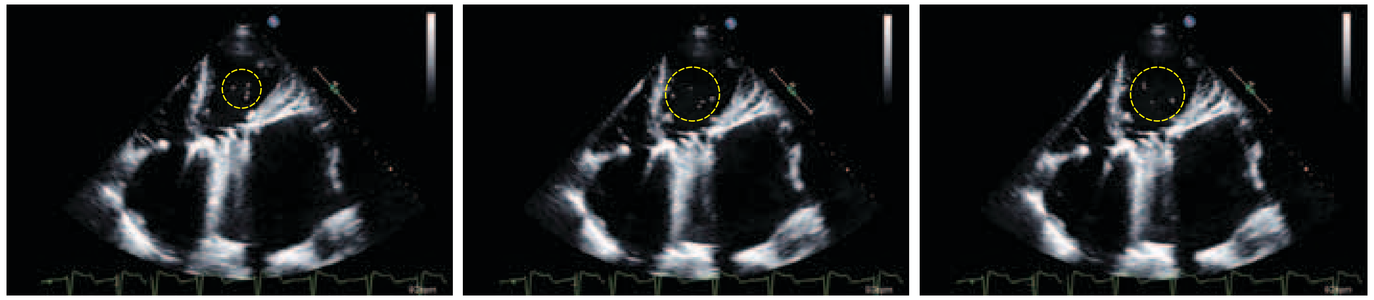

Figure 10.10 This series of images shows microbubbles within the left ventricle (*circled*). These microbubbles are created by the degassing phenomenon which occurs as carbon dioxide separates from blood as blood flows through this 31 mm St Jude mitral valve replacement (see text for details). Images are recorded from an apical 4-chamber view.

Degree and Type of Prosthetic Valve Regurgitation

As indicated in Tables 10.1-10.3, 'physiological' transprosthetic regurgitation is frequently present in all types of mechanical valves and is also common in many biological valves. The appearance of regurgitation is related to the flow profiles through each valve. For example, with the bileaflet tilting disc valves two small leakage jets are often seen at the periphery of the valve (Fig. 10.11). Importantly, this normal prosthetic valve regurgitation should be distinguished from pathological regurgitation (see Complications of Prosthetic Valves below).

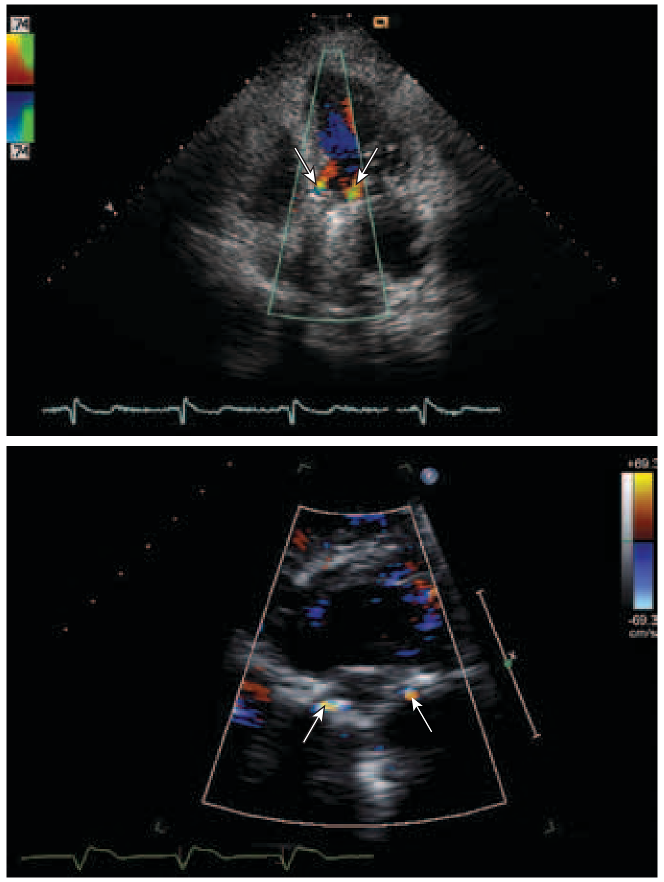

Figure 10.11 Normal leakage volume regurgitation through bileaflet tilting disc valves in the aortic and mitral position are shown; images were acquired from two different patients. The image of the aortic prosthesis was recorded from the apical 5-chamber view (*top*). The image of the mitral prosthesis was recorded from the parasternal short axis view (*bottom*). Observe that these normal jets appear at the periphery of the valve where the closed discs meet the housing (*arrows*). The jets appear short and narrow in the case of the aortic prosthesis and small in area in the case of the mitral prosthesis.

