General Thoracic and Cardiovascular Surgery (2019) 67:510–517
https://doi.org/10.1007/s11748-018-1053-4

ORIGINAL ARTICLE

Outcomes after aortic valve replacement for aortic valve stenosis, with or without concomitant coronary artery bypass grafting

Reo Sakakura[1] · Tohru Asai[1] · Tomoaki Suzuki[1] · Takeshi Kinoshita[1] · Masahide Enomoto[1] · Yasuo Kondo[1] · Shoichiro Shiraishi[1,2]

Received: 19 August 2018 / Accepted: 10 December 2018 / Published online: 17 December 2018

Abstract

Objectives To assess the effects of concomitant coronary artery bypass grafting (CABG), we analyzed the outcomes after aortic valve replacement (AVR) for aortic stenosis (AS) with and without coronary artery bypass grafting (CABG) at our institution.

Methods Between 2002 and 2014, 605 consecutive patients underwent AVR for AS. Of these, the 275 who received isolated AVR (Group A) and the 122 who received both AVR and CABG (Group AC) patients were enrolled, after the exclusion of 8 patients who underwent reoperation and 200 who received other concomitant surgery. AVR and all bypass anastomoses were performed under intermittent retrograde cold blood cardioplegia. Multivariate analysis was used to assess any association of concomitant CABG with morbidity and mortality. Kaplan–Meier analysis was used to assess all-cause mortality.

Results No significant difference in 30-day mortality was found between Group A and Group AC (1.5% vs. 0.8%, $P=1.000$). Nor did post-discharge survival differ significantly between the two groups ($P=0.20$). Likewise, multivariate analysis showed that concomitant CABG was not associated with significantly greater in-hospital or mid-term mortality. Operative morbidities were comparable between the two groups, in terms of stroke (1.8% vs. 3.3%, $P=0.466$), prolonged ventilation (4.0% vs. 5.5%, $P=0.565$), deep sternal infection (1.8% vs. 3.3%, $P=0.466$), and acute renal failure (0.4% vs. 1.6% $P=0.176$).

Conclusions Concomitant CABG at the time of AVR was performed without increasing early- or mid-term mortality. This absence of increased risk deserves consideration when choosing between different treatment strategies.

Keywords Aortic valve stenosis · Coronary artery disease · Aortic valve replacement · Coronary artery bypass grafting

Introduction

Significant coronary artery disease (CAD) is often present in patients with severe aortic stenosis (AS). It is present in more than 50% of patients over 70 years of age with AS [1]. When CAD is present in AVR patients, early- and long-term survival rates have been found worse without CABG [2–4]. On AVR with CABG, however, there is conflicting evidence. Some reports demonstrated higher rates of early mortality [2–10], whereas other reports showed no significant difference with concomitant CABG [1, 11–16].

In recent years, the range of treatment options, non-surgical as well as surgical, has increased, and so has the need for reliable assessment of relative risks associated with those options. Outcomes have improved with developments in surgical techniques, myocardial protection, and perioperative management, and the present study was intended to contribute data on the risks of AVR with and without CABG. Here we analyze the early- and mid-term outcomes of these two common surgical procedures in our institution.

✉ Tohru Asai
toruasai@belle.shiga-med.ac.jp

[1] Division of Cardiovascular Surgery, Shiga University of Medical Science, Seta Tsukinowacho, Otsu, Shiga 520-2192, Japan

[2] Division of Cardiovascular Surgery, Kusatsu General Hospital, Kusatsu, Japan

Patients and methods

Patient population

Between January 2002 and December 2014, 275 consecutive patients underwent isolated AVR (Group A), and 122 consecutive patients underwent only combined AVR plus CABG (Group AC). To exclude possible confounding factors, 200 patients undergoing AVR with other concomitant procedures (mitral valve surgery, tricuspid valve surgery, thoracic aortic surgery, surgical ablation for atrial fibrillation, and non-cardiac surgery) and 8 repeat sternotomy cases were excluded. There were 192 males and 205 females, with a mean age of 74.2 years (range 40–90 years). Preoperative coronary angiography was performed in all patients, with coronary stenosis considered significant in cases of 50% stenosis in the left main artery or 75% occlusion or worse in other proximal major branches, the left anterior descending (LAD) artery, left circumflex (LCX) artery, or right coronary artery (RCA). We classed all of these as target vessels for CABG, and we performed complete revascularization. Therefore, none of Group A had un-bypassed significant coronary artery disease.

