Results of surgical treatment of moderate ischemic mitral regurgitation: A propensity analysis

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Abstract

Background and Aim of the Study: Ischemic mitral valve regurgitation (IMR) in patients undergoing coronary artery bypass grafting (CABG) is associated with worse long-term outcomes. The aim of this study was to assess the impact of mitral valve repair with CABG in patients with moderate IMR.

Method: This observational study enrolled 3,215 consecutive patients from the Juntendo CABG registry with moderate IMR and multivessel coronary artery disease who underwent CABG between 2002 and 2017. The CABG alone and CABG with mitral valve surgery (MVs) groups were compared. The propensity score was calculated for each patient. Long-term all-cause death, cardiac death, and major adverse cardiac and cerebrovascular events (MACCEs) were compared between the two groups.

Results: A total of 101 patients who underwent CABG had moderate IMR in our database. Propensity score matching selected 40 pairs for final analysis. MVs was associated with increased risks of postoperative atrial fibrillation, blood transfusion, and longer hospitalization. There were no differences between the two groups in long-term outcomes, including all-cause mortality, cardiac mortality, and the incidence of MACCEs.

Conclusions: Surgical treatment of moderate IMR combined with CABG was as safe as CABG alone, with no differences in long-term outcomes. Further studies are needed to determine the effects of MVs in patients with moderate IMR and severe coronary artery disease.

Introduction

Ischemic mitral regurgitation (IMR) is a disorder with a poor prognosis caused by ischemic heart disease. The mitral valve consists of two leaflets, the annulus, and the subvalvular apparatus including the chordae, papillary muscle, and left ventricle. Hence, dysfunction of the mitral valve could develop due to impairment of any of these components. The principle mechanisms of IMR involve mitral leaflet tethering due to displacement of the papillary muscles and increased interpapillary muscle distance, based on impaired left ventricular (LV) systolic function, LV remodeling and dilatation, and mitral valve annulus dilation.[1,2] Thus, IMR is recognized not only as a valvular disease but also as a LV disorder. In addition to the presence of coronary artery disease, the strategy for treatment of IMR becomes more complex than that for primary mitral regurgitation that is caused by leaflet degeneration, prolapse, and chordal perforation.

The severity of regurgitation in patients with IMR is changed by preload, afterload, and the development of myocardial ischemia. Theoretically, LV reverse remodeling with improvement of myocardial ischemia leads to resolution of mitral regurgitation. Thus, it is difficult to establish treatment strategies for IMR, especially in cases of moderate IMR, where performing coronary artery bypass grafting (CABG) alone or CABG plus mitral valve surgery (MVs) remains controversial.[3,4] Meanwhile, surgeons need to decide to treat or leave the mitral valve at CABG in patients with moderate IMR in each case. The aim of this study was to compare the short-term and long-term outcomes of CABG alone and CABG plus MVs in patients with moderate IMR.

Materials and methods

Study design

The management of this database was performed according to the institutional review board in our hospital, and written informed consent was obtained from all patients prior to operation. This was a retrospective, observational cohort study of prospectively collected data. Consecutive patients who underwent CABG between 2002 and 2017 were examined. Patients who had multivessel coronary artery disease and moderate IMR were selected. Patients were further divided into two groups: those who underwent CABG alone and those who underwent CABG with MVs. Before propensity score matching, baseline characteristics were analyzed for the general samples. The propensity score was calculated for each patient from the results of multivariate logistic regression analysis. Long-term all-cause death, cardiac death, and incidence of major adverse cardiac and cerebrovascular events (MACCEs) were compared between the two groups. Exclusion criteria included any echocardiographic findings of degenerative (chordal or leaflet) mitral valve disease or ruptured papillary muscles. Patients who had a history of previous cardiac surgery were also excluded from the present study.

Patient data and follow-up

Patient data, including preoperative characteristics, operative data, and postoperative outcomes, were collected from the Juntendo CABG database. Remote outcomes were collected by serial contact (every 3 years) with patients or their families until September 2018. Study coordinators called participants to ask them about adverse events.

