Introduction

Heart valve prostheses have been used successfully since 1960. As stated by Roberts [1] the 1960s will probably be remembered most in the annals of cardiology as the decade during which cardiac valve replacement became a successful reality. Of the more than 50 different cardiac valves introduced over the past 25 years, many have been discarded due to their lack of success, and of those remaining several modifications have been made or are being made at the time of this writing. The five most commonly used basic types of prosthetic valves at present are: caged ball, caged disc, tilting disc, bi-leaflet and bioprostheses. At present over 75,000 prosthetic valves of different designs are used annually throughout the world. Even after 25 years of experience the problems associated with heart valve prostheses have not been totally eliminated. The most serious problems and complications associated with heart valve prostheses are: thromboembolism, tissue overgrowth, infection, tearing of sewing sutures, red cell destruction (haemolysis), valve failure due to material fatigue or chemical change, damage to the endothelial tissue lining of the vessel wall adjacent to the valve and leaks caused by failure of the valve to close properly. Thromboembolism, tissue overgrowth, red cell destruction and endothelial damage are directly related to the fluid dynamics associated with the various prosthetic heart valves and need to be addressed in more detail by investigators studying biofluid mechanics. The other problems are indirectly related to fluid mechanics. Problems relating to valve failure due to material fatigue or chemical change also need to be studied, especially in relation to bioprostheses.

Tissue bioprostheses gained widespread use during the mid-1970s. The major advantage of tissue bioprostheses compared to their mechanical counterparts is that they have a lower incidence of thromboembolic complications. Therefore, tissue valves for a large part can be used without anticoagulants. Unfortunately, the tissue bioprostheses clinically used at present also have major disadvantages such as relatively large pressure drops compared to some of the mechanical valves (especially in the smaller sizes), jet-like flow through the valve leaflets, material fatigue and/or wear of valve leaflets, and calcification of valve leaflets, especially in children and young adults. Because of
these drawbacks, valve manufacturers are now developing newer designs of bioprostheses and trileaflet valves made from polymeric materials.

The ideal heart valve prosthesis has not yet been designed and probably will never exist. An ideal valve should:

1. Be fully sterile at the time of implantation and be non-toxic.
2. Be surgically convenient to insert at or near the normal location in the heart.
3. Conform to the heart structure rather than the heart structure conforming to the valve (i.e. the size and shape of the prosthesis should not interfere with cardiac function).
4. Show a minimum resistance to flow so as to prevent a significant pressure drop across the valve.
5. Have minimal reverse flow necessary for valve closure, so as to keep the incompetence of the valve at a low level.
6. Show long resistance to mechanical and structural wear.
7. Be long-lasting (25 years) and maintain its normal functional performance (i.e. must not deteriorate with time).
8. Cause minimum trauma to blood elements and the endothelial tissue of the cardiovascular structure surrounding the valve.
9. Show a low probability for thromboembolic complications without the use of anticoagulants.
10. Be sufficiently quiet so as to not disturb the patient.
11. Be radiographically visible.
12. Have an acceptable cost.

**Mechanical Valves**

The use of a caged-ball valve in the descending aorta became obsolete with the development of what today is still referred to as the Starr-Edwards ball-and-cage valve in 1960, as illustrated in Fig. 5.1. In concept it was similar to the original Hufnagel valve but was designed to be inserted in place of the excised diseased natural valve. This form of intracardiac valve replacement in the mitral position was reported by Starr [2] and for aortic and multiple valve replacements by Cartwright et al. [3]. Since 1962, the Starr-Edwards valve has undergone many modifications in order to improve its performance in terms of reduced haemolysis and thromboembolic complications. However, the changes have involved materials and techniques of construction and have not altered the overall concept of the valve design in any way.

Other manufacturers have produced variations of the ball and cage valve, notably the Smeloff-Cutter valve and the Magovern prosthesis. In the case of the former, the ball is slightly smaller than the orifice. A subcage on the proximal side of the valve retains the ball in the closed position with its equator in the plane of the sewing ring. A small clearance around the ball ensures easy