Aortic valve-sparing surgery for aortic root aneurysm

Giuseppe Di Eusanio, Andrea Quarti, Marco Di Eusanio, Michele Danilo Pierri, Carlo Zingaro, Mauro Borioni, Carlo Sorbara, Gian Piero Piccoli

Department of Cardiac Surgery, G.M. Lancisi Hospital, Ancona, Italy

Key words:
Aortic aneurysm; Aortic valve.

Background. **Replacement of the aortic valve and ascending aorta with a composite graft is the most common surgical treatment for aortic root aneurysms with or without aortic regurgitation (AR). In the early 90's reconstructive procedures of the aortic root have been described with encouraging results. This paper presents our experience with this technique.**

Methods. **Between January 2001 and May 2003, 28 patients (25 males, 3 females, mean age 60 years) with aortic root aneurysm were treated with reimplantation of the aortic valve. Twenty-two patients had AR > 2+, 5 had Marfan syndrome, 5 had an aortic arch aneurysm, 4 had type A aortic dissection, 2 patients had associated coronary artery disease, and one had mitral valve insufficiency. The only contraindication was primitive disease of the aortic leaflets.**

Results. **There was one perioperative death (type A aortic dissection) and 1 patient was discharged with mild to moderate AR requiring aortic valve replacement. The cardiopulmonary bypass and aortic cross-clamping times were 230 and 184 min respectively. No neurological events were recorded. During follow-up (mean 16.7 months, range 3-32 months) 1 patient died and one had mild AR. Freedom from reoperation and from AR at 24 months was 94 and 89% respectively. At multivariate analyses we did not find any correlation between Marfan syndrome, type A aortic dissection, grade of preoperative AR, and recurrence of AR.**

Conclusions. **In our experience, valve-sparing surgery was feasible with a low mortality and morbidity and with good early results. It should be applied to all patients requiring aortic root surgery for aortic root aneurysm, a diseased aortic valve being the only contraindication.**

(Ital Heart J 2004; 5 (4): 265-270)

Received October 9, 2003; revision received February 16, 2004; accepted February 25, 2004.

Address:

Dr. Giuseppe Di Eusanio

Dipartimento di Cardiochirurgia Azienda Ospedaliera G.M. Lancisi Via Conca, 71 60020 Torrette di Ancona E-mail: gdieusanio@libero.it

Introduction

Aortic root aneurysm may be associated with aortic insufficiency depending on the involvement of the whole aortic closure complex. The standard operation is composite replacement of the aortic valve and ascending aorta[1], but despite a low mortality, the mechanical prosthesis in the aortic position is associated with thromboembolic events, bleeding and the presence of a gradient across the valve[2].

Recently, two reconstructive procedures have been developed[3,4] with the aim of sparing the valve and replacing the diseased aorta. The early and mid-term results are really encouraging and the surgeon has to apply as much basic science principles as possible to achieve a good outcome.

In this paper we present the results of a series of 28 consecutive patients treated at our institution with reimplantation of the valve as described by David and Feindel[4].

Methods

Population. From January 2001 to May 2003, aortic valve-sparing surgery was performed in 28 patients (25 males, 3 females, mean age 60.6 ± 13.97 years).

The selection of patients was based on the presence of aortic root aneurysm and on the pathophysiology of the valve. Only patients with normal cusps were treated with the reimplantation technique. Neither the annulus size nor the grade of aortic regurgitation (AR) was considered as a contraindication.

All patients underwent a complete invasive and noninvasive cardiac evaluation including heart catheterization, computed tomographic scan or magnetic resonance and echocardiographic examination, focusing on the level of the aneurysm and valve function (leaflet primitive disease, degree of regurgitation). The surgical indication was based on the ratio between the observed aortic diameter and the expected one, as described by others[5,6], tailoring the indication on the type of aortic pathology (e.g. type A aortic dissection, Marfan syndrome). The clinical profile of the patients is summarized in table I and the anatomical profile in figure 1.