Haemodynamic Assessment of Prosthetic Valves

The haemodynamic assessment of prosthetic valves includes measurement of the transprosthetic velocities and the maximum and/or mean pressure gradients, estimation of the EOA, and the calculation of the Doppler velocity index (DVI). For mitral and tricuspid prosthetic valves, the pressure half-time is also measured.

As previously stated, prior to performing an echocardiogram in a patient with a prosthetic valve, it is crucial that the type and size of prosthetic valve is known. This is because the normal haemodynamic values for prosthetic valves are based on the valve type and size as well as on the position of the valve. The normal Doppler haemodynamic values for various prosthetic valves are listed in Appendices 1-4.

> All haemodynamic measurements should be averaged over at least two consecutive cardiac cycles when the patient is in sinus rhythm. In patients with atrial fibrillation (AF), measurements should be averaged over five cycles, on beats that exhibit minimal variation in the R-R intervals, and at a heart rate that is close to normal.

Transprosthetic Velocities and Pressure Gradients

The peak velocities and pressure gradients are measured via continuous-wave (CW) Doppler from the view which best aligns flow parallel with the ultrasound beam. Parallel alignment of the Doppler beam with transprosthetic flow can be assisted by using colour flow imaging (CFI); this is especially useful in the Starr-Edwards valve where flow diverges laterally around the ball occluder (Fig. 10.12). CFI is also useful in distinguishing laminar from turbulent flow (Fig. 10.13).

From the spectral Doppler trace, transprosthetic pressure gradients are estimated by application of the simplified Bernoulli equation (see Chapter 1). The maximum instantaneous pressure gradient is measured from the peak Doppler velocity while the mean pressure gradient is calculated by tracing the Doppler signal over the flow period. For prosthetic mitral and tricuspid valves, the mean pressure gradient rather than the maximum pressure gradient is important as the transprosthetic pressure gradient varies over the diastolic period. In addition, for mitral and tricuspid prosthetic valves, the heart rate at which mean pressure gradients are measured should also be reported; this is especially important at rapid heart rates where the mean gradients tend to be increased.

AVR Caveats

Importantly, mechanical AVRs must be assessed using the non-imaging CW Doppler probe from multiple acoustic windows in a manner as described for native AS. This is because the transprosthetic jet direction may be quite eccentric. In normal biological valves, especially allograft, autograft and stentless bioprostheses, flow characteristics are very similar to the native aortic valve so the CW Doppler assessment is usually adequate from the apical window. However, when the valve leaflets are thickened, these valves must be interrogated from multiple acoustic windows as the stenotic jet direction is often eccentric.

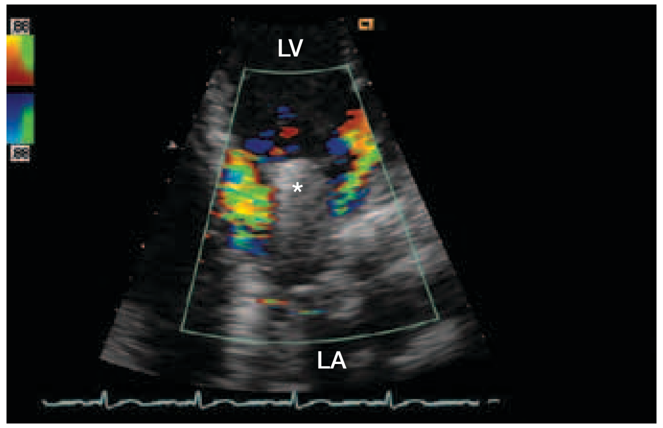

Figure 10.12 This zoomed apical 4-chamber view was recorded from a patient with a Starr-Edwards mitral valve replacement. Observe that transprosthetic flow diverges laterally around ball occluder (*).