Surgical procedure

Patients were placed supine, and anesthesia was maintained in a standard manner. Transesophageal echocardiography was used to confirm details of cardiac and valve functions. The procedures were performed via standard full median sternotomy in all cases. The internal thoracic artery (ITA) and right gastroepiploic artery (RGEA) were harvested with an ultrasonic scalpel using the skeletonizing technique (Harmonic Scalpel; Ethicon Endo-Surgery; Cincinnati, OH, USA) [17]. The saphenous vein (SV)was prepared when necessary.

The cardiopulmonary bypass was established with the ascending aorta and the superior and inferior vena cava, those veins being snared to the cannulate to isolate the right atrium. A left ventricular vent was placed through the right superior pulmonary vein. Cold blood cardioplegia was initiated with antegrade infusion from the aortic root, then continued with retrograde input directly through the coronary sinus via right atriotomy. Subsequent retrograde doses every 20–30 min were delivered through the coronary sinus throughout the aortic cross-clamp time (XCT). Core temperature was maintained at 32 °C.

After the diseased aortic valve had been excised, the aortic valve prosthesis was implanted. The selection of the valve prosthesis type was at the discretion of the operating surgeon. After the aorta was closed, all distal, and then proximal, anastomoses were constructed during aortic XCT. Transit time flowmetry was used to assess graft function.

Graft conduit selection

The internal thoracic artery (ITA) was mostly grafted to the left anterior descending (LAD). In some cases, bilateral ITAs and the right gastroepiploic artery [17] were additionally used. All arterial conduits were skeletonized and harvested. The SV was grafted to the rest of the target sites.

Definitions

Postoperative stroke was defined as a newly developing neurological deficit with CT findings of infarction in the appropriate territory. Prolonged ventilation was defined as intubation lasting more than 48 h. Postoperative acute renal failure was defined by a new need for hemodialysis. Perioperative myocardial infarction was defined as the presence of new Q waves on electrocardiograms or an unexpected need for CABG during operation. Deep sternal wound infection was defined as any wound infection involving the sternum or mediastinal tissues that required operative intervention. All patient data were collected prospectively in our database.

Statistical analysis

All continuous variables were expressed as mean ± standard deviation (SD). Nominal variables were expressed as actual numbers and percentages of the total. For nominal variables, a Chi-square test or Fisher's exact test was used to analyze relations between Group A and Group AC. Continuous variables were analyzed using the t test or the Mann–Whitney *U* test. Calculated *P* values of less than 0.05 were considered significant. To identify risk factors associated with in-hospital mortality, multivariate logistic regression analyses were performed. Concomitant CABG and variables that were associated with in-hospital mortality based on clinical knowledge and with a significance level $P < 0.05$ in univariate logistic regression models were entered into the multivariate model as covariates in a stepwise manner. The estimated survival rates were calculated using the Kaplan–Meier method and compared with the log rank test. To identify the significant predictors of remote all-cause mortality, univariate and multivariate Cox proportional hazards analyses were performed, using the variables shown in Table 1. Concomitant CABG and the variables with a significance level of $P < 0.05$ in

