Aortic root replacement after previous surgical intervention on the aortic valve, aortic root, or ascending aorta

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Background: Aortic root replacement after a previous operation on the aortic valve, aortic root, or ascending aorta remains a major challenge.

Methods: Records of 56 consecutive patients (44 men; mean age, 56.4 ± 13.6 years) undergoing reoperative aortic root replacement between June 1994 and June 2005 were reviewed retrospectively.

Results: Reoperation was performed 9.4 ± 6.7 years after the last cardiac operation. Indications for reoperation were true aneurysm ($n = 14$ [25%]), false aneurysm ($n = 10$ [18%]), dissection or redissection ($n = 9$ [16%]), structural or nonstructural valve dysfunction ($n = 10$ [18%]), prosthetic valve-graft infection ($n = 12$ [21%]), and miscellaneous ($n = 1$ [2%]). Procedures performed were aortic root replacement ($n = 47$ [84%]), aortic root replacement plus mitral valve procedure ($n = 5$ [9%]), and aortic root replacement plus arch replacement ($n = 4$ [7%]). In 14 (25%) patients coronary artery bypass grafting had to be performed unexpectedly during the same procedure or immediately after the procedure to re-establish coronary perfusion. Hospital mortality reached 17.9% ($n = 10$). Multivariate logistic regression analysis revealed the need for unplanned perioperative coronary artery bypass grafting as the sole independent risk factor for hospital death ($P = .005$). Actuarial survival was $83.8\% \pm 4.9\%$ at 1 month, $73.0\% \pm 6.3\%$ at 1 year, and $65.7\% \pm 9.0\%$ at 5 years after the operation. One patient had recurrence of endocarditis 6.7 months after the operation and required repeated homograft aortic root replacement.

Conclusion: Reoperative aortic root replacement remains associated with a high postoperative mortality. The need to perform unplanned coronary artery bypass grafting during reoperative aortic root replacement is a major risk factor for hospital death. The optimal technique for coronary reconstruction in this setting remains to be debated.

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In 1968, Bentall and De Bono described a technique for total aortic root replacement (ARR) using a composite tubular graft containing a prosthetic valve. In their original technique coronary reimplantation was performed without ostia mobilization by means of direct side-to-end anastomosis. Although this technique reduced the risk of recurrent proximal aortic aneurysms, it exposed the patient to serious bleeding complications and the development of pseudoaneurysms at the level of the reimplanted coronary ostia. During the last 3 decades, several technical improvements, the development of new aortic root substitutes, and the use of biologic adjuncts, such as surgical glues and hemostatic drugs, have rendered total ARR a safe and reproducible procedure.¹ Although this procedure yields excellent results when performed as a primary procedure,² it remains a major challenge when performed after previous cardiac surgery, aortic surgery, or both. Indeed, reoperative ARR combines the odds of sternal re-entry with those of coronary artery ostia mobilization and reimplantation.

Abbreviations and Acronyms

ARR	= aortic root replacement
CABG	= coronary artery bypass grafting
CPB	= cardiopulmonary bypass
ICU	= intensive care unit

The purpose of the present study was to analyze our experience with ARR after previous surgical intervention on the aortic valve, aortic root, or ascending aorta during the last 12 years.

Patients and Methods**Patient Selection**

Between June 1, 1994, and June 1, 2005, 273 consecutive patients underwent ARR with the modified button technique at Henri Mondor University Hospital, Créteil, France. Among these, 56 (21%) patients had at least 1 previous aortic operation, which was defined as any procedure involving the aortic valve, aortic root, and/or tubular ascending aorta. Patients who underwent ARR after a cardiac operation that did not directly involve one of these structures were excluded from analysis. Eighteen (32%) patients were operated on during the first half of the study period (1994-1999), and 38 (68%) patients have been operated on since 2000.