Surgical technique. Cardiopulmonary bypass was established by cannulating the right atrium and the aorta above the aneurysm except in patients with type A aortic dissection and aortic arch aneurysm, who had femoral artery and right atrial cannulation. The systemic temperature (as measured at the nasopharynx) was lowered to 28°C or to 22-25°C in patients undergoing aortic arch replacement with antegrade selective cerebral perfusion[7].

Intermittent antegrade isothermic blood cardioplegic solution consisting of 16 mEq of KCl and 3.25 g of MgCl with a total volume of 20 ml diluted in 1 liter of blood, in accordance with our protocol was used for myocardial protection.

The left ventricle was vented through a cannula inserted in the right superior pulmonary vein. The proximal aorta was dissected just to the level of the aortic annulus. The three sinuses of Valsalva were excised and the coronary ostia were prepared with a small button around them (Fig. 2).

Multiple interrupted sutures of 4-0 polyester were passed from the inside to the outside the left ventricle at the level of the aortic annulus.

In patients with a normal annulus diameter, the size of the tubular graft was taken using a Freestyle Medtronic sizer to measure the annulus and choosing a tube two sizes greater than the sizer used. On the other hand, the rules described by David and Feindel[4] were followed in patients with a dilated annulus.

The sizes of the Dacron tubular grafts used were 32 mm in 2 patients, 30 mm in 6 patients, 28 mm in 16 patients, 26 mm in 3 patients, and 24 mm in 1 patient.

The tubular Dacron graft was attached to the annulus by means of the sutures and the commissures of the

Table I. Preoperative characteristics.

Age (years)	60.6 ± 13.97
Sex (M/F)	25 (89%)/3 (11%)
NYHA functional class	
I	9 (32.2%)
II	9 (32.2%)
III	9 (32.2%)
IV	1 (3.4%)
Typa A aortic dissection	4 (14%)
Acute	3
Chronic	1
Aortic valve regurgitation	
1+	1 (3.5%)
2+	5 (18%)
3+	4 (14%)
4+	18 (64.5%)
Marfan syndrome	5 (18%)
Aortic arch aneurysm	5 (18%)
Coronary artery disease	2 (7%)
Mitral valve regurgitation	1 (3.5%)

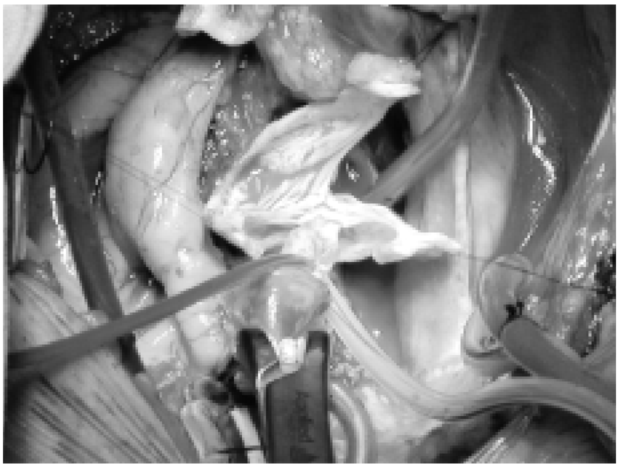

Figure 2. *Dissection of the aortic root and harvesting of the coronary arteries.*

