Seven Year Experience with Mounted Porcine Valves

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From March, 1969, through June 1976, 108 porcine aortic xenograft valves were used for mitral or aortic valve replacement in 95 patients. This experience provides one of the longest follow-ups available for evaluation of the porcine bioprosthesis. The first fifteen valves were locally mounted on Cutter stents and preserved in buffered formalin. Subsequent valves were prepared by the Edwards and Hancock Companies with glutaraldehyde preservation. Oral anticoagulation was routinely used for the first 6 weeks following surgery.

Hospital mortality was unrelated to the valve type. All but four of the surviving patients with formalin preserved valves have required reoperation because of valve failure. There have been two valve failures in the patients who received gluteraldehyde valves, but there have been no embolic or thrombotic complications. Late cardiac catheterization has shown hemodynamic results equal to or better than prosthetic valves.

The continuing long-term results indicate that the porcine xenograft is the valve of choice for cardiac valve replacement.

IN 1968 WE reviewed our long-term results with prosthetic valve replacement and found that the five year life expectancy of the operative survivors was only 40%. This low survival rate in the Charity Hospital patients was largely due to cerebral embolization, complete thrombosis of the valves and complications of anticoagulation. The results of this review stimulated us to look for valves less subject to the above complications. The results presented by Ionescu[5,6] and by Carpentier[1] led to the trial of stented aortic porcine valves.

There appeared to be several theoretical advantages of these mounted heterografts: (1) the technique for implantation is essentially the same as for prosthetic valves; (2) they should not be thrombogenic after the cloth stents are endothelialized; (3) they are center-flow and can, therefore, be used in a larger size than a prosthetic valve; (4) since anticoagulants would not be used except for a short period, there should be few anticoagulation complications; (5) they should be readily available in all sizes. The one disadvantage was that there was no information on how long the valves would last. Because of this lack of knowledge concerning durability of the valves, it was decided initially to implant them in only New York Heart Association (N.Y.H.A.) class IV patients.

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Clinical Material and Methods

In this series, from March, 1969 through June, 1976, 95 patients have had 108 stented porcine valves of three different types implanted. The patients were subjected to total cardiopulmonary bypass with cardiac anoxic arrest with or without hypothermia. The valves were implanted by several different suture techniques but the methods were similar to those employed for the implantation of any prosthetic valve. If there were a history of embolism or if thrombi were found in the left atrium at operation, ligation of the appendage or suture closure of its orifice was done. Sodium Warfarin was started on the fifth post-operative day and continued for the first 6 weeks following operation. No other form of anticoagulation was used in these patients.

The 52 females and 43 males in this series ranged in age from two to 72 years. Seventy-one patients were in N.Y.H.A. class IV, 22 were in class III, and two were in class II. Twelve patients had active, sub-acute, or acute bacterial endocarditis necessitating emergency or semi-emergency valve replacement for progressive intractable cardiac failure.

The first group included 17 patients who received 18 valves that had been locally prepared. For preparation, the aortic valves were trimmed from freshly killed porcine hearts, then suture mounted onto Cutter-Angell stents. Figure 1. The first few were then fixed and preserved in buffered formaldehyde. We then found that first fixing the valves in buffered formaldehyde provided easier and more accurate mounting.

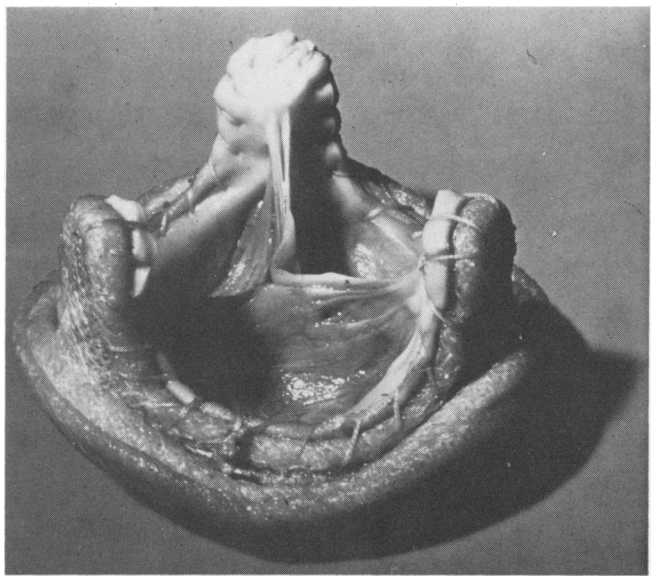

FIG. 1. Example of locally mounted, formalin fixed porcine valve.