TABLE 1. Patient-, cardiac-, and operation-related factors relevant to the EuroSCORE

Variable	No. of patients (%)
Patient-related factors	
Mean age (range)	56.4 ± 13.6 (26-82)
Sex, M/F	44/12 (78.6/21.4)
Chronic pulmonary disease	1 (1.8)
Extracardiac arteriopathy	1 (1.8)
Neurologic dysfunction	3 (5.4)
Preoperative renal failure	1 (1.8)
Active endocarditis	10 (17.9)
Critical preoperative state	4 (7.1)
Cardiac-related factors	
Unstable angina	1 (1.8)
LV dysfunction	
Moderate (EF 30%-50%)	9 (16.1)
Poor (EF <30%)	3 (5.4)
Recent MI (<90 d)	1 (1.8)
Pulmonary hypertension (SPAP >60 mm Hg)	3 (5.4)
Operation-related factors	
Emergency	9 (16.1)
EuroSCORE	
Mean (range)	10.9 ± 2.9 (8-19)
EuroSCORE ≥8 and ≤10	31 (55.4)
EuroSCORE >10	25 (44.6)

LV, Left ventricular; MI, myocardial infarction; EF, ejection fraction; SPAP, systolic pulmonary artery pressure.

TABLE 2. Most recent procedure performed on the aortic valve, aortic root, and/or tubular ascending aorta

Procedure	n (%)
AV repair	2 (3.6)
Aortic root remodeling (Yacoub)	1 (1.8)
AV replacement	
Isolated	35 (62.5)
+ Supracoronary aortic procedure	4 (7.1)
Supracoronary aortic replacement	
Isolated	3 (5.4)
+ Arch replacement	5 (8.9)
Aortic root replacement (Bentall procedure)	6 (10.7)
Total	56 (100)

AV, Aortic valve.

The mean patient age was 56.4 ± 13.6 years (range, 26-82 years). There were 44 (78.6%) male and 12 (21.4%) female patients. Other patient-, cardiac-, and operation-related factors relevant to the EuroSCORE³ are listed in Table 1.

Prior Operations Performed on the Ascending Aorta

The most recent procedure performed on the aortic valve, aortic root, or ascending aorta are listed in Table 2. Prior cardiac procedures performed on structures other than the aortic valve, aortic root, or tubular ascending aorta are not shown.

Index Reoperation

The index reoperation was performed at a mean interval of 9.4 ± 6.7 years (range, 0.04-26.1 years) after the latest aortic operation. The index reoperation was the second cardiac operation performed during cardiopulmonary bypass (CPB) in 49 (87.5%), the third in 5 (8.9%), and the fourth in 2 (3.6%) patients. However, it ac-

TABLE 3. Indications for index reoperation

Indication	n (%)
Aortic	
Degenerative AAA	14 (25)
False aneurysm	10 (17.9)
Redissection	5 (8.9)
Postoperative dissection	4 (7.1)
Valvular	
Bioprosthetic SVD	1 (1.8)
Bioprosthetic SVD + degenerative AAA	6 (10.7)
Non-SVD	3 (5.4)
AI after aortic root remodeling (Yacoub)	1 (1.8)
Infectious	
Prosthetic valve endocarditis	9 (16.1)*
Prosthetic graft infection	1 (1.8)
Prosthetic valve + graft infection	1 (1.8)
Native valve endocarditis (after AV repair)	1 (1.8)
Total	56 (100)

AAA, Ascending aortic aneurysm; SVD, structural valve dysfunction; AI, aortic insufficiency; AV, aortic valve. *Only 7 patients were receiving antibiotic treatment at the time of the index reoperation.

TABLE 4. Patient subgroup analysis according to the indication for reoperation

Indication	Dissection, redissection, false aneurysm (n = 19)	Infection (n = 12)	Other (n = 25)	P value
Patients				
Age	57.2 ± 12.2	47.9 ± 15.4	59.8 ± 12.3*	.038
EuroSCORE	10.4 ± 3.2	13.1 ± 3.1	10.4 ± 2.1*	.013
Operation				
Aortic crossclamp time (min)	199.9 ± 50.9	219.3 ± 58.0	148.3 ± 43.1†	.000
CPB time (min)	328.9 ± 130.6	333.7 ± 121.0	229.6 ± 96.4†	.008
Unplanned perioperative CABG	8 (42.1%)	1 (8.3%)	5 (20%)	.08
Outcome				
Postoperative troponin I (ng/mL)	41.5 ± 55.2	24.9 ± 33.1	30.8 ± 68.1	.80
Hospital death	5 (26.3%)	3 (25.0%)	2 (8.0%)	.22