Study outcomes and definitions

The endpoints to compare the efficacy of the two strategies were hospital outcomes, all-cause death, and MACCEs. Postoperative death was defined as death within 30 days of surgery. Postoperative stroke was defined as a new stroke diagnosed on magnetic resonance imaging (MRI) or computed tomography (CT). Postoperative acute kidney injury was defined by a greater than 50% increase in the serum creatinine level from baseline. Cardiac death was defined as death by myocardial infarction, congestive heart failure, arrhythmia, or sudden death. The definition of MACCEs included all-cause death, nonfatal myocardial infarction, target vessel revascularization, heart failure requiring hospital admission, and stroke.

Moderate IMR was defined based on the presence of at least two of three criteria recommended by the American Society of Echocardiography: an effective regurgitant orifice area of 0.2 to < 0.4 cm^2; a vena contracta width of 3 to < 7 mm; and a ratio of the mitral regurgitant jet area to the left atrial area of 20% to < 40%.[5] Supportive criteria included the chamber size, the eccentricity of the jet, the E-wave height, and the pulmonary vein Doppler flow pattern. Qualifying transthoracic echocardiography was performed before surgery.

Operative procedures

All patients underwent surgery with median sternotomy. In isolated CABG cases, off-pump coronary artery bypass (off-pump CABG), which involves performing CABG on the beating heart without cardiopulmonary bypass, was generally performed.

In CABG and MVs cases, cardiopulmonary bypass was established with ascending aorta and right atrial cannulation. Cardiac arrest was obtained with both antegrade and retrograde blood cardioplegia. The strategies for mitral valve intervention were left to the discretion of the surgeons. Mitral valve repair was performed by restrictive mitral annuloplasty (MAP) using a artificial ring to correct annular dilatation. Mitral valve replacement was performed with preservation of the posterior leaflet or subvalvular apparatus. The techniques of mitral valve repair and the choice of prosthetic valve were determined by the surgeons.

Statistical analysis

Continuous variables are expressed as means ± standard deviation, and categorical data are tabulated as frequencies and percentages. These data were compared using Student's *t*-test and the χ^2 test or Fisher's exact test. The propensity score was calculated for each patient from the results of multivariate logistic regression analysis based on 9 preoperative covariates (sex, age, diabetes mellitus, eGFR, history of cerebrovascular accident, prior myocardial infarction, serum level of brain natriuretic peptide, LV ejection fraction, and sinus rhythm on ECG) as independent variables with CABG alone vs. CABG plus MVs as binary dependent variables. A higher propensity score indicated a higher probability of undergoing CABG plus MVs at baseline. Long-term all-cause death, cardiac death, and MACCEs were compared between the two groups.

Short-term postoperative complications were compared using multivariate regression analyses, adjusted for the European system for the cardiac operative risk evaluation score II (EuroSCORE II). The Kaplan-Meier method with the log-rank test was used for survival analyses. A Cox proportional-hazards model was used to assess the risks of combined MVs at the time of CABG. Values of $p<0.05$ were considered significant. All data were analyzed using SPSS version 23.0 for Windows (SPSS, Chicago, IL).

Results

Patients' characteristics and operative data

A total of 3,215 patients underwent CABG between 2002 and 2017. Of these patients, 101 who had multivessel coronary artery disease and moderate IMR were eligible for the study. These 101 patients were divided into two groups, 60 (59.4%) who underwent CABG alone and 41 (40.6%) who underwent CABG with MVs. Propensity score matching selected 40 pairs for final analysis. The characteristics used in propensity score matching are shown in Table 1. The p-value of the Hosmer-Lemeshow test for the model was 0.787, and the c-statistic (area under the ROC curve) was 0.707 (Figure 1). The mean propensity score of the CABG alone group was 0.50 ± 0.25, and that of the CABG plus MVs group was 0.58 ± 0.22. A higher propensity score indicated a higher probability of undergoing CABG with MVs at baseline.

The comparison of the baseline characteristics between the CABG alone and CABG plus MVs groups before and after propensity score matching is shown in Table 2. Even before propensity score matching, there were no significant differences between the two groups in the variables shown in Table 2.

Operative parameters are shown in Tables 3 and 4. Overall, 95% of patients (n = 38) in the CABG alone group underwent CABG without cardiopulmonary bypass (off-pump CABG). The number of coronary anastomoses was comparable between the two groups (3.7 ± 1.4 vs. 3.6 ± 1.7; p = 0.52). In the CABG alone group, the rate of using bilateral internal thoracic arteries was significantly higher (75.0% vs. 47.5%; p = 0.012), and saphenous vein grafts were less likely to be used (40.0% vs. 62.5%; p = 0.07). The mean operation time was significantly longer in the CABG plus MVs group than in the CABG alone group.

