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Techniques for repairing the aortic and truncal valves

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THERE ARE NOW MANY SURGICAL ALTERNATIVES available for repairing the aortic valve, depending on whether the primary problem is one of stenosis or insufficiency. Patients with insufficiency of the common truncal valve have a unique anatomic substrate, which in some cases allows an innovative strategy of repair not available for the typical patient with a diseased aortic valve. Surgeons should be aware that there are a large number of techniques described for repair of the aortic valve. Some of these are shown in Table 1. For repair of the truncal valve, in contrast, fewer techniques have been described. As shown in Table 2, they are significantly different than those available for repair of the aortic valve.

Table 1. Techniques for repairing the aortic valve.

- Extension of leaflets with pericardium
- Conversion of bifoliate to trifoliate valve
- Repair of torn leaflets
- Thinning of leaflets
- "Commissurotomy"
- Resuspension of leaflets
- Shortening of free edge of prolapsed leaflet (Trusler valvoplasty)
- Closure of fenestration in leaflet

Table 2. Techniques for repairing the truncal valve.

- Approximation of leaflets
- Conversion of quadrifoliate to tri- or bifoliate valve
- Resection of leaflets with remodeling of annular support
- Extension of leaflets
- External annuloplasty

Repair of the aortic valve

Indications for repair are most commonly either valvar stenosis or insufficiency. The valve having two leaflets is the most common substrate for aortic stenosis, while rheumatic fever in underdeveloped countries, and balloon dilations in developed countries, are the most common causes of valvar insufficiency. Insufficiency may also be associated with prolapse of the valvar leaflets in association with a ventricular septal defect. For many reasons, techniques used for repair of aortic valves has lagged behind those designed for atrioventricular valves, but that gap is being narrowed.

The technique of repair on which I will focus is that of extending the leaflets with pericardium. This was first proposed by Duran et al. in 1988.[1] The principle is to utilize glutaraldehyde-preserved autologous pericardium to augment the valvar leaflets. Pericardial strips are sutured to the leading edge of the leaflets, and anchored to the aortic wall (Fig. 1). The technique may include conversion of a bifoliate valve to one with three leaflets. The pericardial strips are anchored to the aortic wall with sutures supported on pledgets. In general, the strips are tailored so as to be slightly redundant, thus allowing approximation of the leaflets. Successful use of this technique has also been reported by the group from Geneva, Switzerland (Figs 2 and 3).[2] Their operations were performed using fresh autologous pericardium to extend the leaflets. They performed the procedure in 41 children, all with rheumatic valvar insufficiency. The mean age of their patients was 11 years. There were no early deaths, and one late death. At discharge, 27 patients had no valvar insufficiency, while the other 14 had only mild insufficiency. There were no reoperations.

The technique has now been modified by Christian Brizard, working at the Royal Children's Hospital in

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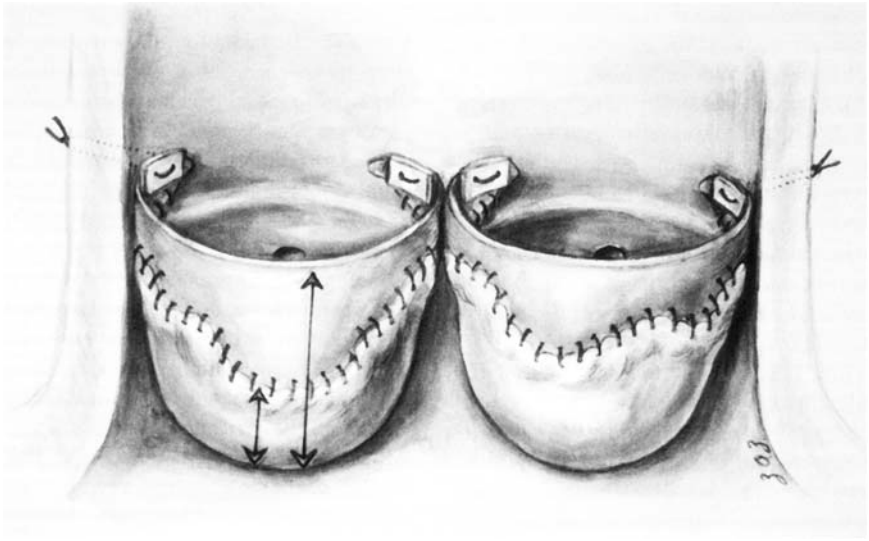

Figure 1.
Lateral view of repaired valve. The deficient and shallow leaflet is augmented with a precisely fitted pericardial patch suspended to the aortic wall. (From Smith PC, Barth MJ, Ilbawi MN. Pericardial leaflet extension for aortic valve repair: techniques and late results. Semin Thorac Cardiovasc Surg Pediatr Card Surg Annu 1999; 2: 83–94. Reproduced with permission.)