* $P < .05$ versus "infection" group. † $P < .05$ versus "infection" and "dissection, redissection, false aneurysm" groups.

counted for the second sternal re-entry in 47 (83.9%), the third in 7 (12.5%), and the fourth in 2 (3.6%) patients. Nine (16.1%) patients required reoperation on an urgent basis, which was defined as a procedure performed on referral before the beginning of the next working day.³

Indications for reoperation were classified as aortic, valvular, or infectious and are listed in Table 3. Infection was considered as active if the patient was still receiving antibiotic treatment at the time of the operation.³ Thus we could differentiate among 3 patient subgroups: (1) patients undergoing reoperation for false aneurysm, redissection, or postoperative dissection (n = 19); (2) patients undergoing reoperation for active prosthetic valve infection, graft infection, or both (n = 10); and (3) patients undergoing reoperation for other reasons (n = 25). Respective patient characteristics are listed in Table 4.

ARR with the modified button technique for coronary reimplantation was planned in all patients. Aortic root substitutes implanted at reoperation are listed in Table 5. Concomitant procedures performed during reoperation are listed in Table 6. Coronary artery bypass grafting (CABG) was performed during the same operation in 14 (25%) patients. The mean number of distal anastomoses performed was 1.6 ± 0.7 grafts per patient. Seven patients had 1, 5 patients had 2, and 2 patients had 3 distal anastomoses. Only saphenous vein grafts were used.

CABG was planned on preoperative coronary angiograms in only 1 (1.8%) patient because of significant coronary artery disease. In the remaining 13 (23.2%) patients, CABG had to be performed unexpectedly during the same operation to re-establish coronary perfusion. One additional patient had to be returned to the

operating room immediately after his arrival in the intensive care unit (ICU) because of right coronary malperfusion and underwent emergency CABG.

We differentiate among 3 indications to perform unexpected CABG during the same operation or immediately after (Table 7): (1) technical impossibility to reimplant one or both coronary buttons (7 patients), (2) evidence of inadequate coronary perfusion after aortic crossclamp release (3 patients), (3) or a combination of both previous situations (4 patients). In 10 patients coronary button reimplantation was not feasible because of extensive tissue destruction caused by a proximal aortic false aneurysm (n = 6, Figure 1), aortic dissection or redissection (n = 3), and prosthetic valve endocarditis (n = 1). In one additional patient, the left coronary ostium appeared significantly obstructed by adherent pseudointimal ingrowth and required resection. Coronary perfusion was achieved through proximal coronary artery ligation with conventional aortocoronary saphenous vein grafts in 5 patients and aortocoronary saphenous vein interposition grafts in 6 patients. In case of coronary malperfusion occurring after aortic crossclamp release, no attempts were made to re-explore and eventually reconstruct coronary buttons during repeated cardioplegic arrest to avoid additional myocardial ischemia. The respective coronary arteries were reperfused by performing conventional CABGs.

TABLE 5. Aortic root substitutes implanted at index reoperation

Substitute	n (%)
Composite graft	43 (76.8)
Bileaflet mechanical valve	12 (21.4)
Tilting-disc mechanical valve	31 (55.4)
Bioprosthetic stentless aortic root	11 (19.6)
Aortic root homograft	2 (3.6)
Total	56 (100)

TABLE 6. Procedures performed at index reoperation

Procedure	n (%)
Aortic root replacement	
Without CABG	38 (67.8)
With CABG*	9 (16.1)
Aortic root replacement + MVR/MVP	
Without CABG	3 (5.4)
With CABG	2 (3.6)
Aortic root replacement + arch	
Without CABG	1 (1.8)
With CABG	3 (5.4)
Total	56 (100)

CABG, Coronary artery bypass grafting; MVR/MVP, mitral valve replacement/mitral valve plasty. *Only one preoperatively planned CABG.

