Valvular heart disease can be treated in a variety of ways:

- valve replacement, in which an artificial (prosthetic) heart valve is implanted surgically to replace an abnormal (regurgitant or stenotic) valve
- valve repair, in which a regurgitant valve is corrected surgically, preserving the original valve rather than replacing it
- percutaneous techniques, which include percutaneous balloon valvuloplasty (in which a stenotic valve is ‘stretched’ with a balloon) and, more recently, transcatheter aortic valve implantation (in which an abnormal aortic valve is replaced with a new valve deployed percutaneously rather than with cardiothoracic surgery).

It is important to be aware of the different valvular procedures that patients undergo, as patients will require follow-up echo studies to confirm the success of the procedure and to monitor their repaired/replaced valve for any subsequent dysfunction. It’s particularly useful to undertake a detailed ‘baseline’ echo study around 6–8 weeks after valve surgery to act as a comparator for subsequent studies.

**Prosthetic valves**

Each year approximately 6000 people in the UK (and 60,000 in the USA) undergo surgery to implant a prosthetic heart valve. Prosthetic valves fall into one of two categories:

- Mechanical valves – in which the valve is constructed using artificial materials.
- Biological valves – in which the valve contains biological material, derived either from a natural valve or fashioned from pericardium. Biological valves are also sometimes called ‘tissue valves’ or ‘bioprosthetic valves’.
Before undertaking an echo assessment of a prosthetic valve, it is essential to know the type of valve implanted. The request form should therefore state:

- the type of prosthetic valve (e.g. biological, mechanical) and its specific name (e.g. Bjork-Shiley)
- the size of prosthetic valve (which is its internal diameter, stated in mm)
- the date of implantation
- current clinical details (e.g. new diastolic murmur)
- a specific question to be addressed (e.g. valve dehiscence?).

Details of the type of valve can usually be obtained from the original operation note.

**Echo assessment of mechanical valves**

A mechanical valve consists of three parts: the **sewing ring** (which is like the ‘annulus’ of the valve, used by the surgeon to sew the valve into position), the **occluder** (the moving part of the valve which opens and closes during the cardiac cycle) and the **retaining mechanism** (which is attached to the sewing ring and holds the occluder in position).

There are three types of mechanical valve (Fig. 16.1):

- Ball and cage valves, consisting of a silastic ball occluder which can move up and down within the cage-like retaining mechanism – this was the earliest type of mechanical valve, introduced during the 1960s
- Tilting disc valves, in which a single disc occluder tilts within its occluder
- Bileaflet valves, in which two semicircular disc occluders open and close on hinges – these are now the most commonly used prosthetic valves.

The advantage of mechanical valves is their long-term durability (although some earlier valves were prone to catastrophic failure). The main disadvantage

![Fig. 16.1 Types of mechanical heart valve](image)
of mechanical valves is that, because they are constructed from artificial materials, they can be a source of thrombus formation. Patients with mechanical valves therefore require lifelong anticoagulation with drugs such as warfarin, which can be a major drawback, particularly in patients at risk of bleeding or women of child-bearing age who wish to become pregnant.

**Mechanical valve structure**

Mechanical valves can be challenging to assess on echo because of the reverberation caused by the materials in the valve (Fig. 16.2). Mitral prostheses are usually best assessed from the apical window, aortic prostheses from the apical and parasternal windows. Transoesophageal echo (TOE) can help, particularly for prosthetic valves in the mitral position (see box).

![Mechanical AVR](image)

**Fig. 16.2** Normal mechanical aortic valve replacement (AVR) (Ao = aorta; LA = left atrium; LV = left ventricle)

As far as possible, examine the structure of the mechanical valve, asking the following questions:

- Is the valve well seated, or does it appear to be ‘rocking’? A rocking valve prosthesis indicates a degree of separation (‘dehiscence’) of the valve’s sewing ring from the rest of the heart – look carefully for associated paravalvular regurgitation.
- Is there a normal range of movement of the valve occluder(s)? Occluder motion can be obstructed by thrombus or pannus (excessive fibrous or
‘scar’ tissue around the valve). Obstruction to occluder opening causes stenosis, while obstruction to occluder closure causes regurgitation.