Preoperative echocardiogram data are shown in Table 5. The preoperative echocardiogram at baseline showed no significant differences between the two groups in LV ejection fraction (LVEF) (39.3% ± 12.8% vs. 36.7% ± 15.5%), LV size (LVDd, Ds, EDVI, ESVI), mitral annular diameter size, and degree of IMR or tethering (ERO and RV(PISA), tenting height).

Short-term outcomes

The postoperative short-term outcomes are shown in Table 6. (Those of the 101 overall patients are also shown in Table 6). There was no early death in the CABG alone group, and only one death in the CABG plus MVs group (1.25% of all matched patients. The incidences of stroke, respiratory failure or pleural effusion, acute kidney injury, and re-exploration for bleeding were similar between the two groups. When compared with the CABG alone group, the incidences of postoperative atrial fibrillation (37.5% vs. 62.5%, p = 0.025) and postoperative blood transfusion (40.0% vs. 75.0%, p = 0.002) were higher, and the mean lengths of ICU stay and hospital stay (3.2 days vs. 6.0 days, p = 0.084, 13.6 days vs. 18.1 days, p = 0.035, respectively) were much longer in the CABG plus MVs group.

Long-term outcomes

The mean follow-up period was 4.8 ± 3.5 years. Cumulative event-free curves with log-rank tests are shown in Figure 1-3. Long-term all-cause mortality (Figure 1), cardiac mortality (Figure 2), and the incidence of MACCEs (Figure 3) did not differ between the groups. Survival rates for patients in the CABG alone group were 80% and 45% at 5 years and 10 years, respectively. Hazard ratios calculated using Cox proportional hazard analyses are shown in Table 7. Survival rates for patients in the CABG plus MVs group were 77% and 56% at 5 years and 10 years, respectively. Concomitant MVs was not associated with an increased risk of long-term all-cause death or MACCE.

Conclusions

This propensity matched study evaluated the short-term and long-term efficacies of CABG alone and CABG plus MVs in patients with moderate IMR. In this study, combined mitral valve treatment was associated with increased risks of several postoperative adverse events (atrial fibrillation, postoperative blood transfusion, and prolonged lengths of ICU stay and hospital stay), but short-term mortality and the incidences of stroke, respiratory failure, acute kidney injury, and bleeding were similar between the two groups. Life-threatening events were not different between CABG alone and CABG plus MVs in the short-term. During the long-term follow-up period of 4.7 years, there were no differences between the two procedures in all-cause death, cardiac death, and the incidence of MACCEs. In addition, postoperative reverse remodeling was observed in both groups. These findings were consistent with two recent prospective, randomized trials.[6,7]

Some studies have shown that off-pump CABG was associated with lower risks of mortality, stroke, renal failure, RBC transfusion, prolonged ventilation, inotropic support, and intra-aortic balloon pumping support, especially in higher risk patients.[8-10] In the present study, almost all isolated CABGs were performed without cardiopulmonary bypass. Short-term mortality, cerebrovascular events, respiratory failure, and kidney injury were similar between the groups. It is interesting that life-threatening, short-term adverse events and long-term outcomes were not different between the two procedures, independent of the use of cardiopulmonary bypass. This result suggests that combined MVs can be performed in patients with moderate IMR relatively as safely as off-pump CABG. Probable explanations for this finding are improvements of cardiopulmonary bypass, cardioplegia, anesthesia, and perioperative medications.[11-14]

The statements for concomitant mitral valve treatment with CABG for patients with moderate IMR are relatively conservative. The latest American Association for Thoracic Surgery Consensus Guidelines, revised in 2016, include a conservative recommendation for MVs for moderate IMR (CORIIb, LOE B).[3] The American College of Cardiology / American Heart Association, published in 2017, recommendation for CABG plus MVs for moderate IMR is also relatively conservative (CORIIb, LOE B).[4] These statements' evidence levels were revised based on the results of recent randomized, controlled studies, but they still do not provide strong guidance as to which patients benefit most from either procedure.[6,7]