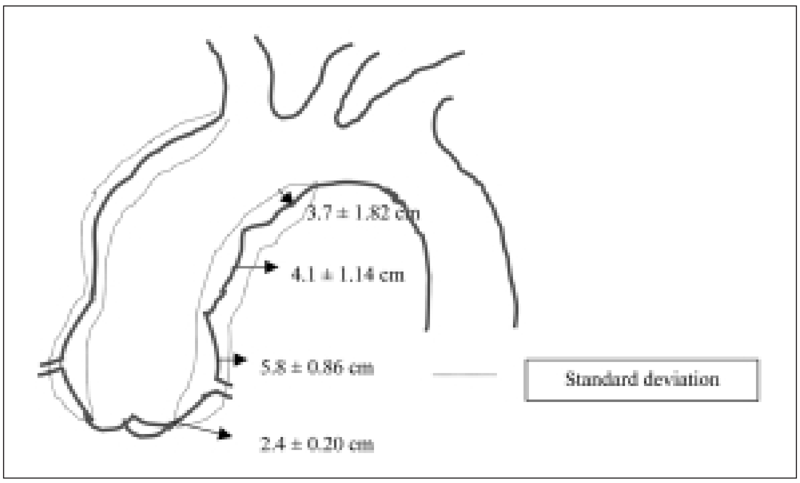

Figure 1. *Anatomical findings in the study population.*

valve were attached with the proper orientation inside the tubular graft using a polypropylene 5-0 suture. Then, the remnant of the arterial wall was secured to the tubular graft with a continuous 5-0 polypropylene suture (Fig. 3). The coronary arteries were reimplanted with a continuous 6-0 polypropylene suture.

Patients with aortic arch involvement had hemiarch replacement in circulatory arrest and cerebral protection with selective cerebral perfusion and then aortic root and ascending aorta replacement during rewarming.

Having released the aortic clamp, the function of the valve was intraoperatively assessed by transesophageal echocardiographic examination (Fig. 4).

Statistical analysis. Continuous variables were expressed as mean ± SD, and categorical variables as percentages. All preoperative and intraoperative variables were first analyzed using univariate analysis (unpaired two tailed Student's t-test, χ^2 test, Fisher's exact test as appropriate) to determine whether any single factor influenced the hospital mortality and neurologic outcome. A p value < 0.05 was considered as statistically significant. Variables that achieved a p value < 0.05 at univariate analysis were examined using multivariate analysis by forward stepwise logistic regression to evaluate the independent risk factors for hospital mortality and by Cox multivariate analysis for late mortality. Event-free data were analyzed with Kaplan-Meyer actuarial techniques for the estimation of survival probabilities.

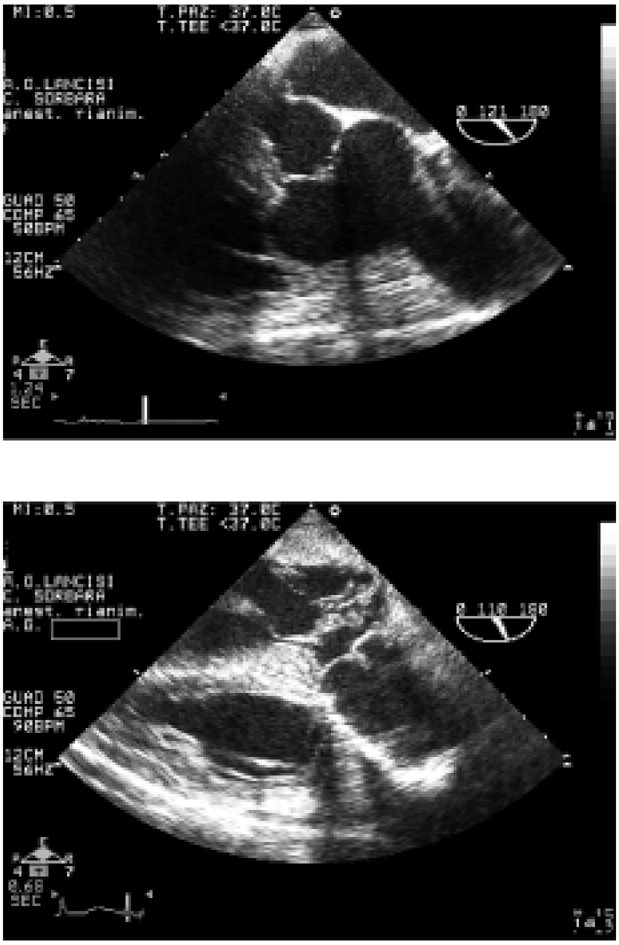

Figure 4. *Comparative echocardiographic view of the aortic root before* (upper panel) *and after surgery* (lower panel).