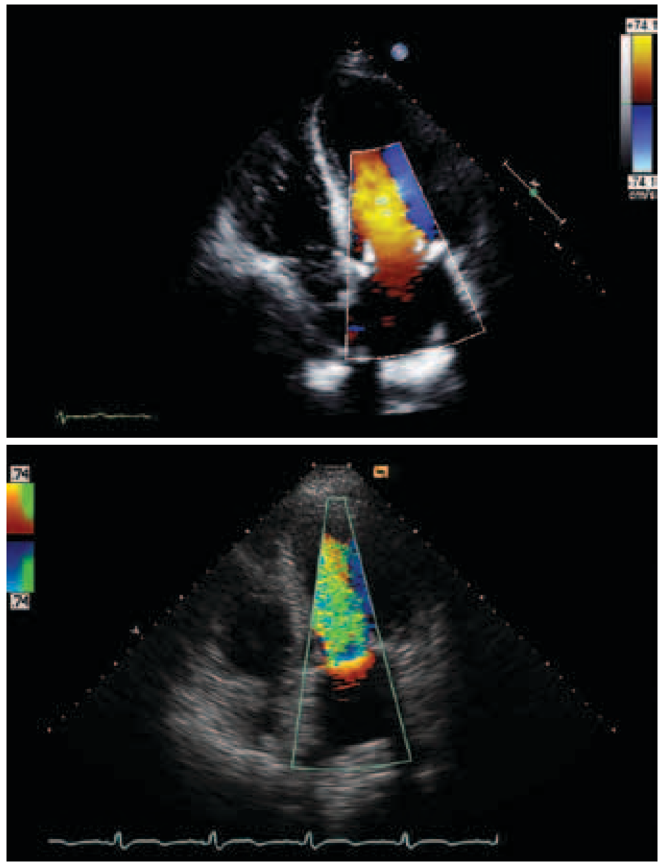

Figure 10.13 These two images were recorded from two different patients with a stented Xenograft mitral valve replacement (MVR). Images are from the apical 4-chamber view during diastole. Diastolic flow through the MVR on the top image appears laminar; this is consistent with normal transprosthetic flow. Diastolic flow through the MVR on the bottom image appears turbulent; this is consistent with an obstructed MVR.

Calculation of pressure gradients via the simplified Bernoulli equation assumes that the velocity proximal to a narrowing is insignificant (< 1.0 m/s). If the velocity within the LVOT is elevated (≥ 1.2 m/s), the maximum and mean pressure gradients derived from the simplified Bernoulli equation will be overestimated (see Chapter 1). Therefore, when the LVOT velocity is ≥ 1.2 m/s, corrected maximum and mean pressure gradients should be derived by using the 'expanded' Bernoulli equation:

Equation 10.1

$$\Delta P_{C} = \Delta P_{AVR} - \Delta P_{LVOT}$$

where ΔP_C = corrected maximum or mean pressure gradient (mm Hg)
ΔP_{AVR} = maximum or mean pressure gradient across the AVR (mm Hg)
ΔP_{LVOT} = maximum or mean pressure gradient at the LVOT (mm Hg)

> The CW Doppler interrogation of mechanical AVRs must be performed from multiple transducer positions, even in haemodynamically normal valves. This is because these valves are inherently stenotic and the structure of mechanical valves often leads to eccentric transprosthetic jets. Therefore, in order to ensure accurate velocities are recorded it is imperative to interrogate these valves from the apex, suprasternal notch, right supraclavicular fossa and the right sternal edge. The window from which the maximal velocity is obtained should also be recorded in the report for future reference; this information is useful for serial studies as the window that reveals the highest velocity usually remains the same. However, if the valve becomes stenotic the window providing the highest velocity may vary.

Effective Orifice Area

Pressure gradients are dependent upon the stroke volume (SV) across the valve as well as the prosthetic valve characteristics. Calculation of the EOA accounts for the volumetric flow at the time of the study and therefore 'compensates' for SV changes. For this reason, the EOA rather than pressure gradients are especially valuable in the serial assessment of prosthetic valves. Estimation of the EOA is based upon the continuity principle (see Chapter 1). In particular, assuming that the SV across the LVOT is the same as the SV across the prosthetic valve, the prosthetic EOA can be calculated from the LVOT SV (derived from the LVOT diameter and velocity time integral [VTI]) and the prosthetic valve VTI (Fig. 10.14-10.15):

Equation 10.2

$$EOA_{VTI} = (CSA_{LVOT} \times VTI_{LVOT}) \div VTI_{PrV}$$

where EOA_{VTI} = effective orifice area [VTI method] (cm^2)
CSA_{LVOT} = cross-sectional area of the LVOT (cm^2)
VTI_{LVOT} = velocity time integral of the LVOT (cm)
VTI_{PrV} = velocity time integral across the prosthetic valve (cm)