Late Postoperative Anatomic Observations after Insertion of Hufnagel Caged-ball Prostheses in Descending Thoracic Aorta*

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Clinical and necropsy observations are described in two patients who died 11 and 13 years, respectively, after implantation of Hufnagel prostheses (the first ever used successfully in humans to treat cardiac valve disease) in descending thoracic aorta. Despite the long implantation periods, there was no evidence of prosthetic degeneration or thrombosis or intravascular hemolysis. Although approximately 4000 Hufnagel descending aortic prostheses were distributed by the manufacturer for human use, data in only 55 patients in whom these prostheses were inserted were found in previous publications, and 26 of them had died. Of the 13 late deaths previously reported, no evidence of prosthetic degeneration or thrombosis was described in the three patients surviving > 3 years (8, 10, 12.5 years, respectively). Since neither our patients nor any of the other three reported long-term survivors had prosthetic-related complications and since the dangers of excising the descending aortic prosthesis are considerable, it appears most reasonable, as a rule, not to remove the descending aortic prosthesis at any time in these patients if aortic valve replacement is subsequently performed.

In 1953 Hufnagel and Harvey1 described successful implantation of a caged-ball prosthesis into descending thoracic aorta in a patient with severe aortic valvular regurgitation. Similar implantations followed,2-4 but few reports provided information on long term survivors. The present report attempts to fill this void somewhat by describing certain findings during life and at necropsy in two patients who lived 11 and 13 years, respectively, after implantation of Hufnagel prostheses into descending thoracic aorta. Also, experience during the past 14 years5-28 with prostheses used to replace malfunctioning cardiac valves, can now be utilized in re-examining or evaluating the first of the caged-ball prostheses.

DESCRIPTION OF PROSTHESIS

In the implantation referred to, the prosthesis consisted of a plastic (plexiglass) tube containing a hollow poppet,5 the wall of which was composed of nylon, which in turn was covered by a 2 mm thick layer of silicone rubber. The prosthesis was attached to aorta by a nylon multiple-point semiflexible fixation ring. Occasionally, the aorta was wrapped with Orlon after attaching the fixation ring. A pressure of only 5 mm Hg was enough to move the poppet in a completely open or closed position.5 To insert the prosthesis, a transverse segment of descending thoracic aorta (about 2 cm in width) was excised and the prosthesis (measuring just under 6 cm in length) was inserted into both cut ends of the aorta (Fig 1).

PATIENTS STUDIED

Certain observations in the two patients are summarized in Table 1. Preoperatively, both had severe aortic regurgitation, and each was in functional class 4 (New York Heart Association classification) from congestive cardiac failure. Postoperatively, both were asymptomatic for several years, and the heart sizes by chest roentgenograms became smaller. Symptoms and signs of congestive cardiac failure recurred in each about one year before death, which shortly followed reoperation (aortic valve replacement). The excised aortic valves in each were three-cusped, diffusely thickened by fibrous tissue, and free of calcific deposits. The Hufnagel prostheses in the descending aorta were not removed at reoperation, but at necropsy both were free of thrombi and no portion of either prosthesis showed evidence of wear or variance. The tissue capsules covering the prostheses consisted of fibrous tissue and lipid. The latter was located adjacent to the prostheses. Several anatomic observations in the two patients are illustrated in Figures 2 to 6.

COMMENTS

Although approximately 4000 Hufnagel prostheses were manufactured and distributed to medical centers in Europe, Africa, Australia and...
North and South America, clinical, hemodynamic or anatomic observations have been reported previously, to our knowledge, in only 55 patients in whom these prostheses were implanted (Table 2). Of the 55 patients, 13 died within two months of operation (early deaths), and 13 at later periods up to 12.5 years. Of the 13 early deaths, four were due to technical problems (apparently the result of prolonged cross-clamping of the aorta), four to infection (prosthesis infected in only one), and five to uncertain causes. Of the 13 late deaths, four appear to have resulted from prosthetic dysfunction due to prosthetic thrombosis, and nine from causes unrelated to the prosthesis. Except for the four with evidences of prosthetic thrombi, the prostheses appear to have functioned properly during the entire postoperative period in the other nine patients. The eventual course in the remaining 21 survivors is unknown, except for the patient reported by Halikier et al. Their patient survived aortic valve replacement and removal of the Hufnagel prosthesis 12.5 years after implantation.