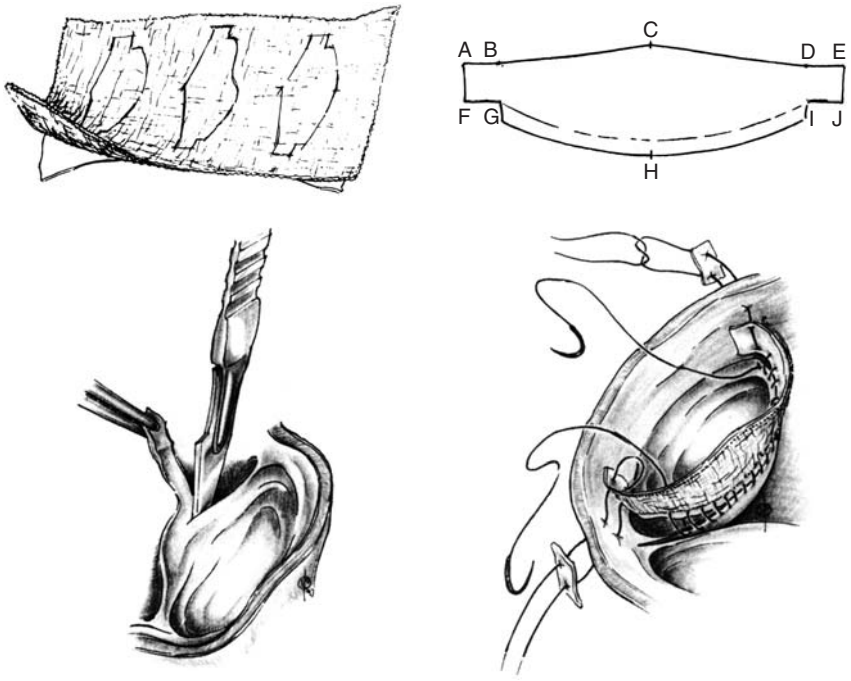

Figure 2.
Surgical technique of extending aortic leaflets with fresh autologous pericardium. (From Kalangos A, Behetti M, Baldovinos A, Vala D, Bichel T, Mermillod B, Murith N, Oberhansli I, Friedli B, Faidutti B. Aortic valve repair by cusp extension with the use of fresh autologous pericardium in children with rheumatic aortic insufficiency. J Thorac Cardiovasc Surg 1999; 118: 225–236. Reproduced with permission.)

Melbourne, so as to convert bifoliate to trileaflet valves.[3] These results were presented at the annual meeting of the Society for Thoracic Surgeons held in 2004. The technique was used in 14 patients between 1996 and 2003, their median age being 9.6 years. There was no mortality. A later Ross operation was needed in one patient for bacterial endocarditis. Another patient has moderate valvar insufficiency, and is being followed. Currently, nine-tenths of the group is free from events after 4 years. It is critical to select carefully the patients who are to be converted from having bifoliate to trifoliate valves. The outcome is better if the diameter of the valvar orifice is equal to, or closer, to the values expected in adults. The hingepoints of the leaflets also need to be pliable. The leaflets themselves should have a thin belly, with no calcifications, and the orifices of the coronary arteries should be normal in size and location.

The technique of extending the leaflets has also been used by the group at the University of California in Los Angeles.[4] They carried out the procedure in 51 patients, having a mean age of 22 years, between 1997 and 2003. Of the patients, 33 had bifoliate valves, 13 had ventricular septal defects, 6 had stenotic trifoliate valves, and 6 were suffering from endocarditis. In one-fifth of their population, there