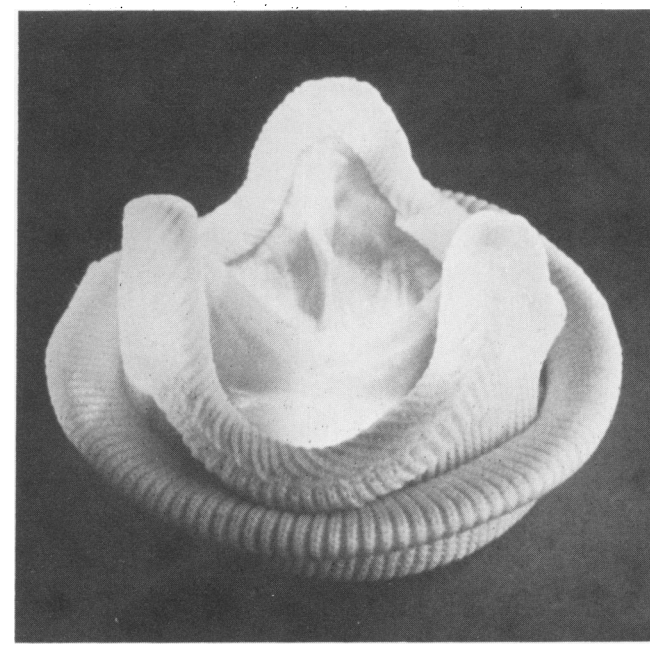

FIG. 2. Hancock Valve

These valves were implanted during 1969 and part of 1970.

The second group consisted of 40 patients who received 43 valves manufactured by the Edwards Company, using the original Carpentier technique of oxidization in Sodium Metaperiodate with preservation in glutaraldehyde.

The third group of 44 patients, including several who required replacements of their porcine valves, had 47 Hancock valves fixed and preserved in buffered glutaraldehyde (Fig. 2).

Results

There were 30 deaths occurring within the first 30 days after operation, resulting in a hospital mortality of 31.5%. This high mortality was due mostly to the extreme illness of the patients since all but one were in N.Y.H.A. class IV, but a few were a result of technical errors. No early deaths could be attributed to the type of valve implanted.

Among the 65 survivors there have been 10 late

TABLE 1. *Analysis of Late Deaths*

Patient	Age	Valve Location	N.Y.H.A. Class at Original Operation	Time Between Implant & Death	Cause of Death
L.B.	55	Mitral	IV	18 mos.	Pulmonary embolus
D.W.	3	Mitral	IV	3 mos.	Sickle cell disease, Cardiomyopathy
J.F.	44	Mitral	III	40 mos.	Coagulopathy at aortic valve replacement for AI
G.I.	48	Mitral	IV	38 mos.	Tricuspid stenosis, missed at catheterization & at operation
W.F.	48	Mitral	IV	3 mos.	Arrythmia, Cardiomyopathy
Z.B.	63	Mitral	IV	4 mos.	Carcinoma of cecum with metastases
M.J.	24	Mitral	IV	1.5 mos.	GI bleeding following massive steroid treatment for pre-existing nephrotic syndrome
M.W.	21	Mitral	IV	16.5 mos.	Thrombosis of Starr-Edwards valve 6 mos. after replacement of failed porcine valve
S.S.	60	Mitral	IV	16 mos.	Oxygenator failure during replacement of failed valve
J.P.	43	Mitral	IV	28 mos.	Sudden death-cause unknown not in hospital

TABLE 2. *Analysis of Valve Failures*

Patient	Valve Location & wtype	Valve Failures Insufficiency Murmurs First Noted	Cause of Failure	Replacement Time after Implant
1.	Mitral L	37 mos.	Pulled off posts	38 mos.
2.	Aortic E-C	—	Calcification producing stenosis	61 mos.
3.	Mitral L & Aortic L	41 mos. 50 mos.	Pulled off posts Pulled off posts	42 mos. 54 mos.
4.	Mitral E-C	—	Calcification producing stenosis	12 mos.
5.	Mitral L	63 mos.	Pulled off ptsts	63 mos.
6.	Mitral L	Immediate Post-op	Poor mount. leaflets not coapted Leaflets stretched and prolapsed	51 mos.
7.	Mitral L	Immediate Post-op	Poor mount. leaflets not coapted Leaflets stretched and prolapsed	9 mos.
8.	Mitral	15 mos.	Pulled off posts	16 mos.
9.	Aortic E-C	2 days	Paravalvular leak	15 mos.