TABLE 7. Coronary problems during reoperative Bentall procedure with management and patient outcome (n = 14 [25%])

Patient no.	Perioperative		Postoperative malperfusion	CABG	Hospital mortality
	Reimplantation not feasible	Malperfusion			
1	RCA	—	—	SV/RCA graft	—
2	RCA	—	—	RCA SV interposition graft	—
3	RCA	—	—	RCA SV interposition graft	—
4	Left main	—	—	SV/LAD and SV/Mg	Died in OR
5	Left main	—	—	SV/LAD and SV/Mg	—
6	Left main	—	—	MS SV interposition graft	—
7	Left main + RCA	—	—	SV/LAD and SV/RCA	Died early (sepsis)
8	—	RCA	—	SV/RCA	Died in OR
9	—	RCA	—	SV/RCA	—
10	—	—	RCA	SV/RCA	Died early
11	RCA	LAD	—	RCA SV interposition graft + SV/LAD	—
12	RCA	Left main	RCA SV interposition graft + SV/LAD and SV/Mg	Died in OR	—
13	Left main	RCA	SV/LAD + SV/RCA	Died in OR	—
14	Left main + RCA	LAD	Left main and RCA SV interposition grafts + SV/LAD	Died in OR	—

CABG, Coronary artery bypass grafting; *RCA*, right coronary artery; *SV*, saphenous vein; *LAD*, left anterior descending coronary artery; *Mg*, obtuse left marginal artery; *OR*, operating room; *MS*, Main stem: left main.

All procedures were performed through a median resternotomy. CPB was established after resternotomy in 43 (76.8%) patients. In these patients the common femoral artery (23 patients) or the distal ascending aorta or the aortic arch (20 patients) were used for arterial inflow. Venous return was achieved by means of central (right atrial or bicaval: 23 and 15 patients, respectively) or femorocentral (5 patients) cannulation. In the remaining 13 patients, CPB was instituted before resternotomy and conducted with femoral artery inflow and femoral (5 patients) or femorocentral (8 patients) venous return. Thus only 2 (3.6%) re-entry accidents were observed in this series. Both occurred at sternotomy and were related to injury to the ascending aorta or an ascending aortic prosthesis. The first patient required immediate institution of femorofemoral bypass, whereas the second was already undergoing peripheral bypass. In both patients the hemorrhage was successfully controlled, and the procedure could be completed.

Mean CPB time was 286.6 ± 123.3 minutes and was significantly longer when instituted before resternotomy (381.1 ± 101.2 vs 257.4 ± 115.4 minutes, $P = .001$). CPB was conducted during moderate systemic hypothermia (lowest esophageal temperature, $26.9^\circ\text{C} \pm 5.4^\circ\text{C}$). Deep hypothermic circulatory arrest was performed in 8 (14.3%) patients at a mean esophageal temperature of $20.1^\circ\text{C} \pm 5.2^\circ\text{C}$. Myocardial protection was achieved with intermittent antegrade cold crystalloid cardioplegia and topical cooling. The mean aortic crossclamp time was 181.6 ± 57.2 minutes.

Data Collection

Hospital records were reviewed retrospectively for patient demographic characteristics, preoperative status, preoperative comorbidity, intraoperative course, and postoperative course. Preopera-

tive risk factor assessment was performed according to the definitions of the EuroSCORE.³

Follow-up information was obtained by means of telephone interview of the patient, the patient's relatives, or the referring physician. Questions were asked in regard to cause and date of death. Late death was defined as death occurring after hospital dismissal. Definitions of complications followed the "Guidelines for reporting morbidity and mortality after cardiac valvular operations."⁴ The total follow-up was 111.5 patient-years, with a mean follow-up period of 2.0 ± 2.4 years per patient (range, 0-9.6 years).