Table 1 Preoperative characteristics

	Group A ($n=275$)	Group A/C ($n=122$)	P value
Age (years)	73.6 ± 8.9	75.1 ± 8.3	0.255
Age > 80 years	71 (25.8)	37 (30.3)	0.352
Male	126 (45.8)	66 (54.1)	0.128
Body mass index (kg/m^2)	22.4 ± 3.6	22.4 ± 3.0	0.912
NYHA class III or IV	94 (34.2)	55 (45.1)	0.043
Smoking history	88 (32.0)	59 (48.4)	**0.000**
Diabetes mellitus	59 (21.5)	47 (38.5)	**0.000**
Hypertension	164 (59.6)	85 (69.7)	0.056
Hyperlipidemia	91 (33.1)	55 (45.1)	0.022
Previous myocardial infarction	3 (1.1)	9 (7.4)	0.002
Previous stroke	8 (2.9)	5 (4.1)	0.539
GFR (ml/min/1.73 m^2) < 60	104 (37.8)	52 (42.6)	0.366
Hemodialysis	31 (11.3)	24 (19.7)	0.025
Congestive heart failure	141 (51.3)	83 (68.0)	0.002
Chronic obstructive pulmonary disease	77 (28.0)	38 (31.1)	0.524
Atrial fibrillation	9 (3.3)	5 (4.1)	0.769
PCI history	26 (9.5)	26 (21.3)	0.001
LV ejection fraction (%)	60.7 ± 10.3	59.8 ± 10.7	0.161
LV end-diastolic dimension (mm)	51.6 ± 28.1	48.7 ± 7.1	0.635
LV end-systolic dimension (mm)	33.8 ± 8.0	33.4 ± 7.8	0.672
Aortic stenosis with regurgitation	159 (57.8)	69 (56.6)	0.815
Aortic valve area (cm^2)	0.85 ± 0.23	0.88 ± 0.24	0.119
Urgency or Emergency operation	15 (5.5)	5 (4.1)	0.804
Preoperative IABP	3 (1.1)	5 (4.1)	0.062
Preoperative PCPS	1 (0.4)	0 (0)	1.000
Logistic EuroSCORE	8.8 ± 0.4	10.9 ± 0.8	0.010

Bold values indicate statistical significance ($P < 0.01$)

univariate Cox proportional hazards models were included in the multivariate models as covariates. All analyses were performed with SPSS, version 20.0 (SPSS Inc, Chicago, IL, USA).

Results

Preoperative characteristics

The preoperative characteristics of the patients are summarized in Table 1. Compared with patients in Group A, patients in Group AC had more severe symptoms (New York Heart Association class III and IV) and significantly higher rates of smoking history, diabetes mellitus, hyperlipidemia, previous myocardial infarction, hemodialysis, congestive heart failure, and previous percutaneous coronary intervention (PCI). The health differences between the groups were reflected in their Logistic EuroSCOREs, significantly higher in Group AC.

Coronary artery bypass grafting

Table 2 shows the details of CAD and graft distribution in CABG. The mean number of distal anastomoses was 2.0 ± 1.0. Ninety-five patients (77.9%) in Group AC had revascularization to their LAD. The ITA was grafted to the LAD in 96.8%. Intraoperative graft function was confirmed using transit time flowmetry prior to chest closure.

Operative data and outcomes

Operative data are shown in Table 3. A biological valve was used in more than 90% of cases in both groups. The mean size of the prosthetic valves was not significantly different between the two groups. Operative and postoperative data are shown in Table 3. The mean times for Group A were shorter than for Group AC, in operation (204.9 ± 39.8 vs. 281.4 ± 51.5 min), cardiopulmonary bypass (94.9 ± 18.6 vs. 128.2 ± 24.4), and aortic XCT (63.0 ± 13.8 vs. 95.7 ± 22.5). Despite the higher logistic EuroSCOREs and longer