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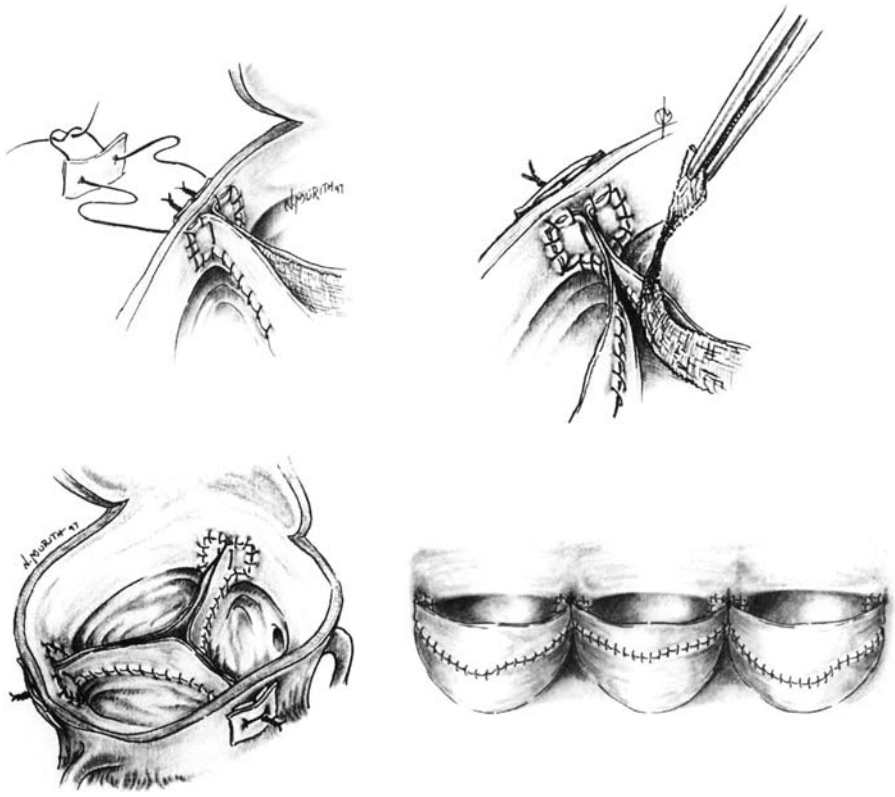

Figure 3.
Completion of repair shown in Figure 2. (From Kalangos A, Behetti M, Baldovinos A, Vala D, Bichel T, Mermillod B, Murith N, Oberhansli I, Friedli B, Faidutti B. Aortic valve repair by cusp extension with the use of fresh autologous pericardium in children with rheumatic aortic insufficiency. J Thorac Cardiovasc Surg 1999; 118: 225–236. Reproduced with permission.)

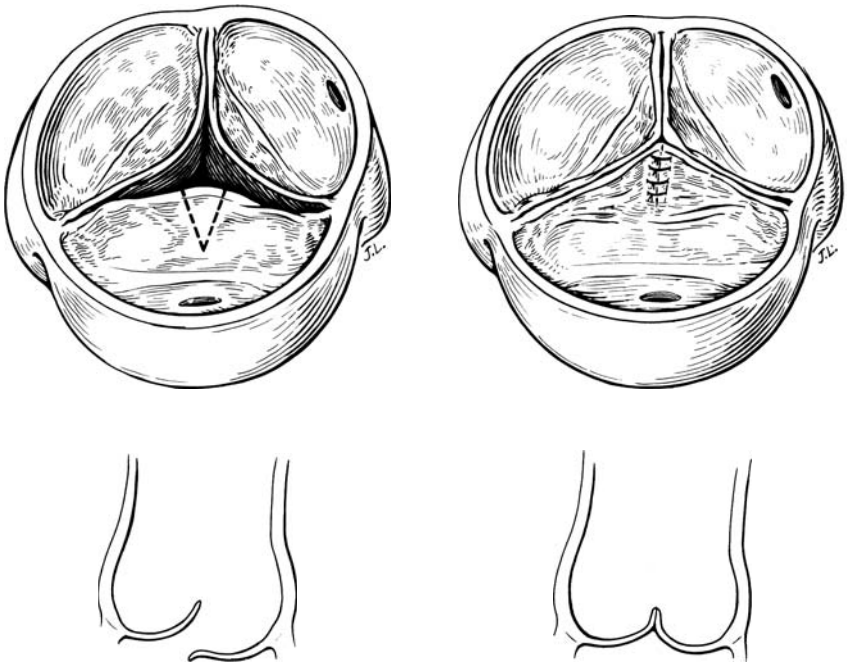

Figure 4.
Aortic valvoplasty technique described by Cosgrove and his associates from the Cleveland Clinic. Upper panel*, a triangular shaped wedge of the prolapsed leaflet is excised (*dashed lines*). The leaflet is then reapproximated with interrupted polypropylene suture. The* left lower panel *shows the prolapsed leaflet, causing aortic insufficiency, which is then corrected by the wedge resection, resulting in a competent valve (*right lower panel*). (From Cosgrove DM, Rosenkranz ER, Hendren WG, Bartlett JC, Stewart WJ. Valvuloplasty for aortic insufficiency. J Thorac Cardiovasc Surg 1991; 102: 571–576. Reproduced with permission.)*