Results

Perioperative results. There was one operative death (3.5%). The patient presented at our institution for an acute type A aortic dissection involving the coronary ostia and was in cardiogenic shock. He finally died of multiorgan failure. One patient had mild AR at the intraoperative echocardiographic evaluation and a mild to moderate AR at discharge.

There were no cases of heart block, and no cases of neurological events.

The average aortic cross-clamping time was 184.9 ± 17.91 min (range 152-223 min), the average cardiopulmonary bypass time 230.4 ± 74.60 min (range 171-483 min), and the average selective cerebral perfusion time 28.4 ± 6.50 min (range 18-35 min).

The postoperative data are summarized in table II.

Figure 3. *Aortic valve reimplantation into the tubular graft.*

Table II. Postoperative results.

Death	1 (3.5%)
Complications	
Bleeding	2 (7%)
PND (coma, stroke)	0
TND	0
Need for PM implantation	0
Multiorgan failure	1 (3.5%)
Myocardial ischemia	0

PM = pacemaker; PND = permanent neurologic dysfunction; TND = transient neurologic dysfunction.

Follow-up and late results. Follow-up was 100% complete and all patients were submitted to echocardiographic study during the last follow-up visit (mean 16.7 ± 9.50 months, range 3-32 months).

There was no late death. One patient had recurrence of AR (moderate) and is currently followed by our cardiologists while the patient discharged with mild-moderate AR was reoperated upon for aortic valve replacement. The freedom from reoperation at 24 months was 94% and the freedom from AR 89% (Fig. 5).

At multivariate analysis, no correlation between mortality or the recurrence of AR and Marfan syndrome, type A aortic dissection, preoperative grade of AR and cardiopulmonary bypass and aortic cross-clamping times was found.

All patients but one were in NYHA functional class I with only mild AR. None of the patients presented with any neurological complication or rhythm disturbances after discharge.

Discussion

The aim of surgery for aortic root aneurysms is to avoid aortic dissection or rupture and to repair the aortic valve if regurgitation is present.

Ascending aorta and aortic root aneurysms are a common finding in the population and may be caused by inflammatory aortitis (syphilis, ankylosing spondylitis, rheumatoid arthritis, psoriasis, Reiter's syndrome, Takayasu's syndrome) or may be due to cystic medial necrosis characterized by degeneration of the elastic elements of the media and cystic vacuoles containing mucopolysaccharides. An inheritance pattern that commonly appears to be autosomal dominant with incomplete penetrance has also been described[8].

The growth rate of ascending thoracic aorta aneurysms is 0.07 cm per year[8] but the larger the aorta the faster the growth.

Critical to decision making in surgery is the balance between the surgical risk and complications related to natural history of the aneurysm (rupture, dissection). If the current mortality risk for elective and urgent surgery of the ascending aorta is about 2-3% and 10-25% respectively[7-9], the risk of rupture and dissection in patients with aortic diameters of 6.0 cm is about 31%[8]. Moreover, it has been suggested that the yearly risk of complications in patients with an aortic size > 5 cm is 6.5% and 14.1% if > 6.0 cm[8]. As suggested by Ergin et al.[5], the inherent weakness of the aortic wall, which may be present in patients with Marfan syndrome, a bicuspid aortic valve and chronic dissection, may prompt an earlier indication. Furthermore, the probability of a satisfactory valve repair declines progressively as the size of the aortic root increases. So it is reasonable to expect a better and more durable repair if only moderate dilation and modest insufficiency are present[5]. These considerations bring to mind that in the current surgical era, patients with aortic root aneurysms should undergo elective surgical repair without delaying definitive treatment to an aortic size of 6.0 cm. More tailored guidelines for surgical timing relate the expected diameter to the observed one. The ratio obtained, different for Marfan syndrome, bicuspid aorta and chronic dissection, forms the basis of the surgical indication[5].

Aortic root aneurysms are nowadays the most common cause of isolated aortic valve insufficiency in North America[10]. Furukawa et al.[11] demonstrated that dilation of the root causes AR if associated with dilation of the sinotubular junction. In the latter case, the outward deviation of the commissures causes a lack of coaptation in the central part of the aortic valve. In case of aortic aneurysm not involving the sinotubular junction, the valve may be competent.