A recent randomized, prospective study, which randomized 301 patients with moderate IMR to isolated CABG or CABG plus MAP, showed no difference between the two procedures in LV reverse remodeling at two years after operation.[6,7] Mortality was 10.6% in patients undergoing CABG alone and 10.0% in patients undergoing CABG plus MVs (HR in the CABG plus MVs = 0.90; 95% CI: 0.45 – 1.83; p = 0.78). Although moderate or severe mitral residual regurgitation was more frequently observed in patients undergoing CABG alone, LV reverse remodeling was similar in the two procedures. The readmission rate and incidence of postoperative adverse events including neurological events and supraventricular arrhythmias were greater in patients undergoing CABG plus MVs. A recent meta-analysis that compared early and remote outcomes between CABG alone and CABG plus MVs for patients with moderate IMR also demonstrated no clinical benefits of additional mitral valve treatment.[15] This meta-analysis included 11 studies, and there were no differences in all-cause mortality, early mortality, and stroke rate between the two procedures. In addition, adverse events during follow-up were lower with CABG alone. Thus, they concluded that there was weak evidence to support MVs for moderate IMR at the time of CABG. These results were consistent with those of the present study.

On the other hand, these results contradicted more previous studies that compared CABG alone vs. CABG plus MVs in moderate IMR patients. Fattouch and colleagues reported the first prospective, randomized study of moderate IMR, comparing 54 patients undergoing CABG alone and 48 patients undergoing CABG plus MAP for an average of 32 months.[16] They showed that the addition of MAP to CABG significantly improved LV reverse remodeling, severity of mitral regurgitation, and NYHA functional class compared with CABG alone. Similarly, the Randomized Ischemic Mitral Evaluation (RIME) trial compared 34 patients undergoing CABG alone and 39 patients undergoing CABG with MVs among patients with moderate IMR.[17] The trial demonstrated that oxygen consumption, severity of mitral regurgitation, plasma B-type natriuretic peptide levels, and LV reverse remodeling were improved in patients assigned to CABG plus MVs compared to those assigned to CABG alone. These studies proved the beneficial effects of CABG plus MVs in patients with moderate IMR by showing that concomitant mitral valve restoration not only reduced the degree of severity of mitral valve regurgitation, but also provided an improvement in the NYHA functional class.

One can only speculate about why these discrepancies occurred among the results of these studies, since the mechanisms of IMR were various and complicated.[1,2] IMR is a disease of the left ventricle, and the severity of mitral regurgitation is defined by the function of the leaflets, chordae, papillary muscle, and left ventricle. Thus, patients' characteristics at baseline might be heterogeneous and imbalanced among these studies. Thus, we cannot simply decide which procedure is preferred in patients with moderate IMR, and we should focus on which kinds of patients' characteristics have an effect on postoperative outcomes. For example, when comparing the three clinical trials mentioned above, in the study by Fattouch and colleagues[16] and in the RIME trail,[17] patients had significantly higher rates of previous MI and larger LV size, and remodeling was more advanced than in the

CTSN trial[7] at baseline. Postoperative echocardiogram showed that the degree of reverse LV remodeling was greater in the first two studies than in the CTSN trial. In each of the three studies, the combined procedure group had a higher rate of postoperative residual or recurrent MR, but there was no significant difference in mortality. It would appear from these studies that combined MVs for moderate IMR is not associated with increased long-term survival, but may contribute to improvement of the other endpoints, including LV reverse remodeling, mitral regurgitation grade, and cardio-humoral factors, especially in patients who had larger ventricles and advanced LV remodeling at baseline. Conversely, patients with smaller ventricles at baseline can obtain benefit from LV reverse remodeling from CABG alone at the same level as with CABG plus MVs. Furthermore, in these studies, patients were selected only by the severity of mitral regurgitation, but the patients' clinical severity was not determined only by the severity of mitral regurgitation. Difficulty comparing between CABG alone and concomitant MVs for moderate IMR was probably driven by the other components that can predict patents' outcomes (e.g. SYNTAX score, LV ejection function, prior myocardial infarction, and ventricular asynergy area). Several studies have demonstrated that the presence of preoperative viable myocardium is closely related to improvements in LV wall motion, reverse LV remodeling, and downgrading of IMR after CABG. Penicka and colleagues demonstrated that reliable improvement in mitral regurgitation after surgery was limited to patients who had viable myocardium and less LV dyssynchrony between papillary muscles at baseline in patients with moderate IMR who underwent isolated CABG.[18] Conversely, patients whose cardiac muscle suffers ischemic changes for a long period and are less likely to have enough viability, and those who have less or no bypass target to the posterior-inferior-lateral area, which is fed by the left circumflex and right coronary circulations in most cases, are not better off with isolated CABG.[19] These findings may explain why various results were observed in studies that compared CABG alone and CABG plus MVs for patients with moderate IMR.