- Are there any masses associated with the valve, and are the masses mobile or immobile? Pannus is an immobile mass, whereas thrombus or vegetations are usually (but not always) mobile. Prosthetic valve masses usually require a TOE study for full characterization.

Sometimes very small bubbles are seen near a mechanical valve just as its occluder closes (Fig. 16.3). These microbubbles are caused by cavitation of blood by the occluder, and are regarded as a harmless finding.

![Image showing microbubbles caused by cavitation](image)

**Fig. 16.3** Normal mechanical mitral valve replacement (MVR) showing cavitation (LA = left atrium; LV = left ventricle)

If the valve prosthesis cannot be imaged adequately, state this in your report so that appropriate alternative imaging can be arranged.

**TOE AND MECHANICAL VALVE ASSESSMENT**

TOE can play a valuable role in the assessment of mechanical valves, particular in the mitral position. TOE provides good resolution of the left atrium and the mitral valve, and so can provide useful information on the function of a mechanical mitral valve prosthesis. TOE is less useful for imaging mechanical aortic valves, particularly when a mechanical mitral valve is also present.
Mechanical valve function

Forward flow

All prosthetic valves exhibit a degree of ‘patient–prosthesis mismatch’, in that the prosthetic valve tends to have a smaller effective orifice area than the native valve it replaces, and so some degree of obstruction to blood flow is to be expected. As for native valves, assess forward flow by measuring:

- gradient (peak and mean) – but beware the problem of pressure recovery (see box)
- pressure half-time (for mitral prostheses)
- effective orifice area (based on pressure half-time for mitral prostheses and the continuity equation for aortic prostheses).

PRESSURE RECOVERY

The phenomenon of pressure recovery is complex, but in essence it describes how pressure increases downstream of a stenosis because of the conversion (‘recovery’) of kinetic energy into potential energy. The practical upshot of pressure recovery is that measured pressure gradients across prosthetic valves can appear misleadingly high, particularly for aortic valves. The phenomenon has been found in both mechanical and biological valves. Calculation of effective orifice area for a prosthetic valve is often more useful than valve gradient alone, and serial measurements are particularly helpful for identifying ‘true’ prosthetic valve stenosis.

The normal ranges of prosthetic valve forward flow parameters vary according to the type and size of the valve concerned, and tables of normal values can be obtained either from the prosthetic valve’s manufacturer or by referring to published tables in the literature (the paper by Rosenhek et al. is particularly useful – see Further Reading below).

Obstruction to forward flow occurs if motion of the valve occluder is obstructed (by thrombus, pannus, vegetations or mechanical failure), so that the occluder cannot open properly, or if there is subvalvular or supravalvular obstruction from pannus formation. Inspect the valve carefully to assess occluder motion where possible. If obstruction occurs intermittently, a prolonged period of Doppler interrogation may be required.

Regurgitant flow

A small amount of regurgitation is normal for mechanical valve prostheses. There is an initial regurgitant flow as the occluder closes and blood is
pushed backwards by it. Then, once the occluder is closed, there is a further regurgitant flow which is intended to ‘wash’ over the prosthesis and reduce the risk of thrombus formation. These normal regurgitant jets are usually small – the precise extent and location of the regurgitant jet(s) depends on the type of valve.

Abnormal regurgitation through the orifice of the prosthetic valve may occur if the occluder fails to close properly, either because closure is obstructed (e.g. by thrombus, vegetations or pannus) or because of mechanical failure of the occluder itself. Regurgitation through a prosthetic valve orifice is called **transvalvular regurgitation**. Regurgitation may also occur around the valve, due to dehiscence of part of the sewing ring – this is **paravalvular regurgitation**. Use colour Doppler to examine the location and extent of any abnormal regurgitation, and describe it as fully as possible. Regurgitation from mitral prostheses can be difficult to see with transthoracic echo and a TOE study may be required.