Table 2 Details of coronary artery disease and coronary artery bypass grafting

Variables	
Coronary artery disease	
Left main disease/three vessel disease	26 (21.3)
Two-vessel disease	42 (34.7)
One-vessel disease	54 (44.6)
Number of distal anastomoses/patient	2.0 ± 1.0
Target vessels of revascularization	
Total number of targets	248
Left anterior descending	95
Diagonal branch	22
High lateral branch	9
Circumflex artery	62
Right coronary artery	60
Type of conduits	
LITA + SVG	53 (43.4)
SVG only	25 (20.5)
LITA only	22 (18.0)
RGEA only	19 (15.6)
BITA + RGEA	1 (0.8)
LITA + RGEA	1 (0.8)
RITA + RGEA	1 (0.8)
Grafts and distribution of distal anastomoses	
LITA	LAD 89, Dg 7, HL 1, OM 2, 14 PL 5, 15 PD 1
RITA	LAD 3, Dg 1, OM 1, 15 PD 1
SVG	LAD 3, Dg 14, HL 8, OM 13, 14 PL 36, 15 PD 2, 4 PD 43, 4 AV 6, 4 PL 1, RCA 8
RGEA	4 PD 2, 14 PL 1
ITA use for LAD	96.8% (91/95)

LITA left internal thoracic artery, *SVG* saphenous vein graft, *RGEA* right gastroepiploic artery, *BITA* bilateral internal thoracic artery, *RITA* right internal thoracic artery, *LAD* left anterior descending artery, *Dg* diagonal branch, *HL* high lateral branch, *OM* obtuse marginal branch, *PL* posterolateral branch, *PD* posterior descending branch, *AV* atrio-ventricular branch, *RCA* right coronary artery

operative times, no members of Group AC required new IABP or PCPS.

Thirty-day mortality rates in Group A and Group AC were not significantly different, at 1.5 and 0.8%, respectively ($P = 1.000$). In-hospital mortality totaled 8 cases (2.0%), with 6 deaths (2.2%) in Group A and 2 deaths (1.6%) in Group AC ($P = 0.341$). In Group A, in-hospital deaths were caused by multiple organ failure in 2 patients, pneumonia in 1 and sepsis in 3. In Group AC, in-hospital deaths were caused by pneumonia in 1 patient and sepsis in 1. Univariate logistic regression analysis showed that lower ejection fraction, urgency, and emergency operation were the predictors of in-hospital death. Multivariate logistic regression analysis identified only urgency and emergency operation as independent predictors of in-hospital death (odds ratio 20.229, 95% confidence interval 3.336–122.670, $P = 0.001$). Concomitant CABG, age, longer duration of operation time, prolonged cardiopulmonary bypass time, and XCT were not risk factors for in-hospital mortality. The pre-discharge CT was performed in 73.0% (89/122). The rates of graft patency were 98.9% (88/89) for the LITA and 97.6% (83/85) for the SV grafts. The overall graft patency rate was 98.3%.

Compared with Group A, Group AC was more likely to have operative complications, including stroke (3.3% vs. 1.8%, $P = 0.466$), prolonged ventilation (5.5% vs. 4.0%, $P = 0.565$), deep sternal wound infection (3.3% vs. 1.8%, $P = 0.466$), and acute renal failure (1.6% vs. 0.4% $P = 0.176$). Prolonged stay rates in the intensive care unit (> 2 days) were 7.3% in Group A and 6.6% in Group AC ($P = 0.797$). We also investigated as a concept of major adverse events combination with stroke, deep sternal wound infection, perioperative myocardial infarction, and acute renal failure. The result showed no significance between the 2 groups. Group AC seemed to have more complications; however, the difference did not reach significance [$n = 10$ (3.6%) in Group A, $n = 10$ (8.2%) in Group AC, $P = 0.055$].