L = locally prepared.
E-C = Edwards-Carpentier prepared.

deaths. The analysis of these deaths is shown in Table 1. No patient has suffered a recognizable episode of embolization and there has been no instance of valve thrombosis.

Among the first group (locally manufactured valves) there were 7 valve failures in the 11 surviving patients and each required replacement. Each of these failures could be attributed to inexpert mounting or the type of stent (Table 2), and all occurred between 9 and 63 months following operation (Fig. 3 and 4). Although all were in N.Y.H.A. class IV at the time of the original operation, none was worse than N.Y.H.A. class III at the time of replacement. There was one death due to oxygenator failure. Three patients remain asymptomatic at 72, 74 and 80 months. One patient was lost to follow-up at four years.

Three patients in the second group (Edwards-Carpentier Oxidized, glutaraldehyde), have required replacement of their porcine valve. Two failures were due to calcification of the leaflets producing stenosis (Fig. 5). The valve in the mitral position was replaced 12 months after implantation, while that

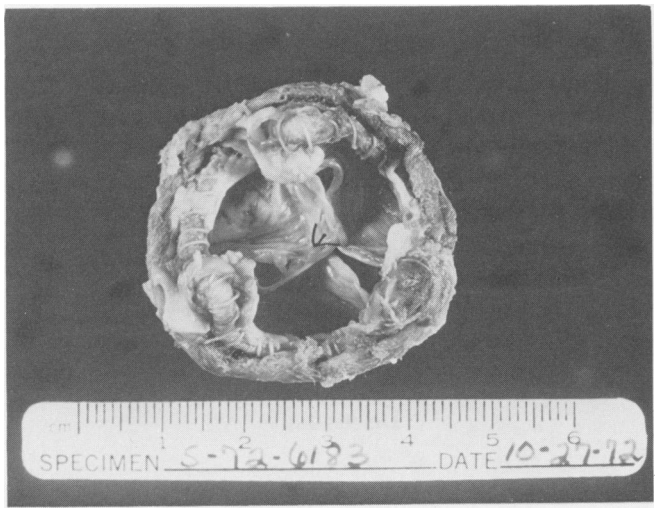

FIG. 3. Locally mounted valve with failure and replacement at 42 mos. The leaflets are thin and pliable but all three commissural attachments have pulled off posts (Leaflet tears were done at removal).

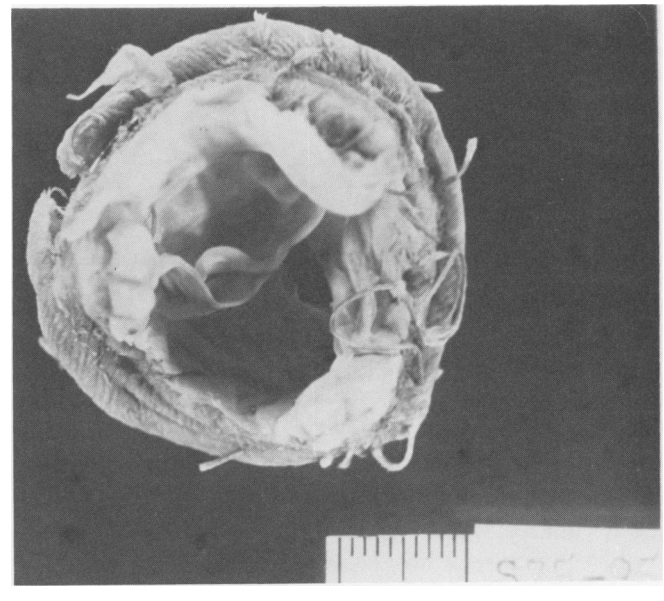

FIG. 4. Locally mounted valve with failure and replacement at 51 mos. Leak was evident immediately after operation. There is stretching and prolapse of the leaflets with poor coaption. One commissural attachment has partially pulled off post.