**Echo assessment of biological valves**

As with a mechanical valve, biological valves contain a sewing ring which the surgeon uses to sew the valve into position. From the sewing ring projects a framework consisting of a number of struts, commonly called stents, to which the valve leaflets are attached. These stents take up space and thus can cause a degree of obstruction to blood flow through the valve. Valves which lack this supporting framework, called ‘stentless valves’ are available and offer a greater orifice area (for the same overall size of valve), reducing the gradient across the prosthetic valve.

There are three types of biological valve:

- Xenograft valves, in which the valve is fashioned from a porcine valve or from bovine pericardium
- Homograft valves, which are human valves obtained from cadavers
- Autograft valves, in which a patient’s own pulmonary valve is used to replace their aortic valve (and the pulmonary valve is itself replaced with a xenograft or homograft valve) – this is known as the Ross procedure.

Unlike mechanical valves, biological valves do not require long-term anticoagulation. However, they do not have the durability of mechanical valves and there is a significant failure rate from 8–10 years onwards after implantation. Failure can occur as a result of gradual calcification of the valve, causing stenosis, or from regurgitation.
**Biological valve structure**

Stentless bioprosthetic valves can look very similar to native valves on echo. For stented valves the stents can be very obvious (Figs 16.4, 16.5) and can cause shadowing of the ultrasound beam.

![Image](image_url)

**Fig. 16.4** Normal biological mitral valve replacement (MVR) (LA = left atrium; LV = left ventricle)

<table>
<thead>
<tr>
<th>View</th>
<th>Apical 4-chamber</th>
</tr>
</thead>
<tbody>
<tr>
<td>Modality</td>
<td>2-D</td>
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</tbody>
</table>

![Image](image_url)

**Fig. 16.5** Normal biological mitral valve replacement (MVR) (LA = left atrium; LV = left ventricle)

<table>
<thead>
<tr>
<th>View</th>
<th>Parasternal long axis</th>
</tr>
</thead>
<tbody>
<tr>
<td>Modality</td>
<td>2-D</td>
</tr>
</tbody>
</table>
Examine the structure of the biological valve, asking the following questions:

- Is the valve well seated, or does it appear to be ‘rocking’? As for mechanical valves, a rocking biological valve indicates dehiscence of the sewing ring, so check for associated paravalvular regurgitation.
- Do the valve leaflets appear thin and mobile? Biological valve leaflets become fibrotic and calcified with time, developing a thickened appearance on echo with reduced mobility.
- Are there any masses associated with the valve (pannus, thrombus, vegetations)?

If the valve prosthesis cannot be imaged adequately, state this in your report so that appropriate alternative imaging can be arranged.

**Biological valve function**

**Forward flow**

As with mechanical valves, biological valves have a smaller effective orifice area than the native valves they replace (although less so with stentless valves). As time passes, biological valve leaflets tend to become deformed as a result of fibrosis, and this can result in stenosis, with an increase in the gradient across the valve (and a decrease in the effective orifice area). As for native valves, assess forward flow by measuring:

- gradient (peak and mean)
- pressure half-time (for mitral prostheses)
- effective orifice area (based on pressure half-time for mitral prostheses and the continuity equation for aortic prostheses).

The normal ranges of prosthetic valve forward flow parameters vary according to the type and size of the valve concerned, and tables of normal values can be obtained either from the prosthetic valve’s manufacturer or by referring to published tables in the literature (the paper by Rosenhek et al. is particularly useful – see Further Reading below).

**Regurgitant flow**

Up to half of normal biological valve prostheses have a mild degree of transvalvular regurgitation. Abnormal transvalvular regurgitation may occur if the valve has developed fibrocalcific degeneration, or if there has been acute leaflet rupture. Paravalvular regurgitation may occur around the valve due to dehiscence of part of the sewing ring (Fig. 16.6), as for mechanical valves. Use Doppler interrogation to examine the location and extent of any abnormal regurgitation, and describe it as fully as possible.
Biological AVR Paravalvular regurgitation

Fig. 16.6  Biological aortic valve replacement (AVR) with paravalvular regurgitation

There is a biological stented aortic valve replacement in situ (stated to be a 23 mm Carpentier-Edwards prosthesis, implanted 3 years ago, on the request form). The valve is well seated. There are no associated masses. The valve cusps are thin and mobile, with a peak gradient of 25 mmHg (mean 13 mmHg) and an effective orifice area of 1.9 cm² (calculated from the continuity equation). There is no transvalvular or paravalvular regurgitation. The findings indicate a normally functioning biological aortic valve replacement.