had been prior operations. They had one early death, and no late deaths. There were four reoperations. The mean score for postoperative regurgitation, as judged echocardiographically, was 1.3 on a scale of 0 to 4.

Those working at the Cleveland Clinic have also reported a valvoplasty technique for insufficient aortic valves.[5] They performed surgery on 28 patients, three-quarters with bifoliate valves. They carried out triangular resection of the free edge of the prolapsing leaflet, coupled with plication of the peripheral attachments of the zones of apposition between the leaflets at the sinutubular junction (Fig. 4). This decreased

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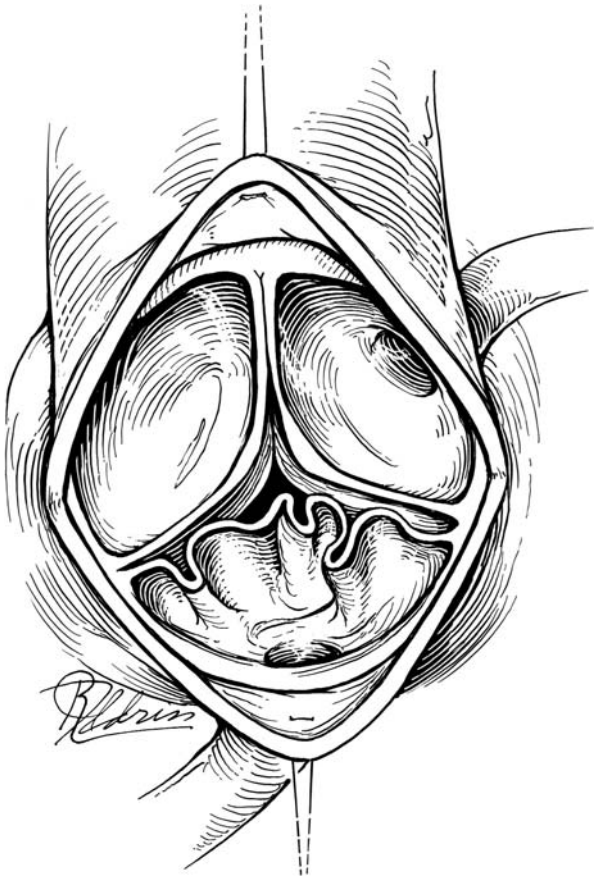

Figure 5.
A redundant, prolapsed right coronary arterial leaflet is demonstrated. The leaflet is pulled down into the ventricular septal defect by the Venturi effect. Aortic valvar insufficiency occurs because of the prolapse of this leaflet, and its failure to coapt with the other leaflets. (From Mavroudis C, Backer CL, Jacobs JP. Ventricular septal defect. In: Mavroudis C, Backer CL (eds). Pediatric Cardiac Surgery, 2nd edn. St. Louis, Mosby, 2003, pp 298–320. Reproduced with permission.)