Table 3 Operative and postoperative data

	Group A (*n*=275)	Group A/C (*n*=122)	*P* value
Operation time (min)	204.9 ± 39.8	281.4 ± 51.5	**0.000**
Cardiopulmonary bypass time (min)	94.9 ± 18.6	128.2 ± 24.4	**0.000**
Aortic cross-clamp time (min)	63.0 ± 13.8	95.7 ± 22.5	**0.000**
Mechanical valve	23 (8.4)	7 (5.7)	0.361
Mean prosthesis size (mm)	22.4 ± 2.1	22.5 ± 2.2	0.800
New IABP	4 (1.5)	0 (0)	0.229
New PCPS	1 (0.4)	0 (0)	1.000
30-Day mortality	4 (1.5)	1 (0.8)	1.000
In-hospital mortality[a]	6 (2.2)	2 (1.6)	0.341
Complications			
Stroke	5 (1.8)	4 (3.3)	0.466
Prolonged ventilation (> 48 h)	11 (4.0)	3 (5.5)	0.565
Reexploration for bleeding	10 (3.6)	2 (1.6)	0.358
Perioperative myocardial infarction	0 (0)	0 (0)	–
Deep sternal infection	5 (1.8)	4 (3.3)	0.466
Acute renal failure	1 (0.4)	2 (1.6)	0.176
Intensive care unit stay (> 2 days)	20 (7.3)	8 (6.6)	0.797

Bold values indicate statistical significance ($P < 0.01$)

IABP intra-aortic balloon pumping, *PCPS* percutaneous cardiopulmonary support

[a]In-hospital mortality include 30-day mortality

Table 4 Multivariate Cox proportional hazards models for the association of patient factors with all-cause mortality

Factor	HR	*P* value	95% CI
Age	1.051	0.033	1.004–1.100
Previous myocardial infarction	1.764	0.513	0.322–9.653
Hemodialysis	0.011	2.961	1.285–6.825
Congestive heart failure	1.093	0.818	0.513–2.330
Atrial fibrillation	2.400	0.103	0.837–6.884
Previous PCI	1.612	0.334	0.612–4.249
LV ejection fraction	0.933	0.005	0.889–0.979
LV systolic dimension	0.956	0.169	0.897–1.019
Urgency or emergency operation	2.281	0.299	0.482–10.798
Concomitant CABG	0.918	0.810	0.454–1.852

HR hazard ration, *CI* confidence interval, *PCI* percutaneous coronary intervention, *LV* left ventricular, *CABG* coronary artery bypass grafting

Mid-term outcomes

The mean follow-up period was 3.9 ± 3.1 years in Group A and 3.1 ± 2.8 years in Group AC. Figure 1 shows overall survival assessed by the Kaplan–Meier method. Compared with Group A, Group AC had worse post-discharge survival (93% vs. 95%, 84% vs. 86, and 55% vs. 79% at 1, 5, and 10 years, respectively), but the differences were not significant (log-rank $P = 0.20$) despite the higher logistic EuroSCOREs in Group AC. Univariate Cox proportional hazard models showed that age, previous myocardial infarction, hemodialysis, congestive heart failure, atrial fibrillation, previous PCI, lower ejection fraction, left ventricular end-systolic dimension, and urgent or emergency operation were the predictors of all-cause mortality. Multivariate Cox proportional hazard models showed that age, hemodialysis, and lower ejection fraction were independently associated with a higher risk of all-cause mortality. Concomitant CABG was not associated with all-cause mortality in the mid-term (Table 4).

Discussion

The main finding of this study is that there were no significant differences between isolated AVR and concomitant AVR and CABG in early- and mid-term outcomes. Concomitant CABG was not associated with early- or mid-term all-cause mortality in our experience.

There have been reports of worse outcomes after AVR with CABG [2–10]. Of particular interest are two quantified findings by Al-Sarraf et al. [18] for both AVR and AVR + CABG patients: firstly, that aortic XCT > 60 min increased risks of morbidities and mortality, and secondly that every extra minute of XCT increased mortality by 2%. Our mean aortic XCT for AVR was 63 (± 14) min (see Table 3), and our mean XCT for group AC was 96 (± 23) min, in the risk-incurring time-range assessed by Al-Sarraf et al., but without any apparent increase in mortality.