Statistical Analysis

Statistical analysis was performed with SPSS Base 12.0 statistical software (SPSS Inc, Chicago, Ill). Continuous variables were expressed as the mean $\pm$ 1 standard deviation and compared by using unpaired 2-tailed *t* tests or 1-way analysis of variance with the Bonferroni post-hoc correction. Categorical variables were expressed as percentages and compared with the χ^2 test. Survival data were analyzed with standard Kaplan-Meier actuarial techniques for estimation of survival probabilities.

Results

Hospital Morbidity

Postoperative ICU stay averaged 6.8 ± 5.9 days (median, 4.0 days), and mean duration of postoperative hospitalization in our department was 14.2 ± 8.5 days (median, 12.0 days). The incidence of various complications is shown in Table 8.

Figure 1. Intraoperative view of a patient with Marfan syndrome undergoing repeated aortic root replacement. The patient had a false aneurysm on the proximal suture line and both coronary ostia. Pledget-reinforced sutures have been placed as horizontal mattress stitches passed from the aortic side through the remaining aortic annulus. The right coronary artery has been extensively mobilized and retracted toward the right atrium for exposure. Note the complete destruction of the aortic wall button around the right coronary ostium (white arrow). Black arrowheads indicate the course of the main right coronary with its 2 first collaterals.

Postoperative troponin I levels were available for 46 patients. The mean peak troponin I level was 33.0 ± 58.8 ng/mL (range, 0.1–284 ng/mL), and 11 patients had a peak level of greater than 20 ng/mL. Peak troponin I levels were not significantly different among the 3 patient groups (Table 4).

Four patients required early reoperation. Indications for early reoperation included mediastinal bleeding (1 patient), pericardial effusion (1 patient), and poststernotomy mediastinitis (1 patient). The fourth patient had inferior myocardial infarction complicated by cardiogenic shock 7 hours after his arrival in the ICU. Despite emergency reperfusion by performing a saphenous vein to right coronary CABG, the patient died 24 hours later of cardiogenic shock.

Hospital Mortality

Hospital mortality reached 17.9% ($n = 10$). Six patients died intraoperatively of refractory cardiac failure. Among these, 5 patients had required nonplanned CABG to re-establish coronary flow (Table 9). Two additional patients died in the ICU because of persistent postoperative low cardiac output. One of these was the previously mentioned patient who underwent emergency CABG because of right coronary malperfusion (patient 10, Table 7). Finally, 2 patients died of septic shock related to methicillin-resistant

TABLE 8. Hospital morbidity

Complication	n (%)
Cardiac	
Need for inotropic support	43 (76.8)
Need for vasoconstrictor support	13 (23.2)
Postoperative troponin I level >20 ng/mL	11 (19.6)
Heart block requiring pacemaker	5 (8.9)
Atrial fibrillation-flutter	11 (19.6)
Ventricular tachycardia-fibrillation	4 (7.1)
Vascular	
Critical leg ischemia	1 (1.8)
Pulmonary	
Prolonged mechanical ventilation ≥ 3 d	15 (26.8)
Neurologic	
Delirium	3 (5.4)
Transient	1 (1.8)
Infection	
Any infection requiring antibiotics	22 (39.3)
Pulmonary infection	9 (16.1)
Renal	
Renal failure requiring dialysis	3 (5.4)
Gastrointestinal	
Intra-abdominal complication requiring surgical intervention	2 (3.6)

Staphylococcus aureus prosthetic valve endocarditis (1 patient) and poststernotomy mediastinitis (1 patient). Neither of these patients was amenable to reoperation.

By means of univariate analysis, risk factors for hospital death were urgent operation (4/9 [44.4%] patients vs 6/47 [12.8%] patients, $P = .044$), the need for unplanned perioperative CABG (7/14 [50%] patients vs 3/42 [7.1%] patients, $P = .001$), and longer CPB (389.0 ± 135.4 minutes vs 263.9 ± 109.5 minutes, $P = .003$) and cardiac ischemic (217.4 ± 56.4 minutes vs 173.7 ± 54.8 minutes, $P = .03$) times. Preoperative active prosthetic valve infection, graft infection, or both ($n = 12$) and reoperation for false aneurysm or redissection or postoperative dissection ($n = 19$) were not identified as significant risk factors (Table 4). Multivariate analysis with regression analysis indicated the need for unplanned perioperative CABG as the sole independent risk factor for hospital mortality ($P = .005$). The need for unplanned perioperative CABG was significantly more frequent in case of reoperation for false aneurysm, redissection, or postoperative dissection than for other indications (8/19 [42.1%] patients vs 6/37 [16.2%] patients, respectively; $P = .05$).

