CONSIDERATIONS IN THE PROSTHETIC CONSTRUCTION OF THE AORTIC VALVE

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> 'I will praise thee; for I am fearfully and wonderfully made; marvellous are thy works; and that my soul knoweth right well.
>
> My substance was not hid from thee, when I was made in secret, and curiously wrought in the lowest parts of the earth'.
>
> *Psalm* 139: 14, 15.

Diseased aortic valves are at present being replaced by prosthetic valves by cardiac and experimental surgeons in many parts of the world. In the construction of such valves synthetic materials,[1, 2, 6, 7, 9, 10, 14] homologous[3, 11, 12] or autogenous[8, 13] tissues are being employed.

The present-day opinion seems to favour synthetic materials. At the same time, however, homologous-organ transplantation[4, 5, 15, 16] is receiving the serious attention of many workers in this field. It has been well established that only in the case of identical twins will the transplanted organ be tolerated by the host, without the development of immunological reactions. In the case of valve surgery it can therefore be justly assumed that the heart will similarly tolerate its own pericardium as a valve. Whether, however, the healing granulation-tissue reaction at the site of union will be so limited to the vicinity of the suture line as not to cause significant scarring and possibly calcification, even after many years, and whether the relatively avascular pericardium will obtain sufficient nutriment from the blood medium as to prevent significant anoxic degeneration with ultimate fibrosis, are questions which, as yet, cannot be fully answered.

Autogenous pericardium has several other important attributes. It is readily and freely available at the time of operation in a fresh and sterile state and at no cost to the patient or institution. It is strong and thin and when employed as a valve cusp it has great mobility.

In order to manufacture such pericardial cusps at the time of operation, a formula was devised whereby it became possible to determine correctly the size and shape of a cusp which would fit the aorta in question in such a way that neither incompetence nor stenosis would either persist or develop. Thereafter the main objection to pericardium seemed a technical one because pericardium was extremely difficult to handle as a single cusp, while as a whole valve it was virtually impossible to handle. This difficulty was

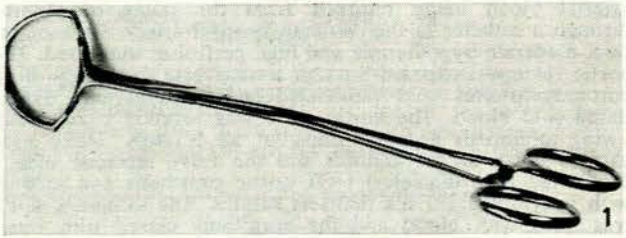

Fig. 1. Aortic pericardial-cusp clamp.

overcome by the development of a pericardial-cusp clamp (Fig. 1) which not only served to hold the cusp, while sutures were being introduced along its free margin, but which also determined the size and shape of the cusp to be inserted.

Seven such aortic pericardial-cusp clamps have been designed for aortas with internal diameters ranging from $\frac{7}{8}$in. to $1\frac{4}{8}$in. The size and shape of the clamping end of each instrument were determined according to the following observations and calculations.

Fig. 2 represents a horizontal section through the ascending aorta immediately above the aortic cusps during diastole. If the internal diameter of the aorta is 1·5 in., then during diastole each side of each cusp measures 0·75 in., the total width of each cusp then being 1·5 in.

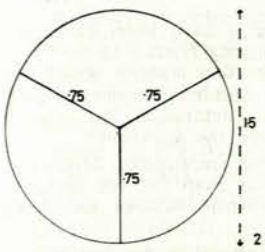

Fig. 2. Horizontal section through the ascending aorta immediately above the aortic cusps during diastole.

A vertical section through the same ascending aorta and 2 cusps in the diastolic position is shown in Fig. 3. During diastole each individual cusp must have a horizontal depth of not less than 0·75 in. to prevent regurgitation.

Fig. 4 again shows a vertical section through the aorta and cusps as in Fig. 3. In addition a circle with a radius of 0·75 in. has been drawn so as to include a cusp body as a quadrant. The vertical depth of this cusp during diastole is also 0·75 in. As the circumference of this circle is 2π R, which equals 33/7 in., the true height of the cusp substance is $33/7 \times \frac{1}{4} = 1{\cdot}18$ in.