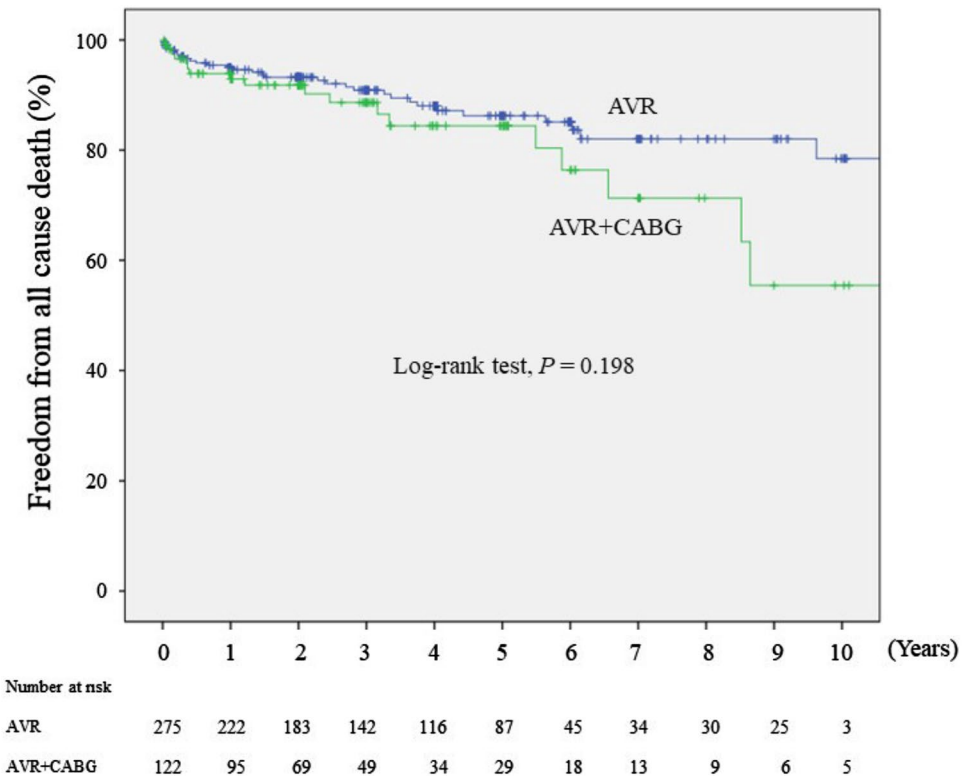

Fig. 1 Survival, free from all-cause death among patients after isolated AVR vs. concomitant AVR and CABG. *AVR* aortic valve replacement, *CABG* coronary artery bypass grafting

Our strategy for AVR with CABG includes two features which we believe to be particularly valuable in this context. Firstly, myocardial protection is performed with intermittent retrograde infusion of cold blood cardioplegic solution introduced directly to the coronary sinus via right atriotomy. Secondly, all bypass anastomoses are constructed after finishing AVR during aortic XCT. This facilitates the bypass procedures and minimizes cardiopulmonary bypass time, and in our experience, some prolongation of arrest time seems not to be a significant problem if adequate cardioplegic protection is achieved. There are various ways to perform AVR plus CABG. If CABG is done before AVR, the distal anastomoses can be constructed either during cardioplegic arrest, or during on-pump beating, or during off-pump beating. On-pump beating CABG can reduce the total XCT, and off-pump CABG can reduce both XCT and CPB time. However, in cases with severe coronary artery disease and cardiomegaly, CABG becomes more technically demanding, construction time for good anastomoses is longer, and the risk of myocardial damage, especially in a hypertrophied left ventricle, increases also. We have found that AVR and CABG can be efficiently performed sequentially under good retrograde cardioplegia, no matter how bad the state of the coronary vessels, and no matter how dysfunctional the LV. Consequently our combined operation times do not over-run, as shown by our Group AC.