Late Mortality and Morbidity

Seven patients died after hospital dismissal. Overall actuarial survival was $83.8\% \pm 4.9\%$ at 1 month, $73.0\% \pm 6.3\%$ at 1 year, and $65.7\% \pm 8.9\%$ at 5 years after the operation. Two patients died after subsequent surgical repair of post-

TABLE 9. Causes of death (n = 17)

Cause of death	Early	Late
Cardiac	8	3
Septic shock (PVE, mediastinitis)	2	—
Suicide	—	1
Subsequent descending thoracic aorta replacement	—	2
Unknown	—	1
Total	10	7

PVE, Prosthetic valve endocarditis.

dissection thoracic and thoracoabdominal aortic aneurysms, respectively. Two patients died of evolving heart failure. One additional patient died suddenly while riding a bicycle, and that patient's death was therefore considered cardiac related. Other causes of late death are listed in Table 9.

No cases of structural valvular deterioration and non-structural valvular dysfunction were observed during the study period. Similarly, no cases of valve thrombosis were noted. One patient experienced embolic occlusion of the central retinal artery 12 days after the operation without evidence of prosthetic valve thrombosis. No patient experienced late bleeding events. One patient had recurrence of prosthetic valve endocarditis 6.7 months after the operation and underwent successful repeated homograft ARR. No other patient underwent subsequent reoperation on the aortic valve, aortic root, or tubular ascending aorta.

Discussion

Reoperations on the aortic root, ascending aorta, or both are being performed with an increasing frequency⁵ and have stimulated a number of recent reports. However, interpretation of these studies is often limited because of great variability between studies in patient selection. Indeed, reoperations on the aortic root and ascending aorta include a large spectrum of clinical situations that can be classified according to the type of prior operation, the indication for reoperation, and the type of procedure performed at reoperation. All of these variables have important implications on the perioperative management and operative strategy. Thus some studies have included patients undergoing any type of proximal aortic procedure, irrespective of the type of cardiac procedure performed previously,⁶⁻⁹ whereas others have included only those patients who had a previous proximal aortic procedure.¹⁰ On the other hand, some groups have focused their studies on patients undergoing total ARR, either after any type of previous cardiac procedure^{5,11} or only after previous total ARR.¹²⁻¹⁴ In the latter case, the series are often limited by their very small patient numbers.^{12,13} Finally, some studies have included patients undergoing any type of proximal aortic reoperation but for a

specific indication, such as false aneurysm¹⁵ or prosthetic valve endocarditis.¹⁶ The present study was undertaken to evaluate outcomes and operative risk factors in a relatively homogeneous patient population undergoing total ARR after previous surgical intervention on the aortic valve, aortic root, and/or ascending aorta.

In our experience this type of procedure carries a high postoperative morbidity and mortality. As stated above, comparison with other series is difficult. However, when considering only reports dealing with total ARR after previous cardiac surgery, operative mortality varies from 7%¹¹ to 28%.⁵ A similar discrepancy can also be noted between studies evaluating perioperative risk factors for hospital mortality after total ARR. Thus some authors have noted that prior cardiac surgery is a significant risk factor for operative mortality after total ARR on univariate¹⁷ or multivariate analysis.¹⁸ In contrast, several other studies have shown that prior cardiac operation does not significantly influence early outcome after total ARR.¹⁹⁻²³

