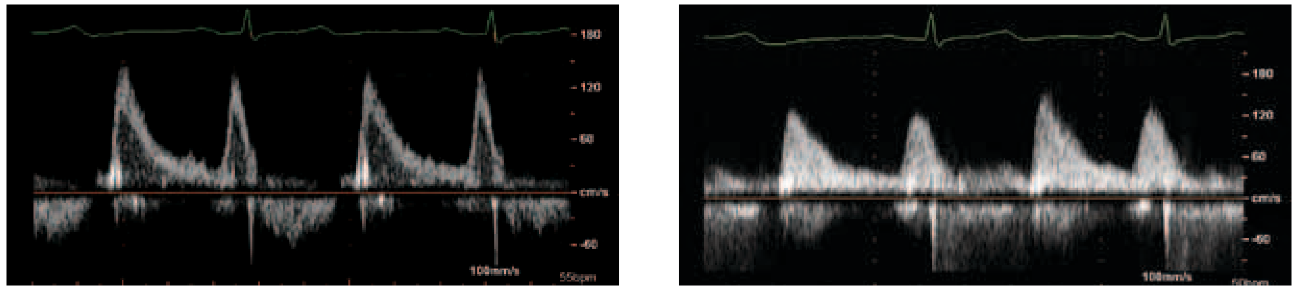

Figure 5.15 These traces acquired from the same patient illustrate the difference between PW and CW Doppler. The trace on the left is an example of a PW Doppler trace recorded with the sample volume at the tips of a normal mitral valve. Note that there is minimal spectral broadening with an obvious spectral window (dark area under the spectral Doppler curve). The trace on the right is an example of a CW Doppler trace through the mitral valve. Observe the increase in spectral broadening and the absence of the spectral window even though flow is laminar.

Spectral Doppler Controls and Optimisation of Spectral Doppler Signals

As for 2D and M-mode, there are a number of controls that can be adjusted to optimise spectral Doppler traces. Importantly, optimisation of spectral Doppler traces will increase the measurement accuracy. As previously mentioned, while many controls are similar in their function, additional controls may be available for optimising spectral Doppler traces. Therefore, the sonographer should be familiar with the available controls for the machine that they operate. Details regarding Doppler controls and how adjustment of these controls affect the spectral trace can usually be found in the User Manual or can be obtained from the Application Specialist. Some of the more commonly used controls are discussed below and are summarised in Table 5.3.

Angle Correction

The most important technical factor which affects the optimal display of Doppler signals is the parallel alignment between blood flow and the ultrasound beam. Hence, the Doppler interrogation is performed from echocardiographic views in which blood flow is aligned as parallel to the ultrasound beam (cursor line) as possible.

While it is possible to use an angle correction control, this is not recommended in echocardiography as blood flow is 3-dimensional and its direction is often difficult to determine. Instead of using angle correction, multiple echocardiographic windows or off-axis imaging are used in an attempt to align blood flow parallel to the ultrasound beam.

Doppler Gain

The Doppler gain function adjusts the degree of amplification of received Doppler signals. The Doppler gain should be adjusted to optimally display the entire Doppler spectrum without excessive background noise.

Velocity Scale and Baseline Shift

The velocity scale adjusts the maximum velocity that can be displayed. When using PW Doppler, this scale is limited by the sampling rate (Nyquist limit). The baseline is the horizontal line on the spectral display representing zero Doppler shift. Traditionally, spectral Doppler signals are displayed so that positive Doppler shifts (blood flow toward the transducer) are displayed above the zero baseline while negative Doppler shifts (blood flow away from the transducer) are displayed below the zero baseline.

Both the velocity scale and baseline are adjustable; an optimal adjustment is when the signal of interest or the signal to be measured fills the display. Importantly, when there is regurgitation it is crucial to display the forward flow as well as the regurgitant jet as this provides indirect clues as to the severity of regurgitation (see Chapter 13).

Wall Filters

Wall filters or low velocity reject functions allow the elimination of low Doppler shifts that typically occur due to motion of the cardiac valves or heart walls. Wall filters should be set sufficiently high to eliminate low Doppler shifts but not so high that the beginning and end of flow is obscured or ambiguous. In particular, clear delineation of the commencement and cessation of flow improves the measurement accuracy of time intervals (Fig. 5.16).