Thorough and adequate cardioplegia distribution becomes vital for myocardial protection during extended surgery, and this can be crucial in AS plus CAD cases; if such protection fails there is serious risk of myocardial ischemic damage. Antegrade infusion can prove inadequate, especially in patients with CAD, as CAD restricts influx. Further, AS patients often have hypertrophic left ventricular myocardium, increasing the demand for perfusion with cardioplegic solution. Retrograde infusion, if done correctly, seems to allow more systematically, globally reliable protection [19] by delivering cardioplegic solution to all parts, except the outflow tract zone of the right ventricle, despite any coronary artery obstructions. Further, when the balloon catheter is secured with a purse-string suture around the orifice of the coronary sinus, there is little risk of missing any tributary coronary veins, which might occur with a blind deep insertion into the coronary sinus. Intermittent retrograde cold blood cardioplegia seems to provide adequate protection during AVR plus CABG under cardioplegic arrest. In Group AC, there was no need for new IABP or PCPS, and there were no perioperative myocardial infarctions in either group.

Concomitant CABG is necessary to avoid perioperative adverse events, such as myocardial infarction, at the time of AVR with CAD [2–4]. Thalji and colleagues demonstrated that concomitant CABG reduced the risk of late death by more than one-third, without increasing operative mortality among patients undergoing AVR with coexistent severe and moderate CAD [4]. In the present study, we performed a complete revascularization for all patients in Group AC and found no patients with significant but

non-revascularized CAD in Group A. We used ITA grafting to the left anterior descending artery (LAD), in order to improve long-term survival, rather than using only a saphenous vein graft for AVR plus CABG [20]. As shown in Table 2, we used ITA grafts for 96.8% of patients who underwent bypass to the LAD. We performed complete revascularizations for all patients in Group AC, and postoperative CT angiography demonstrated an ITA-LAD patency rate of 98.4% (64/65).

We found that the all-cause mortality in the Group AC tended to increase after 6 years postoperatively in the present study. It may be attributed to the fact that Group AC had considerably more preoperative high-risk comorbidities. These findings concur with the report by Beach and colleagues that patients' comorbidity affected survival more than did procedures [15].

The evidences and guidelines for AS and CAD, AVR + CABG and alternative strategy are still limited. Currently, alternative options such as TAVI + PCI, AVR + PCI may be increasingly offered. However, these alternative strategies should always be discussed in consideration of the benchmark results of AVR + CABG and each patient surgical risk. The heart team has to select the best therapy with careful consideration of individual patient prognosis.

The present study has some limitations. First, this is a retrospective study with unpaired groups from a single center and the number of patients was relatively small. Second, there was no distinction between aortic valve pathologies; all being stenotic, not all with regurgitation. There was no comparison between patients who underwent concomitant CABG and those who did not in the patients who had AS with CAD, because all patients with CAD underwent concomitant CABG. Finally, we were unable to follow-up some of the patients.

Conclusions

Our strategy of AVR with CABG can be safely used. No increase in early- and mid-term mortality was found with concomitant CABG.

Acknowledgements We thank Mr. Piers Vigars for reviewing our manuscript.

Funding None.

Compliance with ethical standards

Conflict of interest The authors have declared that no conflict of interest exists.