The sinotubular junction is an anatomic ridge found at the level of the commissures and forming the upper border of the sinuses. The sinotubular junction diameter is 15 to 20% smaller than the annulus diameter[3,12], which is 3% less than that of the sinuses[13]. In the fresh aortic root, the diameter of the sinotubular junction is approximately 30% larger than the average length of the free margins of the aortic cusps.

The mechanism of aperture and closure of the valve involves the whole aortic complex consisting of the an-

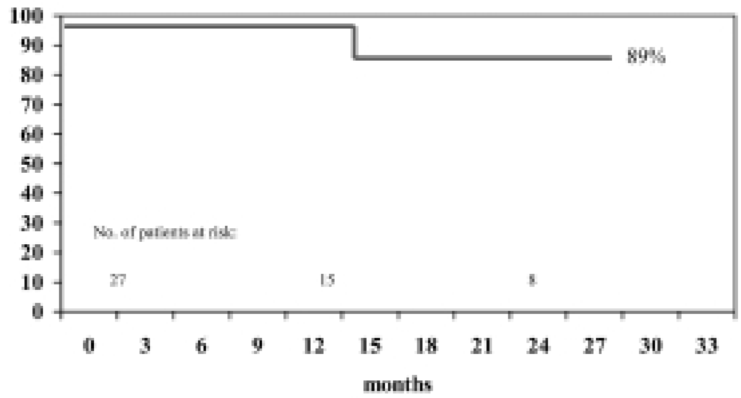

Figure 5. *Freedom from aortic regurgitation.*

nulus, leaflets, interleaflet tissues, commissures, sinuses of Valsalva and the ascending aorta. Therefore, despite normal leaflets, AR may still be caused by a complex abnormality.

The most common surgical treatment for aortic root aneurysms is composite replacement of the diseased aorta and of the aortic valve as described by Bentall and DeBono[1] and good results in terms of early mortality and morbidity have been reported. However, the lifelong need of anticoagulation is associated with thromboembolic and hemorrhagic complications that are thought to be responsible for 75% of valve-related complications with mechanical aortic valve prostheses with an annual incidence of 2-4% reported in the literature[2].

In the early 90's David and Feindel[4] described a valve-sparing operation for patients with aortic root aneurysm and AR. The technique consists of reimplantation of the native valve inside a tubular graft fixed to the left ventricle. The results were immediately encouraging and valve-sparing operations have also been extended to patients with Marfan syndrome and acute type A aortic dissection.

In our institution, we started performing valve-sparing surgery in patients with aortic root aneurysms with or without aortic insufficiency and normal aortic leaflets in 2001.

In this initial series of 28 patients, we had one hospital death (3.5%). The patient presented at our institution in cardiogenic shock for acute type A aortic dissection involving both the coronary ostia. He died of multiorgan failure with a competent repaired aortic valve. Our early results compare favorably with those reported in the literature[14-16].

Following the data of David and others[17,18], showing excellent results in terms of early mortality, freedom from reoperation, freedom from AR > 2+ and from the risks of thromboembolism, we have also extended the indication for valve-sparing surgery to patients with Marfan syndrome and acute type A aortic dissection with similar results.

Although valve-sparing surgery requires a prolonged period of cardioplegic arrest, as we gained more experience, we combined the valve-sparing operation with other surgical procedures such as mitral valve repair, myocardial revascularization, aortic arch replacement and redo operation with an early survival of 96.5%. Indeed, in the approach to these patients, optimal methods of myocardial and brain protection are crucial.

Our mid-term results were encouraging too. In fact, at 16.7 months (range 3-32 months), the late survival was 100%, and at 24 months the freedom from reoperation and that from AR were 94 and 89% respectively.