Therefore, in order to decide whether to add MVs to CABG in patients with moderate IMR, it is necessary to evaluate which patient may benefit most from CABG plus MVs rather than CABG alone, and as a matter of course, one must balance the benefits of additional MVs against the risks of adverse perioperative events. Preoperative evaluation of several factors, severity of MR, enlargement of the left atrium or dilatation of the mitral annulus, LV size and degree of remodeling, severity of LV dysfunction, presence of LV scar tissue or myocardial viability, and presence of an efficient bypass target to the posterior-inferior-lateral area, might be helpful to determine the surgical plan, although there has been insufficient validation.[3,7] To assess these variables, preoperative stress echocardiography and cardiac catheterization, single photon emission computed tomography (SPECT), and functional cardiac MRI are preferred, if possible.[20,21] In deciding on additional MVs, the presence of symptoms due to IMR, such as dyspnea, shortness of breath, and heart failure, are also important. In addition, we should consider patient factors or comorbidities such as age, frailty, number of bypass targets, renal failure, respiratory failure, peripheral artery disease, thoracic aortic calcification, arteriosclerosis, previous cerebral infarction, etc. The surgeon's experience with MVs is important as well, because the effect of mitral valve repair depends on the accuracy with which it is performed, and if the surgeon lacks experience with mitral valve repair, not adding MVs may be better in order to decrease the duration and total risk of the operation.

Study limitations

Despite the prospective collection of operative data, this was a retrospective study in a single institution. Although propensity score analysis was performed, the number of patients was small because moderate IMR is an unusual disease. This study was susceptible to various sources of bias. Whether or not to add MVs was not decided based on specific preoperative criteria, and as mentioned above, the surgeon determined the surgical plan based on various kinds of center/patient-specific factors. In some cases, the decision to add MVs was made based on findings of the intraoperative transesophageal echocardiogram (TEE). However, the degree of IMR changes is dependent on preload and afterload; thus, it is difficult to interpret during the changing hemodynamics under general anesthesia. There was a potential risk of underestimating intraoperative IMR in this study.

Another limitation is that clinical outcomes related to heart-failure symptoms such as NYHA class were not assessed, and neither were improvements of patients' quality of life and physical function, which might be the benefits of a lower incidence of postoperative MR by additional MVs, as reported in some studies.

In conclusion, in the present study there were no differences between CABG alone and CABG plus MVs in postoperative complications, except for postoperative atrial fibrillation and length of hospital stay, which were higher in patients who underwent CABG plus MVs. This result suggests that surgical treatment of moderate IMR combined with CABG might be as safe as isolated CABG (off-pump CABG). In contrast, surgical treatment of moderate IMR did not improve long-term outcomes, including all-cause mortality, cardiac mortality, and the incidence of MACCEs. In patients with moderate IMR, the indication for concomitant mitral valve surgery and the problem of whether to replace or repair, and whether to add subvalvular and leaflet approaches to ring annuloplasty, remain controversial. Further studies are needed to determine the effects of MVs in patients with moderate IMR with severe coronary artery disease.