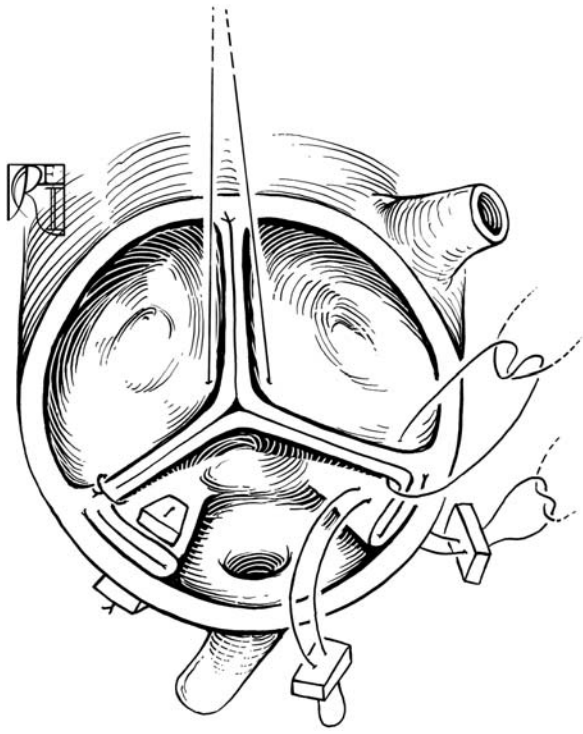

Figure 6.
The redundant, prolapsing coronary arterial leaflet has been plicated at the zones of attachment at the sinutubular junction with pledget-supported sutures. Stay sutures have been placed through the nodules of Arantius to demonstrate the correct apposition point of the valve. (From Mavroudis C, Backer CL, Jacobs JP. Ventricular septal defect. In: Mavroudis C, Backer CL (eds). Pediatric Cardiac Surgery, 2nd edn. St. Louis, Mosby, 2003, pp 298–320. Reproduced with permission.)

the mean amount of insufficiency, as graded echocardiographically, from 3.4 to 0.6. There was one death and one reoperation.

A time-honoured standard surgical procedure for repair of the bifoliate aortic valve is so-called "commissurotomy". This is typically performed with a number 11 blade, incising the fused ends of the zones of apposition between the leaflets, without dividing the raphe between the right and the left coronary leaflets, this usually being the site of fusion. Division of this raphe can lead to flail leaflets and valvar insufficiency. Use of this technique should not be forgotten in this era of balloon dilation.[6]

The group of patients with an associated ventricular septal defect leading to prolapse of a leaflet through the defect, with subsequent valvar insufficiency, may be treated using the operation first described by Trusler et al.[7] Walters et al.,[8] at the Children's Hospital of Michigan, have reported their results using this technique in 24 patients. Two-thirds of their patients had perimembranous defects, with the defect being doubly committed and subarterial in the remainder. It was the right coronary leaflet that prolapsed in half of their patients, and the non-coronary leaflet in one-quarter. Following this procedure (Figs 5 and 6), the Michigan group reports a mean follow-up of 7 years, with postoperative valvar insufficiency deemed to be trivial in 11, mild in nine, moderate in one, and severe in three. Table 3 summarizes the results for repair of the aortic valve in several institutions.

Repair of the common truncal valve

The repair of the insufficient arterial valve in patients with common arterial trunk offers some opportunities not available for the bifoliate or trifoliate aortic valve. The reported techniques can be summarized as approximation, resection, or extension of the leaflets, remodeling of the valvar support, and

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Table 3. Results of repairing the aortic valve.

Institution	Year	Patients	Success
Cleveland Clinic Foundation, Cleveland[5]	1991	28	26
University Cantonal Hospital-Geneva, Switzerland[2]	1999	41	40
Children's Hospital of Michigan, Detroit[8]	1999	24	21
Royal Children's Hospital, Melbourne[3]	2004	14	13
University of California, Los Angeles[4]	2004	51	46
		158	146 (92%)

external annuloplasty. The magnitude of the problem of truncal valvar insufficiency is illustrated by the series of patients reported from the University of California at San Francisco.[9] They analysed 89 patients with truncal valvar insufficiency undergoing surgery between 1975 and 1995. The insufficiency was judged to be mild in 37, moderate in 33, and severe in 19. Of note, eight of these patients died prior to surgical intervention. The pulmonary arteries had been banded in 4 patients, and all died. The valve was replaced in 10 patients, with 7 of these dying. In the five patients undergoing valvar repair, however, there were no deaths. The estimated actuarial survival at 1 year of patients with severe truncal valvar insufficiency was 32 percent. This series highlights this significant problem in patients with a common arterial trunk.

Since 1995, we have performed surgery on 8 patients with severe truncal valvar insufficiency at Children's Memorial Hospital in Chicago.[10] In 3 of these, who were infants, we repaired the valve at the same time that we repaired the common trunk, at an average age of 4.5 days. In another 5 children, we repaired the valve when changing the conduit, at an average age of 10 years. One technique we have used is the approximation technique, based on the fact that many patients will have a quadrifoliate valve. The valve can be converted to a trifoliate or bifoliate structure by approximating one or two of the leaflets (Fig. 7). The other technique that we have found most successful is to resect the leaflets while remodeling the attachments of their semilunar hingepoints (Figs 8 and 9).