In detail, one patient had a suboptimal correction of the aortic valve. He presented at our institution with type A aortic dissection and intraoperative echocardiography showed mild AR due to residual prolapse of a cusp. At discharge, moderate-severe AR was present and the patient was reoperated upon for aortic valve replacement. A second patient, who was discharged with no AR, lately developed mild AR. He is currently followed by our cardiologists and is being submitted to 6-monthly echocardiographic examination. Both patients were operated upon at the beginning of our experience.

The long-term results we have reported in this preliminary experience are similar to those reported by other authors. David et al.[14], at 5 years, reported a survival rate of 94%, a freedom from reoperation of 99% and a freedom from AR of 90%. At 8 years, the survival was 83%, the freedom from reoperation 99%, and the freedom from AR > 2+ was 90%[15].

At multivariate evaluation the risk factor found to be correlated with early valve failure was the type of coaptation. Following repair, cusp coaptation > 2 mm below the lower rim of the tubular prosthesis constitutes the strongest risk factor for the development of AR[19].

Interestingly, progressive AR after surgery may be due to structural degeneration of the valve consequent to a suboptimal geometry of coaptation, but no subgroups (e.g. Marfan patients, type A dissection) are at higher risk for early valve failure[19].

Actually[17], this technique when applied to Marfan patients, has been associated with good results (96% freedom from AR > 2+ at 8 years) underlying that in this subgroup of patients stabilization of the annulus favors a long durability of the repair.

The graft size selection still remains difficult and many technique of sizing have been proposed in the last years.

In our institution, in patients with a dilated annulus (the minority) the choice of the graft was based on the height of the cusps and on the length of the free margin of the leaflets being the leaflet a sure marker of a normal anatomy in these patients as suggested by David and Feindel[4]. In patients with a normal annulus, the problem of the size was solved by using a Freestyle Medtronic valve sizer to measure the annulus of the valve and by choosing a Dacron tubular graft two sizes greater in order to avoid stretching of the commissures and to simulate the aortic wall thickness.

In order to avoid late annular dilation and the recurrence of AR, we never used the remodeling technique described by Sarsam and Yacoub[3] giving precedence to the stabilization of the annulus. This may explain the good results we had with this subgroup of patients who are prone to annular dilation even though they present at the time of surgery without AR and with a normal annulus diameter. Furthermore, during type A aortic dissection repair a lower risk of bleeding than that observed in case of aortic remodeling may be expected when the reimplantation technique is employed.

The possibility of leaflet abrasion and of closure abnormalities of the valve related to the absence of the sinuses of Valsalva has been hypothesized. Bellhouse[20,21] noted, on a fluid dynamic model, the formation of fluid flow eddies between the leaflet and the sinuses which prevent the aortic leaflet from impacting on the aortic wall and promoting valve closure. Recently, new aortic grafts with prefabricated sinuses of Valsalva have been introduced[22], but a longer follow-up and prospective randomized comparative studies are necessary to determine the superiority of this prosthesis in terms of freedom from AR and from reoperation.

The present study refers to a preliminary experience with valve-sparing surgery and carries the burden of the limitations inherent to its retrospective nature. However some conclusions could be reached.

The early and mid-term results were encouraging, even when this complex aortic procedure was performed in high-risk patients such as those with acute type A aortic dissection and/or undergoing associated procedures.

With regard to mitral valve surgery, we believe that the avoidance of mechanical valve prosthesis even in the aortic position is crucial to reduce valve-related morbidity such as thromboembolism or excessive bleeding.

The results reported by other authors and in our institution should encourage us to try to repeat the same progress that cardiac surgery had in the last 25 years in mitral valve repair even in aortic root complex procedures, in an attempt to achieve in the future the same results in terms of durability and quality of life.