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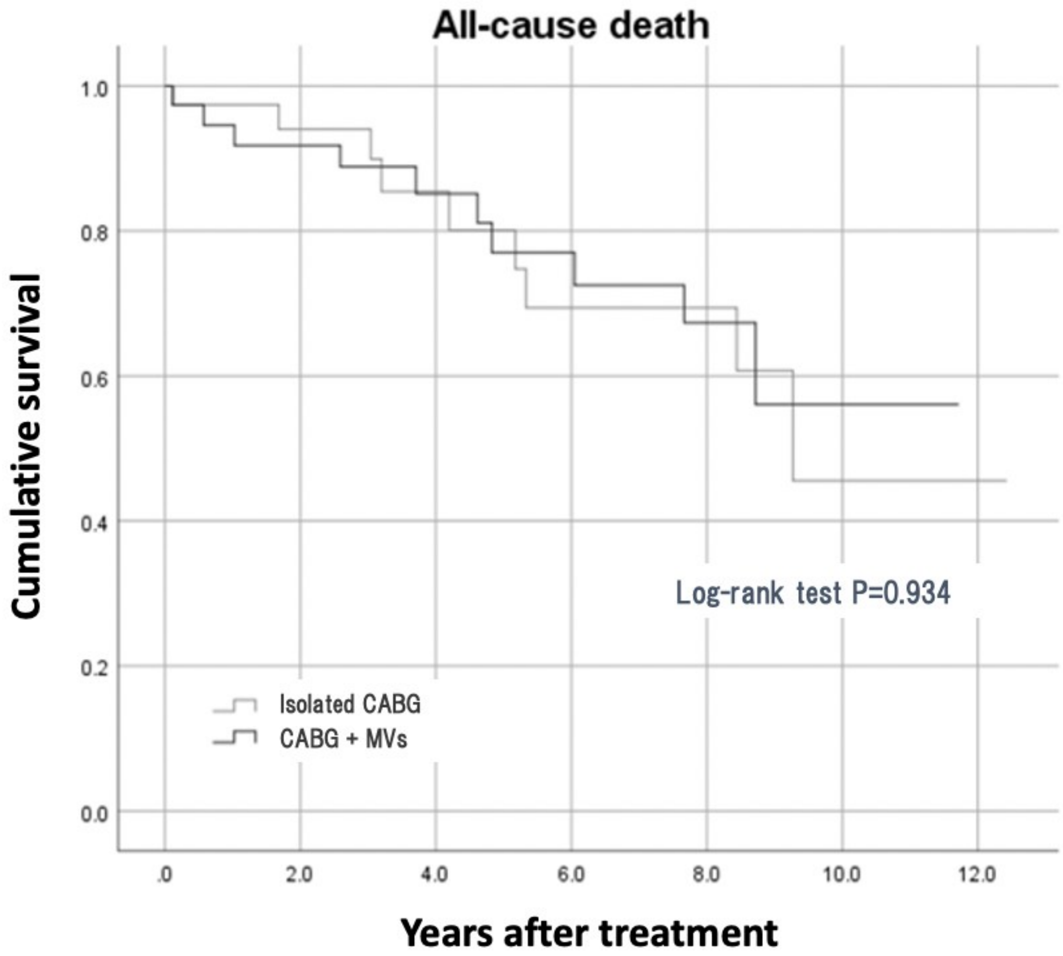