Although, as noted above, dysfunction occurred within this prosthesis, thrombus formation did not occur in any of the reported patients dying within two months of operation or in any survivors with implantation periods longer than three years. Neither of our two patients, surviving 11 and 13 years, respectively, and none of the three previously reported long survivors (eight years, ten years, and

| Table 1—Data in the 2 Patients with Hufnagel Descending Aortic Prostheses |
|-----------------|-----------------|-----------------|-----------------|-----------------|-----------------|-----------------|-----------------|-----------------|-----------------|
| Patient        | Age at death (Yrs) | Sex | History of ARF | Age at onset of symptoms (Yrs) | Age at operation (Yrs) | Implantation period (Yrs) | Pressures (mm Hg) shortly before death | Body weight (Kg) | Heart weight (Gm) |
|                |                  |     |                |                              |                          |                             | PA (s/d) | PAW (s/d) | LV (s/d) | Aorta (s/d) | CI (L/min/M²) |                  |
| 1*             | 41               | M   | +              | 23                            | 30                         | 11                         | 60/30        | 19       | 88/18      | 90/17        | 1.8              | 52              | 920             |
| 2**            | 40               | M   | +              | 26                            | 27                         | 13                         | 24/6         | 12       | 190/31     | 190/60       | 3.6              | 64              | 575             |

*Case illustrated in Figures 2 and 3. **Case illustrated in Figures 4 and 5. Abbreviations: CI = cardiac index; L/min/M² = liters per minute per meter squared; LV = left ventricle; PA = pulmonary artery; PAW = pulmonary arterial wedge; s/d = systole/diastole.
Hufnagel Frosthesis

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FISHBEIN, ROBERTS

CHEST, 68: 1, JULY, 1975

Figure 2. Aortogram from patient just before aortic valve replacement and death. The poppet of the prosthesis appears as a non-opacified circle (bracket). The poppet excursions appeared to be normal.

12.5 years, respectively) had prosthetic thrombi.

Periprosthetic leakage is a well known complication of implantation of prosthetic cardiac valves. Of the 24 patients dying after insertion of Hufnagel prostheses into descending aorta, only one had clinical evidence of leakage, and this resulted in massive hemorrhage and death six weeks after implantation. Infection at the implantation site, however, appears to have been responsible for the suture line disrup-

Table 2—Previously Reported Studies on Hufnagel Prosthesis in Descending Aorta

<table>
<thead>
<tr>
<th>Year (Ref)</th>
<th>No. of patients</th>
<th>Ages at operation (Yrs)</th>
<th>Implantation periods</th>
<th>Early deaths (&lt;2 mo)</th>
<th>Late deaths (&gt;2 mo)</th>
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</thead>
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<tr>
<td>19542,8</td>
<td>23</td>
<td>17-57</td>
<td>op to 11 mos</td>
<td>6</td>
<td>4</td>
</tr>
<tr>
<td>19542</td>
<td>1</td>
<td>35</td>
<td>3 mos</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
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<td>24</td>
<td>10-63</td>
<td>op to 18 mos</td>
<td>5</td>
<td>5</td>
</tr>
<tr>
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<td>37</td>
<td>3 yrs</td>
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<td>1</td>
</tr>
<tr>
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<td>1</td>
<td>21</td>
<td>10 yrs</td>
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<td>1</td>
</tr>
<tr>
<td>19706</td>
<td>5</td>
<td>18-45</td>
<td>op to 12.5 yrs</td>
<td>2</td>
<td>2</td>
</tr>
<tr>
<td>Totals</td>
<td>55</td>
<td>10-63</td>
<td>op to 12.5 yrs</td>
<td>13</td>
<td>13</td>
</tr>
</tbody>
</table>

Abbreviations: mos = months; op = death during operation; Ref = reference number.

Figure 3. Heart and aorta in same patient as in Figure 2. The width of the prosthesis is greater than the width of adjacent aorta. LV = left ventricle; PT = pulmonary trunk; RV = right ventricle.

Figure 4. Hufnagel descending aortic prosthesis in a second patient. a. Opened aorta showing lining surface of the fibrous capsule which surrounded the prosthesis. Atheromatous plaques are present on the inner lining of the fibrous capsule but not in the adjacent aorta. b. Close-up of Hufnagel prosthesis. c. External surface of poppet, which is brown in color. (The poppet was similar in color when inserted 13 years earlier.) There is no evidence of degeneration of the silicone covering over the polyethylene poppet. d and d' One-half of the silicone rubber covering now has been removed (d') demonstrating the polyethylene poppet, which shows no evidence of degeneration.
FIGURE 5. Photomicrographs of wall of fibrous capsule covering descending aortic prosthesis (a) and of junction of aorta and fibrous capsule at proximal suture line (b) in second patient (same as in Fig. 4). The inner portion of the tissue capsule surrounding the prosthesis (a) is infiltrated by lipid. The plastic tube containing the poppet had been located to the left. Oil red 0 stain on formalin-fixed frozen section, × 31. b. The junction of aorta and capsule covering the prosthesis. Remnants of Orlon cloth are embedded in dense fibrous tissue where the aorta ends and capsule begins. Elastic–van Gieson stain, × 9.