David and colleagues¹¹ have reported that increasing patient age and preoperative New York Heart Association functional class IV were the only 2 independent risk factors for death in a series of 165 patients undergoing total ARR after previous cardiac surgery. In a similar but much smaller series of 32 patients, Valletly and associates⁵ have observed that emergency presentation had a very poor postoperative prognosis. In the present study no patient-related factors were identified as significant risk factors for hospital mortality. Interestingly, preoperative active prosthetic valve infection, graft infection, or both and reoperation for false aneurysm or redissection or postoperative dissection did not influence early outcome. However, this finding might be related to the small number of patients in each patient group. In contrast, procedure-related factors, such as emergency procedure, prolonged CPB, aortic crossclamp times, and the need for unplanned CABG, were found to significantly influence early outcome on univariate analysis. However, logistic regression identified the need for unplanned CABG as the sole independent risk factor for hospital mortality. Thus the need for unplanned CABG appeared to affect patient outcome adversely independently of prolonged operative times. One explanation might be inadequate myocardial protection in these patients. Indeed, severe involvement of coronary ostia by disease processes, such as false aneurysm, aortic root dissection, or endocarditis, might compromise homogenous distribution of antegrade cardioplegia. However, we found no significant differences in peak postoperative levels of troponin I between these patient groups. Byrne and coworkers²⁴ have stressed the importance of retrograde cardioplegia in this setting and have shown that the failure to use retrograde cardioplegia in patients undergoing total ARR with concomitant CABG is a significant risk factor for operative mortality. The advent of

new noninvasive computed tomographic and magnetic resonance coronary imaging techniques might facilitate the preoperative identification of significant coronary ostial involvement and allow us to tailor the myocardial protection strategy to each situation.

Unplanned CABG was performed either because coronary ostia reimplantation was deemed impossible, because of suspected coronary malperfusion after aortic unclamping as a consequence of technical error in coronary button anastomosis or unrecognized coronary artery disease, or both. The need for unplanned CABG occurred with an incidence of 25% in the present experience. This is much higher than the reported incidence of 6% cited by Valley and associates,⁵ despite a similar proportion of reoperations performed because of postoperative dissection or false aneurysm. In some of our patients, intraoperative observation of macroscopically necrotic tissues suggested that the use of gelatin-resorcinol-formalin glue at the first operation might have contributed to the extent of the pathologic process. Indeed, several recent reports have raised concerns about the toxic effects of the gelatin-resorcinol-formalin glue,^{25,26} which could favor the occurrence of postoperative dissection or false aneurysm and compromise coronary ostia reimplantation at reoperation.

Thus coronary reimplantation remains a major concern when performing reoperative total ARR. In some patients direct coronary button reimplantation is not feasible because of widely separated coronary ostia or because of complete destruction of the coronary ostia by the disease process (false aneurysm, dissection, and endocarditis). When coronary ostia reimplantation is not feasible, several surgical options are available. In 1978, Cabrol and colleagues²⁷ modified the original technique described by Bentall and De Bono by introducing a second smaller tube graft interposed between both coronary ostia and anastomized side-to-side to the composite valve conduit. Others have described the use of expanded polytetraethylene²⁸ or Dacron interposition grafts.²⁹ Although these techniques are certainly useful for the management of widely separated coronary ostia during ARR, these techniques are not applicable when the coronary ostia are destroyed by the disease process and the distal anastomosis has to be performed on the proximal main stem or the proximal right coronary artery (Figure 1). In this setting the size mismatch and the friability of the coronary arteries do not allow a safe prosthetic graft-to-coronary anastomosis. Therefore we favor the use of saphenous interposition grafting or conventional CABG with proximal coronary artery ligation,^{30,31} although the former exposes to graft kinking, the latter to the inconveniences of retrograde coronary flow, and both to late graft atherosclerosis. Our data do not allow us to support one or the other technique. However, we believe that in these complex patients, the

technique that allows the most expedient and safe repair should be preferred.

Conclusion

ARR after previous operations on the aortic valve, aortic root, or ascending aorta remains a major surgical challenge with high postoperative mortality. The need for unexpected CABG to achieve coronary perfusion appears as a major risk factor for hospital death. The optimal technique for coronary reconstruction in this setting remains to be debated.

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