Of our three neonatal patients, the first patient required placement of a 13 millimetre homograft aortic valve after failed approximation of the leaflets, and survived subsequent to extracorporeal membrane oxygenation. A second operation, using a homograft to replace the insufficient valve, was required at 4 months of age, and a third operation, re-replacing

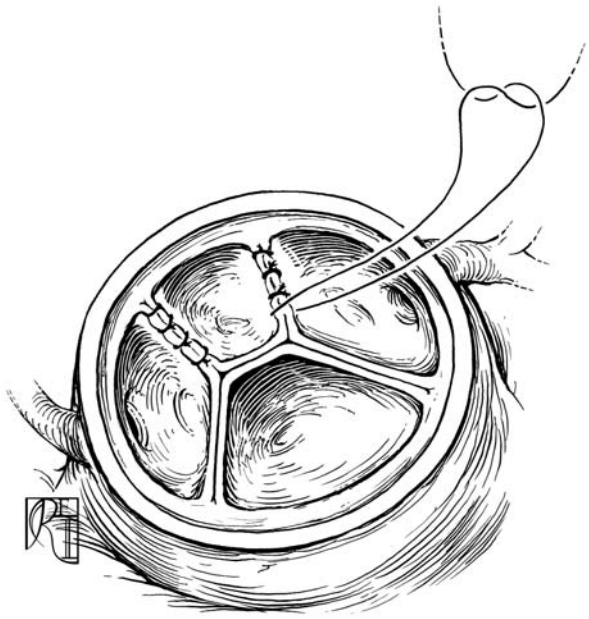

Figure 7.
Approximation of the leaflets for correction of truncal valvar insufficiency. A small posterior noncoronary leaflet is approximated to the right and left coronary arterial leaflets, effectively converting this valve into one with two leaflets. The prolapsing small valve is then provided with annular support, thus reducing its insufficiency. (From Mavroudis C, Backer CL. Surgical management of severe truncal insufficiency: experience with truncal valve remodeling techniques. Ann Thorac Surg 2001; 72: 396–400. Reproduced with permission.)

the homograft because of insufficiency and stenosis, was needed at 4.5 years of age.

In the second patient, we approximated the valvar leaflets, but postoperatively extracorporeal membrane oxygenation was needed, and the patient died. In the third patient, we resected part of the leaflets, remodeled their circumferential support, and reimplanted the coronary arteries, with an excellent result. In the other five patients, we repaired the truncal valve at the time of changing the conduit. In two of these patients, the truncal valve had four leaflets, with three leaflets present in two patients, and a bifoliate valve if the final patient. In the first patient, we were able successfully to resuspend the attachments of the zones of apposition between the leaflets at the sinutubular junction. We also attempted resuspension in the second patient, along with reducing the orificial diameter, but eventually we had to replace the valve with an aortic homograft of 22 millimetre diameter. In the third patient, we excised part of the leaflets and reduced the dimensions of their hingepoints, with a good result. We attempted valvoplasty combined with remodeling of the support of the leaflets in the patient, but without success, and we needed to replacement the valve with a porcine aortic valvar prosthesis. In the fifth patient,

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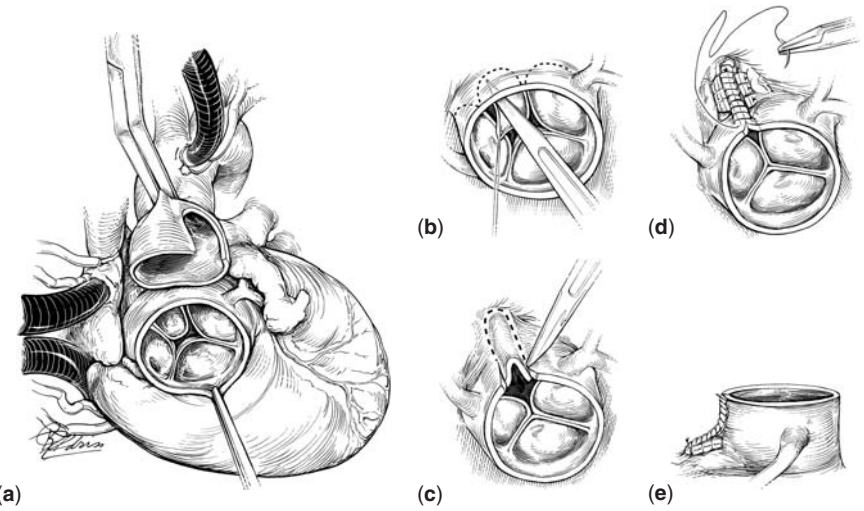