CHEST, 68: 1, JULY, 1975

LATE POSTOPERATIVE OBSERVATIONS OF HUFNAGEL CAGED-BALL PROSTHESSES

 Degeneration (variance) of silicone poppets or discs is common in prosthetic valves used presently to replace malfunctioning mitral and aortic valves. Degeneration of the poppet or the plexiglass housing has not been observed in any of the Hufnagel descending aortic prostheses despite implantation periods of up to 13 years. Furthermore, intravascular hemolysis, an almost invariable consequence of mitral or aortic valve replacement, has not been observed, to our knowledge, in any patients with only a Hufnagel descending thoracic
aortic prosthesis. Despite the 11- and 13-year transplantation periods, respectively, in our patients, no clinical (decreased red blood cell survival, elevated reticulocyte count, hemoglobinemia or hemoglobinuria) or anatomic (renal hemosiderosis) evidence of intravascular hemolysis was present.

A caged-ball prosthesis in the descending thoracic aorta obviously only partially diminishes aortic valvular regurgitant flow. Regurgitation from the innominate, left carotid and left subclavian arteries persists, and the pulse pressures in these arteries continue to be wide. The volume of regurgitant flow eliminated by this prosthesis is uncertain. Hufnagel and associates estimated that the prosthesis decreased regurgitant flow by 75 percent. Hemodynamic studies in nine patients postoperatively showed a greater improvement in circulation time (to upper and lower extremities as measured by dye injection curves), cardiac index, and stroke volume than might have been expected by elimination of regurgitant flow from the lower extremities alone. Rose and associates postulated that, because the amount of regurgitation decreased, ventricular contractions became more efficient and stroke volume and cardiac index increased.

Because aortic valvular regurgitation is incompletely relieved by a Hufnagel prosthesis in descending aorta, replacement of the aortic valve usually will be required eventually in the long surviving patients. Halkier and associates and du Plessis and associates each removed a Hufnagel descending aortic prosthesis several weeks after aortic valve replacement for recurrence of congestive heart failure from aortic valvular regurgitation. The Hufnagel prostheses in both patients were removed purely because of uncertainty regarding their eventual fate if left in place. Removal was technically difficult in both patients because of dense fibrous adhesions between aorta and lung and erosion of bony structures adjacent to the prostheses. One patient died shortly after the operation to remove the descending aortic prosthesis; the other required an additional thoracotomy because of postoperative bleeding. Because of the difficulty and danger associated with removal of a Hufnagel descending aortic prosthesis, and because none of the late survivors with this prosthesis, including the patients of Halkier et al and du Plessis et al, had evidence of prosthetic dysfunction, wear, or thrombosis, excision of a Hufnagel descending aortic prosthesis at any time after aortic valve replacement probably is infrequently justified.

Although virtually all prostheses now used to correct malfunctioning aortic valves are implanted into the aortic root, certain patients might benefit from at least temporary implantation of a prosthesis into the descending thoracic aorta. Aortic valve replacement may be fruitless in some patients with active infective endocarditis of the aortic valve with ring abscesses or in subjects with endocarditis at sites of attachment of prosthetic aortic valves. Such patients might benefit by use of a caged-ball prosthesis implanted into the descending aorta, after excision of the infected natural or prosthetic aortic valve. (Danielson and associates recently implanted a valve prosthesis in the ascending aorta [above the coronary ostia] combined with saphenous vein bypass in a patient with an infected aortic root.)

REFERENCES
15 Roberts WC, Morrow AG: Secondary left ventricular
26 Personal communication with Mr. Charles Hewson, Brunswick Manufacturing Company, North Quincy, Mass

Diamond Cutting

Until a diamond is cut it is visually quite uninteresting. Often it is greasy-looking or looks like a frosted pebble or lump of crystals. It was Euclid who proved most useful to the diamond cutter, for diamond cutting is half unbearable tension (will it cleave as planned?) and half pure mathematics. During the fourteenth and fifteenth centuries some experimentation was done on cutting, but it was as if “knowing better is not doing better.” Africa’s record of the Cullinan diamond, three thousand one hundred and six carats, has never been equaled. This was the stone that the famous Mr. Joseph Asscher studied for months before deciding to cut it. On February 10, 1908, in the early afternoon, he set the stone under the cleaver and gave it a strong rap. Nothing happened to the stone, but the steel blade broke. He hit it again at a later date, and when it fell apart precisely as planned, Mr. Asscher fell to the floor in a dead faint.

Wilson, M: Gems, New York, Viking, 1967