References

1. KvidalP, BergströmR, HörteLG, StåhleE. Observed and relative survival after aortic valve replacement. J Am Coll Cardiol. 2000;35(3):747–56.
2. MullanyCJ, ElvebackLR, FryeRL, PluthJR, EdwardsWD, OrszulakTA, DanielsonGK, et al. Coronary artery disease and its management: influence on survival in patients undergoing aortic valve replacement. J Am Coll Cardiol. 1987;10(1):66–72.
3. JonesM, SchofieldPM, BrooksNH, DarkJF, MoussalliH, DeiraniyaAK, LawsonRA, et al. Aortic valve replacement with combined myocardial revascularisation. Br Heart J. 1989;62(1):9–15.
4. ThaljiNM, SuriRM, DalyRC, GreasonKL, DearaniJA, StulakJM, JoyceLD, et al. The prognostic impact of concomitant coronary artery bypass grafting during aortic valve surgery: implications for revascularization in the transcatheter era. J Thorac Cardiovasc Surg. 2015;149(2):451–60.
5. BerndtTB, HancockEW, ShumwayNE, HarrisonDC. Aortic valve replacement with and without coronary artery bypass surgery. Circulation. 1974;50(5):967–71.
6. EdwardsFH, PetersonED, CoombsLP, DeLongER, JamiesonWR, ShroyerALW, et al. Prediction of operative mortality after valve replacement surgery. J Am Coll Cardiol. 2001;37(3):885–92.
7. KobayashiKJ, WilliamsJA, NwakanmaL, GottVL, BaumgartnerWA, ConteJV. Aortic valve replacement and concomitant coronary artery bypass: assessing the impact of multiple grafts. Ann Thorac Surg. 2007;83(3):969–78.
8. Carnero-AlcázarM, Reguillo-LacruzF, AlswiesA, Villagrán-MedinillaE, Maroto-CastellanosLC, Rodríguez-HernándezJ. Short- and mid-term results for aortic valve replacement in octogenarians. Interact Cardiovasc Thorac Surg. 2010;10(4):549–54.
9. JamiesonWR, YeJ, HigginsJ, CheungA, FradetGJ, SkarsgardP, GermannE, et al. Effect of prosthesis-patient mismatch on long-term survival with aortic valve replacement: assessment to 15 years. Ann Thorac Surg. 2010;89(1):51–8(discussion 59).
10. DunningJ, GaoH, ChambersJ, MoatN, MurphyG, PaganoD, RayS, RoxburghJ, et al. Aortic valve surgery: marked increases in volume and significant decreases in mechanical valve use—an analysis of 41,227 patients over 5 years from the Society for Cardiothoracic Surgery in Great Britain and Ireland National database. J Thorac Cardiovasc Surg. 2011;142(4):776–82.e3.
11. GunayR, SensozY, KayaciogluI, TuygunAK, BalciAY, KisaU, et al. Is the aortic valve pathology type different for early and late mortality in concomitant aortic valve replacement and coronary artery bypass surgery?Interact Cardiovasc Thorac Surg. 2009;9(4):630–4.
12. Dell'AmoreA, AquinoTM, PagliaroM, LamarraM, ZussaC. Aortic valve replacement with and without combined coronary bypass grafts in very elderly patients: early and long-term results. Eur J Cardiothorac Surg. 2012;41(3):491–8.
13. deWaardGA, JansenEK, deMulderM, VonkAB, UmansVA. Long-term outcomes of isolated aortic valve replacement and concomitant AVR and coronary artery bypass grafting. Neth Heart J. 2012;20(3):110–7.
14. AbelNJ, RogalGJ, BurnsP, SaundersCR, ChamberlainRS. Aortic valve replacement with and without coronary artery bypass graft surgery in octogenarians: is it safe and feasible?Cardiology. 2013;124(3):163–73.
15. BeachJM, MihaljevicT, SvenssonLG, RajeswaranJ, MarwickT, GriffinB, et al. Coronary artery disease and outcomes of aortic valve replacement for severe aortic stenosis. J Am Coll Cardiol. 2013;26(8):837–48.
16. RahimtoolaSH. The year in valvular heart disease. J Am Coll Cardiol. 2014;20(19):1948–58.

17. AsaiT, TabataS. Skeletonization of the right gastroepiploic artery using an ultrasonic scalpel. Ann Thorac Surg. 2002;74(5):1715–7.
18. Al-SarrafN, ThalibL, HughesA, HoulihanM, TolanM, YoungV, et al. Cross-clamp time is an independent predictor of mortality and morbidity in low-and high-risk cardiac patients. Int J Surg. 2011;9(1):104–9.
19. MenascheP, PiwnicaA. Cardioplegia by way of the coronary sinus for valvular and coronary surgery. J Am Coll Cardiol. 1991;18(2):628–36.
20. GallSJr, LoweJE, WolfeWG, OldhamHNJr, VanTrigtP3rd, GlowerDD. Efficacy of the internal mammary artery in combined aortic valve replacement-coronary artery bypass grafting. Ann Thorac Surg. 2000;69(2):524–30.