A Complication of Valve Replacement
by a Caged-Lens Prosthesis


SUMMARY
Five of 37 patients undergoing valve replacement with a “caged-lens” prosthesis demonstrated intermittent insufficiency of the prosthesis. Four of these patients had mitral valve replacement, three of whom had uncorrected aortic insufficiency. Cineradiography showed tilting of the prosthetic lens and impingement within the cage in an oblique position.

Additional Indexing Words:
Uncorrected aortic insufficiency Arterial pressure curve Valvular malfunction
Left ventricular failure

SINCE the introduction of artificial heart valves, investigators have been continuously modifying them, endeavoring to eliminate complications associated with their use. The Starr-Edwards ball-valve prosthesis was the first to be widely accepted; however, problems due to its weight, cage size, and resistance to blood flow have stimulated the search for a better prosthetic device. In spite of this effort, the ideal heart valve has not been developed. Recently, a “caged-lens” design has become the prosthesis of choice in some centers.

One type, Cross-Jones, consists of a titanium frame, a silicone rubber lens-shaped disc, and a woven Teflon fixation flange. The freely floating disc is held in position over the valve seat by a cage of three titanium legs (fig. 1 left). The silicone rubber lens is reinforced by a titanium ring molded within it. The ring prevents excessive deformation of the lens, and, being 0.010 inch larger in diameter than the valve orifice, it prohibits the lens from slipping through the orifice under high closing pressure.

The Hufnagel discoid valve differs in construction; it is made of a plastic material and has four struts forming the cage (fig. 1 right). The discoid valves have some inherent advantages over the ball-valve prosthesis: (1) less space is occupied by the valve (this may be very important in the mitral area if the left ventricle is small), (2) being isobaric with blood, the disc will move when a minimal force is applied to its surface, (3) less energy is transmitted to the sewing cuff during the impact of opening or closing, and (4) the valve functions more effectively than a ball valve during rapid tachycardia.

Cross and Jones have reported small emboli and leaks between the rim and the annulus as complications of caged-lens prostheses. However, no mention has been made in the literature of valve malfunction. In the last 2 years we have seen this occur when the disc becomes temporarily impinged in an oblique position within the cage, resulting in serious valvular insufficiency.

Report of Case
E. A. is a 29-year-old Caucasian woman with inactive rheumatic heart disease with clinical, radiographic, and electrocardiographic features of

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Because of progression of her symptoms, the mitral valve was replaced on April 19, 1966, with a no. 85 Cross-Jones prosthesis. Postoperatively, the patient was found to have complete heart block, with an initial ventricular rate of 60 beats per minute, which gradually slowed to 40 beats per minute. With the concern of possible digitalis toxicity, the drug was withheld for several days but complete heart block persisted. It was also noted that the mitral prosthesis intermittently failed to close; when this occurred a loud insufficiency murmur replaced the closure sound of the prosthesis. The arterial pressure markedly declined with each insufficiency beat (fig. 2). At cinefluorography, the lens of the prosthetic valve was seen to tilt intermittently during late diastole, allowing one edge of the disc to become impinged below the valve seat. In this “cocked” position the valve was insufficient.

Six weeks postoperatively the patient required insertion of an internal cardiac pacemaker. Despite rate adjustments, intermittent valvular dysfunction has persisted. Interestingly, the number of insufficient beats is related to the heart rate. When the ventricular rate is less than 60 beats per minute, malfunction of the prosthesis

Figure 1
Cross-Jones discoid valve (left) and Hufnagel discoid valve (right).

serious mitral insufficiency and mild aortic incompetency. During several years of observation, increasing cardiomegaly and persistent atrial fibrillation accompanied a progressive symptomatic deterioration. Despite a supervised medical program, minimal activity resulted in extreme fatigue and dyspnea.

Figure 2
Simultaneous recording of the femoral arterial pressure, apex phonocardiogram, and standard lead II of the electrocardiogram. The ECG was taken simultaneously, but on a standard ECG machine, while the pulse pressure and phonocardiogram were recorded on a multichannel photographic recorder. With “cocking” of the prosthesis, the closing and opening clicks of the prosthesis (small arrows) are replaced by a pansystolic regurgitant murmur (large arrows) with a marked decrease in arterial pressure.
is so frequent that incapacitating dyspnea and lightheadedness occur; however, when the rate is 90 beats per minute malfunction is infrequent.

**Discussion**

Our experience with the caged-lens prosthesis extends from December 1964 to the present. During this interval 37 patients have undergone replacement of the mitral, aortic, or tricuspid valve, or two valves by this prosthesis (table 1). Malfunction of the prosthesis was observed in five of these patients.

Of these five cases with valvular malfunction, four were of the mitral valve, and 1 was of the aortic valve. Three cases of mitral valve replacement had coexistent uncorrected aortic insufficiency. Additional information referable to these cases is listed in table 2.