Figure 8.
*(**a**) A patient with common arterial trunk, on cardiopulmonary bypass, after aortic cross-clamp has been applied and cold blood cardioplegia delivered. The aorta has been transected and the origin of the pulmonary trunk from the aortic root excised. This patient has a quadrifoliate truncal valve. (**b**) Resection of the smaller of the four leaflets. (**c**) Resection of the truncal wall adjacent to that leaflet. (**d**) Remodelling of the annular support with pledget-based sutures to reduce the diameter of the outflow tract. The truncal wall is closed with running polypropylene suture in two layers. (**e**) The completed truncal root, now the aortic root, prior to anastomosis to the ascending aorta. (From Mavroudis C, Backer CL. Surgical management of severe truncal insufficiency: experience with truncal valve remodeling techniques. Ann Thorac Surg 2001; 72: 396–400. Reproduced with permission.)*

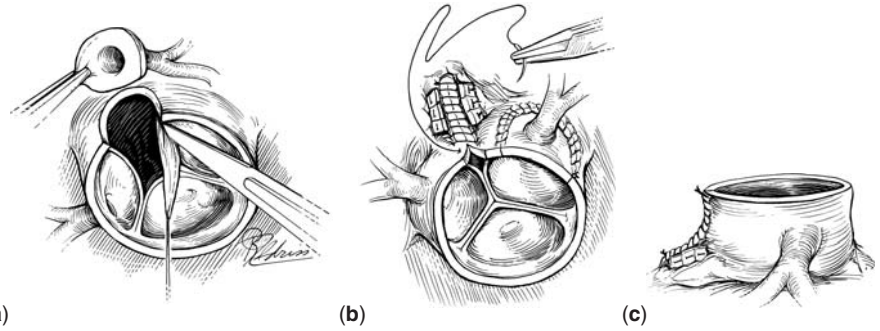

Figure 9.
*The same procedure performed in a patient in whom the prolapsing small leaflet arises from a truncal sinus that gives rise to a coronary artery. (**a**) A coronary arterial button has been excised, and the leaflet is being excised with a number 11 blade. (**b**) The coronary arterial button has been reimplanted into the adjacent sinus of the truncal root. The annular support of the leaflets has been remodeled with pledget-supported sutures, and the truncal wall is being closed. (**c**) The completed result. (From Mavroudis C, Backer CL. Surgical management of severe truncal insufficiency: experience with truncal valve remodeling techniques. Ann Thorac Surg 2001; 72: 396–400. Reproduced with permission.)*

excision of leaflets, reduction in annular support, and reimplantation of the main stem of the left coronary artery produced an excellent result. In summary, from this group we lost one patient, giving mortality of 12.5 percent, while two patients required extracorporeal membrane oxygenation. The attempted repair was successful in four patients, achieved in three by means of resection of leaflets and reduction in the dimensions of the annular support.

The overall results of attempted repair of the truncal valve at six different institutions are illustrated in Table 4.[9–14] In 29 patients in whom attempts had been made to repair the valve, this was successful in 23, an overall success of 80 percent.

Conclusions

Repair of the truncal valve can be successfully accomplished in both infancy and childhood. Truncal valves with four leaflets offer the best substrate for successful repair. When possible, we advocate excision of the leaflets with remodeling of the annular support. Coronary arterial impediments can be treated by reimplantation. For patients who require repair of

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Table 4. Results of repairing the truncal valve.

Institution	Year	Patients	Success
University of California, Los Angeles[11]	1994	5	4
University of California, San Francisco[9]	1998	5	5
The Hospital for Sick Children, Toronto[12]	1998	3	2
Cleveland Clinic Foundation, Cleveland[13]	1999	4	3
Children's Hospital, Boston[14]	2000	5	5
Children's Memorial Hospital, Chicago[10]	2001	7	4
		29	23 (80%)

the aortic valve, excellent results can be obtained using a variety of innovative techniques, for those with both insufficiency and stenosis. Extension of the leaflets with pericardial strips, conversion of bifoliate to trifoliate valves, and the Trusler valvoplasty for prolapsed leaflets, are all procedures that have excellent results in the immediate term.

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