Valve repair

Mitral valve repair is, where feasible, the preferred surgical option for mitral regurgitation with better long-term outcomes than valve replacement. The operation usually involves resection of a wedge of redundant mitral tissue and, where necessary, inserting an annuloplasty ring to reinforce the mitral annulus and repairing/replacing damaged chordae tendineae. An alternative technique is the so-called Alfieri or ‘edge-to-edge’ repair, in which the central points of the two mitral leaflets are sutured together to create a double-orifice mitral valve.
Echo assessment of valve repair
When performing an echo following mitral valve repair (Fig. 16.7), assess:

- mitral valve morphology, looking in particular at leaflet mobility and for
  the presence of an annuloplasty ring and/or repaired/replaced chordae
- mitral valve flow, looking for evidence of stenosis or regurgitation as for
  a native valve.

![Echo image of mitral valve repair](image)

**Fig. 16.7** Normal mitral valve repair (LA = left atrium; LV = left ventricle)

### Percutaneous techniques
Percutaneous techniques for valvular intervention include percutaneous balloon mitral valvuloplasty (PBMV) and transcatheter aortic valve implantation (TAVI).

**Percutaneous balloon mitral valvuloplasty**
PBMV is a technique in which a balloon is passed to the heart via a femoral vein and a deliberate puncture is made in the interatrial septum to allow access to the left atrium. The balloon is then passed across the stenosed mitral valve and inflated to relieve the stenosis. The technique works primarily through commissural splitting, and it is important to assess the mitral valve (and particularly the commissures) to select patients most likely to benefit from this procedure.
Echo assessment for PBMV is formalised in the Wilkins score, which grades the valve’s suitability according to four criteria: leaflet mobility, valvular thickening, subvalvular thickening and valvular calcification. Each criterion is scored from 1 to 4, and a total score >8 indicates a low probability of successful PBMV. Full assessment will entail a TOE. Patients not suitable for PBMV include those with:

- significant mitral regurgitation
- bilateral commissural calcification
- thrombus on the interatrial septum, protruding into the atrial cavity or obstructing the mitral orifice.

The presence of unilateral commissural calcification or thrombus in the left atrial appendage is a relative contraindication to PBMV.

Following PBMV the valve should be assessed carefully for any residual stenosis or for the development of mitral regurgitation, and for any residual atrial septal defect. Note that mitral valve pressure half-time is not a reliable way to assess mitral stenosis in the 72 h following PBMV. During this period the improvement in transmitral flow following the procedure causes an increase in left atrial (and a decrease in left ventricular) compliance, which affects pressure half-time measurements. Once chamber compliance has stabilised after 72 h, pressure half-time can be used once again.

**Transcatheter aortic valve implantation (TAVI)**

For many years balloon valvuloplasty has been available to treat aortic stenosis in patients for whom conventional surgery is contraindicated. More recently, there has been growing interest in new techniques not just to dilate a stenosed aortic valve but also to replace the aortic valve via a transcatheter approach, particularly in elderly patients with aortic stenosis who have multiple comorbidities and for whom conventional aortic valve surgery would present a high risk. TAVI can be performed either via the femoral artery (transluminal approach) or via a direct puncture at the left ventricular apex (transapical approach). A balloon is placed across the stenosed aortic valve and inflated to dilate it. A replacement valve, which is mounted within a stent, is then deployed using either a balloon or a self-expanding system.

Following TAVI, echo is important is assessing the function of the prosthetic aortic valve and checking for any complications of the procedure (such as pericardial effusion/cardiac tamponade).

*British Society of Echocardiography Distance Learning Module 8: The Echocardiographic Assessment of Prosthetic Heart Valves.* Accessible from the BSE website (www.bsecho.org).