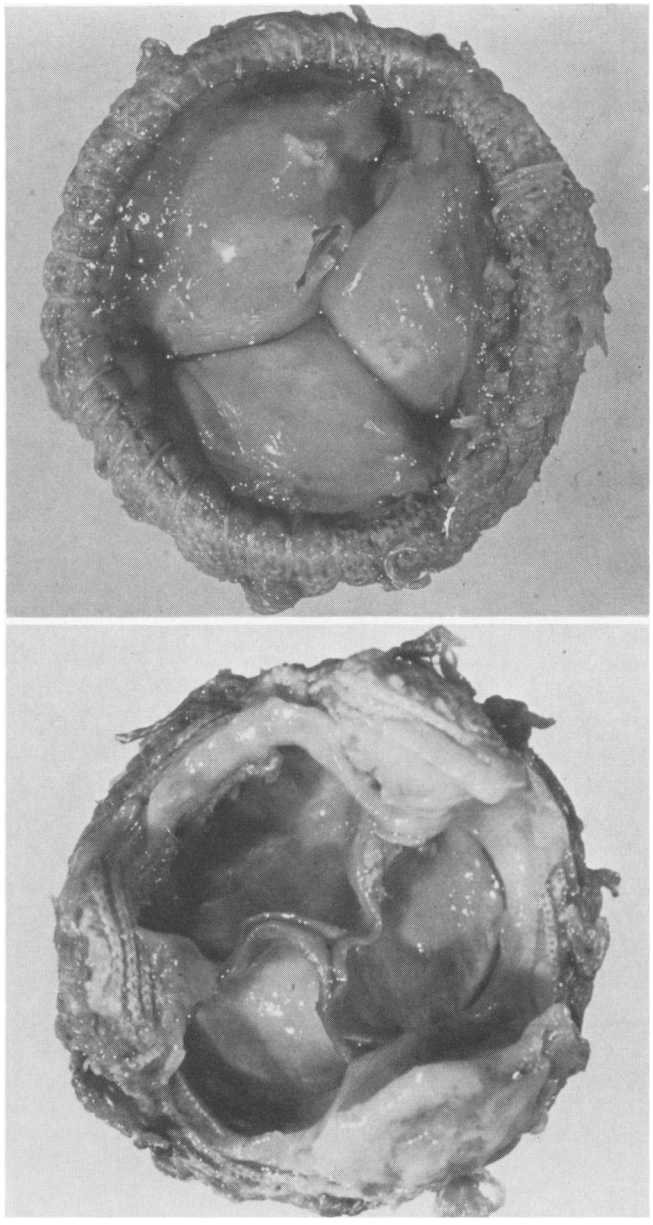

FIG. 5. Edward-Carpentier valve with stenosis and replacement at 61 mos. The easily visible thickening is mostly calcification which severely limited leaflet motion. Note excellent leaflet coaptation precluding leakage. (Perforation was produced at removal.)

in the aortic position did not require replacement until 61 months. The third replacement was for para-valvular leak (Table 2).

In the third group (Hancock, glutaraldehyde), there have been no valve failures, no evidence of stenosis, and no para-valvular leaks.

There have been no instances of bacterial or fungal infections involving the bioprostheses even though seven survivors had active sub-acute or acute bacterial endocarditis at the time of implantation.

Of the 55 long-term survivors, all except one are asymptomatic and can properly be assigned to class I or class II (N.Y.H.A.). The symptomatic patient has no evidence of valve dysfunction but she does get short of breath after walking up two flights of stairs and requires maintenance on digitalis and diuretics.

Thirteen patients were considered too ill for catheterization before operation, and the studies were interrupted in two others because deterioration in their clinical condition made immediate operation mandatory. Of those having complete studies, the cardiac index ranged between 1.2 L/min/M^2 and 3.0 L/min/M^2, with an average of 1.6 L/min/M^2. After operation, few asymptomatic patients would consent to follow-up catheterization. The average cardiac index in those who underwent studies, was 3.2 L/min./M^2 with a range of 2.2 to 3.9 L/min/M^2. The mitral valve end-diastolic gradient ranged from 2 to 9 mm Hg. The peak to peak systolic gradient across the aortic valve ranged from 0 to 26 mm Hg. The patient with calcification of the porcine valve in the aortic position was asymptomatic one year before its replacement, but had a gradient of 50 mm Hg. Just prior to reoperation, however, when he began to have near syncopal episodes, the gradient was 96 mm Hg.