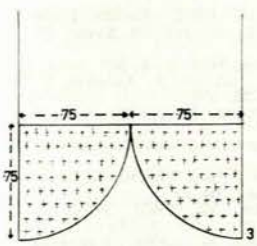

Fig. 3. Vertical section through the same ascending aorta as in Fig. 2, showing 2 cusps in diastole.

Fig. 5 illustrates the incorrect and the correct size and shape of a flat pericardial cusp to fit competently an aorta with an internal diameter of 1·5 in.

Fig. 6 shows cusps 1 and 2 in diastole and cusp 3 (broken line) in systole. As the internal circumference of the aorta is 33/7 in., one-third of the circumference is 1·57 in. Should the systolic width of each cusp be its diastolic width, viz. 1·5 in., then the cusp (broken line) will not reach the aortic wall in systole and therefore cause some slight systolic obstruction. The width of the cusp should therefore be 1·57 in. and not 1·5 in. Anatomically, however, the width of the proximal part of the ascending aorta is wider than the rest of the ascending aorta owing to the presence of the sinuses of Valsalva. If each sinus is but 0·09375 (3/32) in. deep, then the radius of the aorta at this level will be increased by 0·09375 in. and the width of the flat cusp by a further 0·1875 (3/16) in. (circumference approximately equals radius × 6).

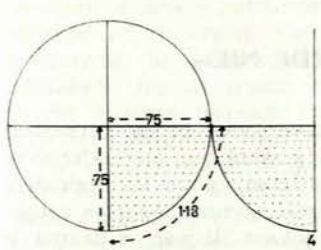

Fig. 4. See text.

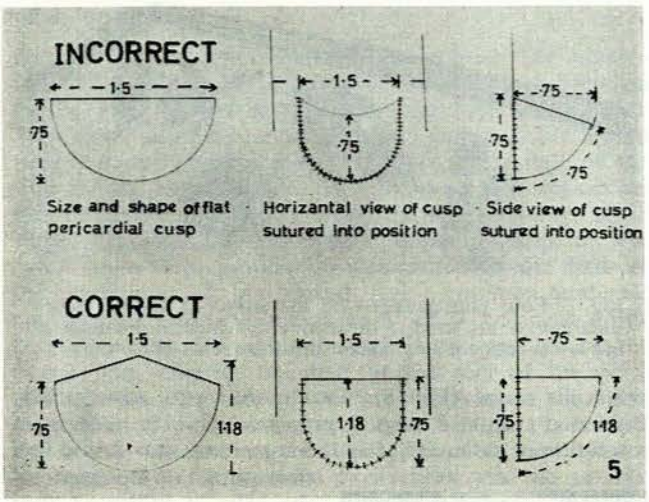

Fig. 5. See text.

The measurements of a pericardial cusp, which will neither cause obstruction nor regurgitation in an aorta with an internal diameter of 1·5 in., will therefore be the following:

Width 1·75 in.
Height at the sides 0·75 in.
Height at the centre 1·18 in.

When an aortagram is available, the diameter of the aorta immediately above the level of the cusps is compared with that at a suitable level higher up. The external diameter at this latter level is determined at the time of operation with the aid of calipers. By subtracting an estimated double wall thickness from the external diameter, the internal diameter can be determined and the diameter at the level of the cusps calculated.

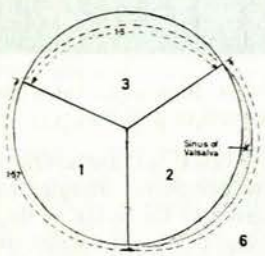

Fig. 6. See text.

In other cases, and particularly when there is significant post-valvular dilatation, the internal diameter of the aorta below the level of the transverse aortotomy is determined by means of a set of 7 screw-on plug type gauges with a universal handle (Fig. 7). These plug-gauges and corresponding cusp clamps are numbered 1 to 7. The serious drawback of this latter technique is that the cusps can only be fashioned after the aortotomy has been completed.