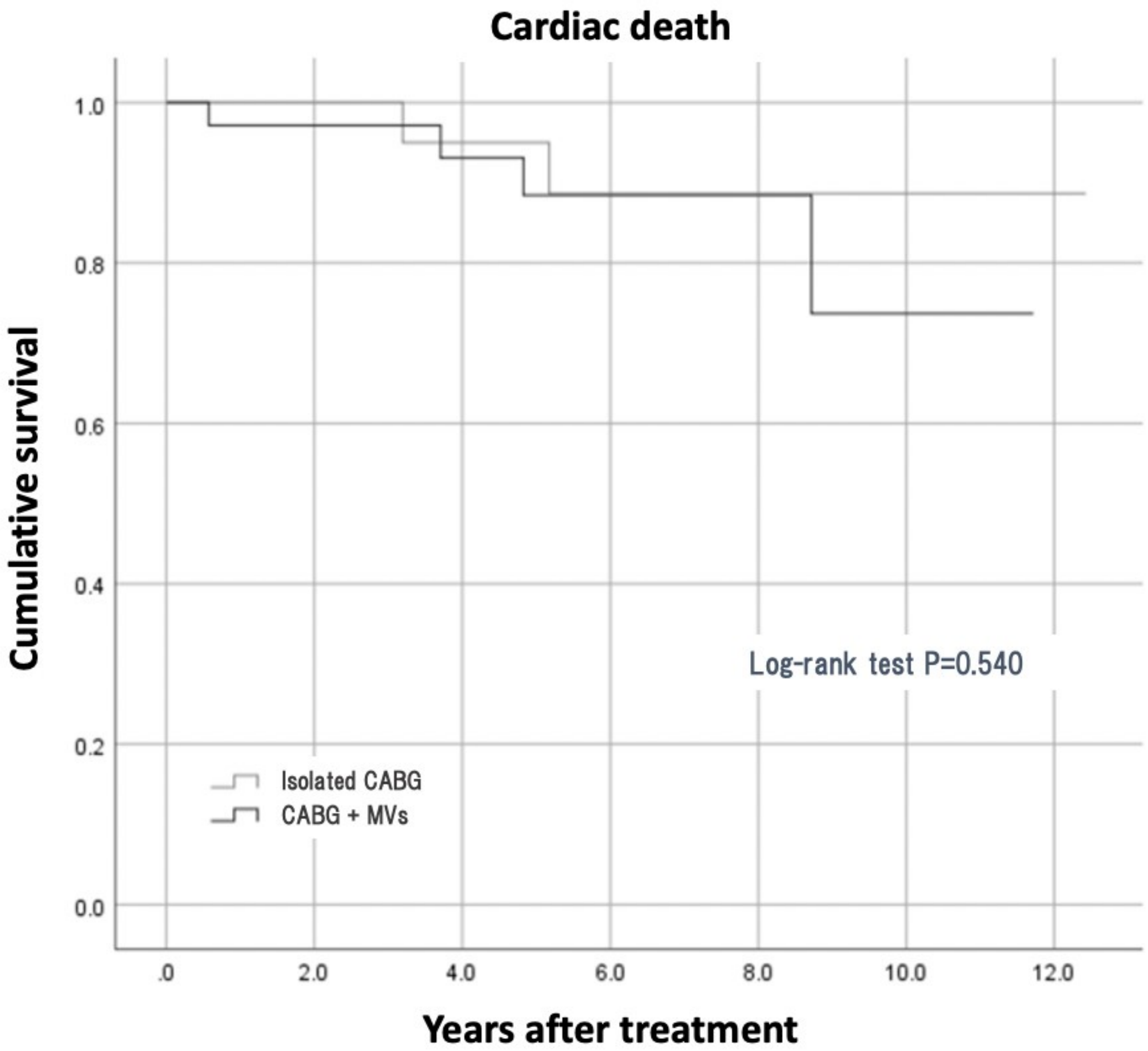
Figure Legends