The cause of the prosthetic valve malfunction is unknown. Normal function depends on the lens traveling parallel to the valve seat throughout its entire excursion. In our case, cinefluorography demonstrated repeatedly that “cocking” of the lens began during diastole, when one edge prematurely moved toward the valve seat while the opposite edge remained in the open position. During the next systolic contraction, the position of the lens remained tilted and valvular insufficiency resulted.

The high incidence of mitral valve dysfunction in the presence of uncorrected aortic insufficiency suggests that the valve lens is being tilted by the regurgitant jet of blood. The jet, acting upon the edge of the valve, may tilt the lens in various positions enough to cause binding within the cage and improper seating during left ventricular ejection (fig. 3a and b). Normal function of the valve is not resumed until the disc becomes a free-floating object again.

An alternative explanation is that the disc is tilted by eddy currents produced within the ventricular cavity (fig. 3c and d). This is analogous to a sail being influenced by slight changes in wind currents. Not excluded, but regarded as unlikely, is the possibility that free motion of the valve lens is impaired by fibrin thrombi or remnants of papillary muscle or chordae tendineae, or both.

That malfunction of the valve is, in part, rate dependent is shown by the patient with complete heart block. As the heart rate decreased, the frequency of valve dysfunction increased. The explanation of this phenomenon is conjectural but must be related to increased diastolic time, with increased diastolic volume tending to exaggerate the effect.

### Table 1

*Experience with “Caged-Lens” Prosthesis (Walter Reed General Hospital)*

<table>
<thead>
<tr>
<th>Type of prosthesis</th>
<th>No. of cases</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cross-Jones</td>
<td>22</td>
</tr>
<tr>
<td>Hufnagel</td>
<td>15</td>
</tr>
<tr>
<td>Valve replaced</td>
<td></td>
</tr>
<tr>
<td>Mitral</td>
<td>18</td>
</tr>
<tr>
<td>Aortic</td>
<td>15</td>
</tr>
<tr>
<td>Aortic and mitral</td>
<td>3</td>
</tr>
<tr>
<td>Tricuspid</td>
<td>1</td>
</tr>
<tr>
<td>Total</td>
<td>37</td>
</tr>
</tbody>
</table>

### Table 2

*Malfunctioning Caged-Lens Prosthesis (5 Cases)*

<table>
<thead>
<tr>
<th></th>
<th>Aortic</th>
<th>Mitral</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number of valves replaced</td>
<td>1</td>
<td>4</td>
</tr>
<tr>
<td>Uncorrected valve lesions</td>
<td>0</td>
<td>3-(A.I.)</td>
</tr>
<tr>
<td>Type of prosthesis</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cross-Jones</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>Hufnagel</td>
<td>2</td>
<td></td>
</tr>
<tr>
<td>Onset of dysfunction</td>
<td>2 Weeks</td>
<td>Immediately</td>
</tr>
<tr>
<td></td>
<td>postoperatively</td>
<td></td>
</tr>
<tr>
<td>Cardiac rhythm</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sinus</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Atrial fibrillation</td>
<td>3</td>
<td></td>
</tr>
<tr>
<td>Heart block</td>
<td>1</td>
<td></td>
</tr>
</tbody>
</table>

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Figure 3

Concept of prosthetic valve dysfunction. (a). The superior edge of the lens is "cocked" open by a regurgitant jet of blood. (b). The superior edge of the lens is impinged behind the valve seat. (c and d). During systole, eddy currents tilt the lens, preventing proper seating of the valve.

of coexistent aortic insufficiency on normal ventricular eddy currents.

Inspection and manipulation of the Cross-Jones prosthesis demonstrate the propensity for an edge of the lens to catch below the valve seat. The presence of only three struts forming the cage allows this to occur. Discoid valves with four struts instead of three do not have this problem. Experience with ball valves has shown that the silicone ball may wear unevenly, increase or decrease in size, crack, or become grooved where it makes contact with the cage. Conceivably, a discoid valve could have mechanical failure due to the same type of wear.

Malfunction of the aortic prosthesis is also unexplained. Auscultation during malfunction revealed a short diastolic murmur that dis-
appeared with proper seating of the valve. This created the impression that the valve was encountering an obstruction during its descent. If the aortic annulus is small or irregular from calcium deposits, there is a tendency for enfolding of the sewing cuff to occur as the valve is being inserted during surgery. Should this happen, the enfolded edge could project inward enough to catch the disc as it descends.

The marked change in hemodynamics caused by prosthetic valve malfunction is shown by the arterial pressure curve in the case report. During periods of prolonged valvular insufficiency, the cardiac output decreased, and symptoms of left ventricular failure developed. In one patient, valve dysfunction was a contributing factor in his early demise. The four surviving patients have shown definite clinical improvement from their preoperative state. This is in spite of continued intermittent prosthetic-valve insufficiency.

Because of these experiences we believe that this type of “caged-lens” prosthesis should not be used in the mitral area in the presence of uncorrected aortic insufficiency.

References

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