Gross and microscopic examination of removed porcine valves has shown no evidence of rejection, thrombi, or gross dissolution of collagen fibers (Fig. 6). In addition there has been no ingrowth or host replacement of leaflet tissue, and Carpentier's[2] designation of these valves as bio-prostheses rather than heterografts is appropriate. The formalin preserved valves retained their pliability and leaflet thinness, but did show stretching with leaflet prolapse in the two with inaccurate coaptation of the leaflets at the time of mounting. A murmur of valvular insufficiency was heard immediately after operation in these two patients. The five valves that had pulled off the post of the stents, had intact leaflets. The double curves of the stent had provided a dead space between the aortic wall of the valve and the stent, with the result that there was no fibrous fixation of the valve to the vertical post. The present methods of commercial manufacture have eliminated this defect.

Discussion

There is little question that properly stented and properly preserved porcine aortic valves function well in all positions in the heart.[2–4,9,10,12,13] With only short term anticoagulation, the incidence of

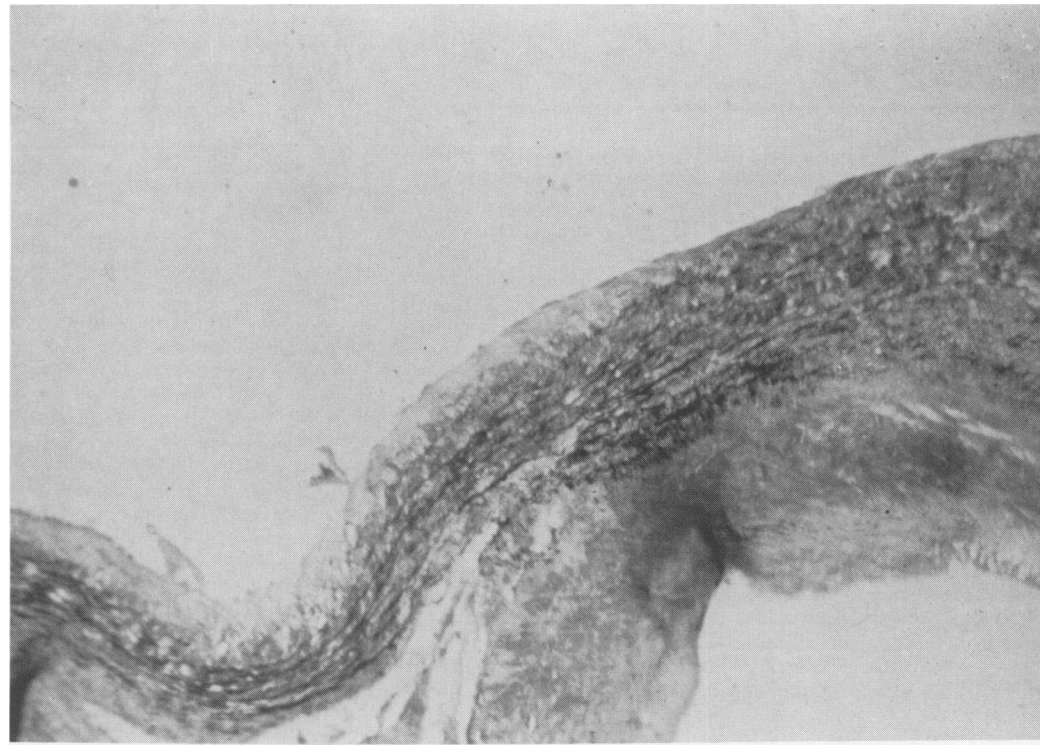

FIG. 6. Microscopic appearance of leaflet from formalin fixed valve removed at 43 mos. after implant. Collagen fibers mostly are intact. Note their fibrin deposition with some pseudo-intima.

thromboembolic complications are almost nil and there were none in this series.

The durability of these valve prostheses is, however, still open to question.[2,8,10,13] The present methods of commercial preparation and testing of the valves have essentially eliminated poor coaptation of the leaflets so they now remain mutually supporting. The stents have been improved and their flexibility may indeed decrease stress on the valves[11] while the method of attachment to the posts has apparently eliminated the problem of detachment. Our four year follow-up of glutaraldehyde fixed and preserved valved prostheses as manufactured by Hancock and now by Edwards, has shown none of the difficulties encountered with the older methods of manufacture. We have had no valve failures since we began implanting the Hancock manufactured bioprostheses. Since July of this year the valve of our choice is the bioprosthesis by Hancock or by Edwards and the implantation of a prosthetic valve is done only under exceptional circumstances.

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