The selected cusp clamp is applied to a suitably prepared portion of pericardium and the cusp excised with a $\frac{1}{4}$-in. margin of pericardium projecting beyond the sides of the clamp. At the proposed free margin of the cusp, the pericardium is trimmed flush with the clamp. A curved length of No. 1 black dermalon is sutured to the free margin of pericardium along the edge of the cusp clamp with interrupted 4-0 white silk sutures, the projecting ends of the

dermalon are cut off long and the cusp removed from the clamp. The cusp will now be of predetermined size and

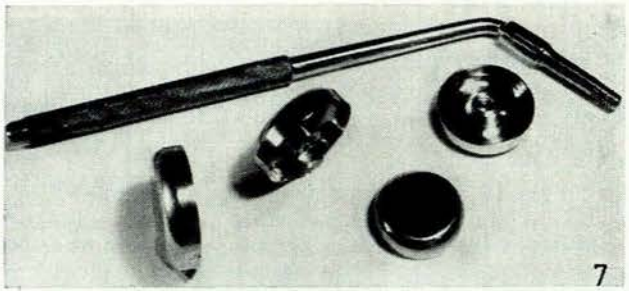

Fig. 7. Four plug-gauges with the universal handle. Seven such gauges are used to determine the internal diameter of the aorta immediately below the transverse aortotomy.

retain its shape (Fig. 8). Two more cusps are similarly fashioned and the 3 cusps kept in readiness for later use in a solution of saline. If after the aortotomy one should find that total replacement of the valve is indicated, then the 3 cusps are sutured together at their commissures with 4-0 white silk sutures, in such a way that the black dermalon threads will face the aortic wall, and the tricuspid pericardial valve inserted as a complete unit. The dermalon threads not only maintain the shape of the individual cusps and of the valve as a whole, but also guide the surgeon when introducing interrupted anchoring sutures along the periphery of the cusps. After all the 2-0 black silk anchoring sutures have been passed through the peripheral margins of the cusps, the valve is approximated to the aorta while applying tension to the anchoring sutures. At this stage the 3 dermalon threads are withdrawn and the valve unit anchored in position by tying the individual 2-0 silk sutures.

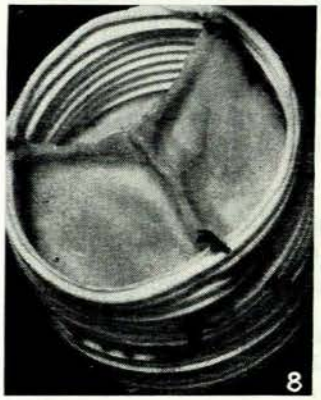

Fig. 8. Pericardial valve cusps sutured in position.

SUMMARY

Provided that the internal diameter of the ascending aorta at a level immediately above the attachment of the cusps is known, then the size and shape of a flat pericardial cusp that will fit the aorta exactly can be determined according to the following formula:

1. Height of cusp at sides where attached to aorta = internal radius of aorta
2. Height of cusp at centre $= \frac{\text{internal circumference of aorta}}{4}$
3. Width of cusp $= \frac{\text{internal circumference of aorta}}{3} + 0{\cdot}188$ in.

Seven aortic pericardial cusp clamps have been developed for aortas with internal diameters ranging from $\frac{7}{8}$ in. to $1\frac{5}{8}$ in. Used in conjunction with the aortic cusp clamps, which are numbered 1 to 7, are seven similarly numbered screw-on plug-gauges, with a universal handle, to determine the internal diameter of the aorta at a level below the aortotomy.

The clamping end of each selected instrument determines the size and shape of the pericardial cusp for the aorta in question and also holds the cusp while sutures are being passed through its free margin.

A curved black dermalon thread, sutured to the free margin of pericardium which projects beyond the sides of the cusp clamp, not only maintains the shape of each individual cusp but also of the tricuspid unit as a whole.

I wish to thank Mr. B. J. Badenhorst, senior heart-lung machine technician, who made the pericardial cusp clamps and plug-gauges, and Mr. T. Marais for the photographs.

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