References

1. Bentall H, DeBono A. A technique for complete replacement of the ascending aorta. Thorax 1968; 23: 338-9.
2. Edmunds H. Thrombotic and bleeding complications of prosthetic heart valves. Ann Thorac Surg 1987; 44: 430-45.
3. Sarsam MA, Yacoub M. Remodeling of the aortic valve annulus. J Thorac Cardiovasc Surg 1993; 105: 435-8.
4. David TE, Feindel CM. An aortic valve-sparing operation for patients with aortic incompetence and aneurysm of the ascending aorta. J Thorac Cardiovasc Surg 1992; 103: 617-22.
5. Ergin MA, Spielvogel D, Apaydin A, et al. Surgical treatment of the dilated ascending aorta: when and how? Ann Thorac Surg 1999; 67: 1834-9.
6. Roman MJ, Devereux RB, Kramer-Fox R, O'Loughlin J. Two-dimensional echocardiographic aortic root dimensions in normal children and adults. Am J Cardiol 1989; 64: 507-12.
7. Di Eusanio M, Schepens MA, Morshuis WJ, Di Bartolomeo R, Pierangeli A, Dossche KM. Antegrade selective cerebral perfusion during operations on the thoracic aorta: factors influencing survival and neurologic outcome in 413 patients. J Thorac Cardiovasc Surg 2002; 124: 1080-6.
8. Elefteriades JA. Natural history of thoracic aortic aneurysms: indications for surgery, and surgical versus nonsurgical risks. Ann Thorac Surg 2002; 74: S1877-S1880.
9. Di Eusanio M, Tan ME, Schepens MA, et al. Surgery for acute type A dissection using antegrade selective cerebral perfusion: experience in 122 patients. Ann Thorac Surg 2003; 74: 514-9.
10. Olson LJ, Subramanian R, Edwards WD. Surgical pathology of pure aortic insufficiency: a study of 225 cases. Mayo Clin Proc 1984; 59: 835-41.
11. Furukawa K, Ohteki H, Cao Z, et al. Does dilatation of the sinotubular junction cause aortic regurgitation? Ann Thorac Surg 1999; 68: 949-54.
12. Reid K. The anatomy of the sinus of Valsalva. Thorax 1970; 25: 79-85.
13. Kunzelman KS, Grande KJ, David TE, Cochran RP, Verrier ED. Aortic root and valve relationships: impact on surgical repair. J Thorac Cardiovasc Surg 1994; 107: 162-70.
14. David TE, Armstrong S, Ivanov J, Feindel CM, Omran A, Webb G. Results of aortic valve-sparing operations. J Thorac Cardiovasc Surg 2001; 122: 39-46.
15. David TE, Ivanov J, Armstrong S, Feindel CM, Webb GD. Aortic valve-sparing operations in patients with aneurysms of the aortic root or ascending aorta. Ann Thorac Surg 2002; 74: S1758-S1761.
16. Kallenbach K, Pethig K, Schwarz M, Milz A, Haverich A, Harringer W. Valve sparing aortic root reconstruction versus composite replacement - perioperative course and early complications. Eur J Cardiothorac Surg 2001; 20: 77-81.
17. de Oliveira NC, David TE, Ivanov J, et al. Results of surgery for aortic root aneurysm in patients with Marfan syndrome. J Thorac Cardiovasc Surg 2003; 125: 789-96.
18. Erasmi AW, Stierle U, Bechtel JF, Schmidtke C, Sievers HH, Kraatz EG. Up to 7 years' experience with valve-sparing aortic root remodeling/reimplantation for acute type A dissection. Ann Thorac Surg 2003; 76: 99-104.
19. Pethig K, Milz A, Hagl C, Harringer W, Haverich A. Aortic valve reimplantation in ascending aortic aneurysm: risk factors for early valve failure. Ann Thorac Surg 2002; 73: 29-33.
20. Bellhouse BJ. Velocity and pressure distributions in the aortic valve. J Fluid Mech 1969; 37 (Part 3): 587-600.
21. Bellhouse BJ. The fluid mechanics of the aortic valve. In: Ionescu ML, Ross DN, Woller GH, eds. Biological tissue in heart valve replacement. London: Butterworth-Heinemann, 1972: 23-47.
22. De Paulis R, De Matteis GM, Nardi P, et al. One-year appraisal of a new aortic root conduit with sinuses of Valsalva. J Thorac Cardiovasc Surg 2002; 123: 33-9.