Figure 1. Kaplan-Meier survival curves for all-cause death



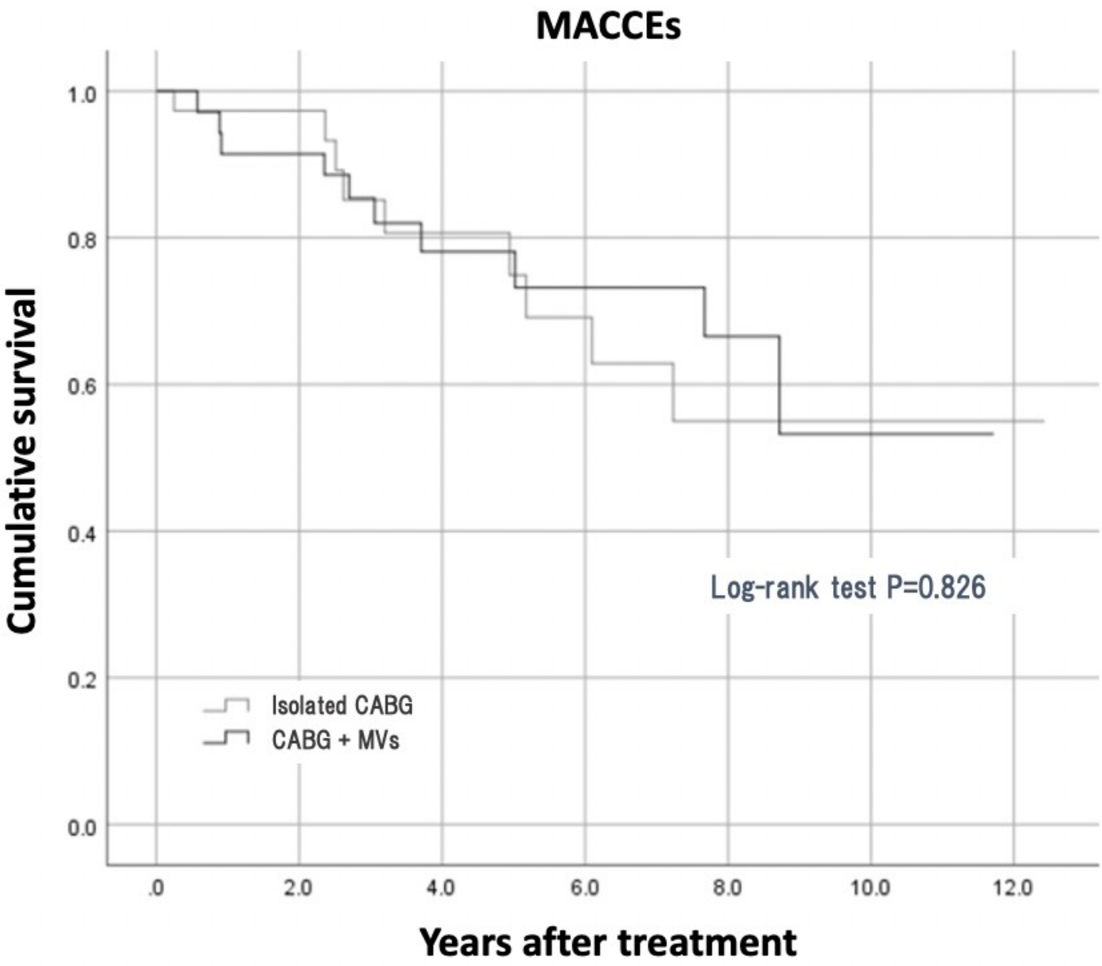
			5 years	10 years
CABG	At risk	40	15	2
	Survival		80%	45%
CABG + MVS	At risk	40	19	4
	Survival		77%	56%

Figure 2. Kaplan-Meier survival curves for cardiac death



			5 years	10 years
CABG	At risk	40	15	2
	Survival		95%	88%
CABG + MVS	At risk	40	19	4
	Survival		88%	73%

Figure 3. Kaplan-Meier survival curves for MACCEs



			5 years	10 years
CABG	At risk	40	13	2
	Survival		82%	60%
CABG + MVS	At risk	40	18	3
	Survival		84%	63%

Table 1. Logistic regression model for propensity score matching

Covariate	**B coefficient**	**Exp(B) [95% CI]**
Sex, male	0.56	1.75 [0.46-6.60]
Age	-0.01	0.99 [0.93-1.05]
BSA	1.22	3.40 [0.16-70.97]
Diabetes	-0.66	0.52 [0.19-1.35]
Dyslipidemia	-0.81	0.45 [0.16-1.22]
Hypertension	-0.28	0.76 [0.25-2.22]
Serum creatinine level	0.15	1.16 [0.94 -1.42]
History of CVA	-0.86	0.42 [0.10-1.75]
History of PAD	0.37	1.45 [0.41-5.08]
History of MI	-0.69	0.50 [0.12-1.99]
BNP	0.00	1.00 [0.99-1.00]
LVEF	-0.03	0.97 [0.93-1.00]
Sinus rhythm	1.20	3.31 [0.78-13.98]

BNP, brain natriuretic peptide; BSA, body surface area; CVA, cerebrovascular accident; LVEF, LV ejection fraction; MI, myocardial infarction; PAD, peripheral artery disease

	Before matching			**After matching**		
	CABG (N=60)	CABG + MVs (N=41)	p-value	CABG (N=40)	CABG + MVs (N=40)	p-value
Age (y) mean ± SD	68.9 ± 9.4	68.2 ± 8.6	0.720	69.5 ± 9.6	68.2 ± 8.7	0.536
Sex male, n (%)	48 (80.0%)	33 (80.4%)	0.556	34 (85.0%)	32 (80.0%)	0.562
Diabetes mellitus, n (%)	37 (61.6%)	21 (51.2%)	0.314	25 (62.5%)	21 (52.5%)	0.372
HbA1c (%), mean ± SD	6.4 ± 1.1	6.1 ± 1.2	0.225	6.4 ± 1.1	6.1 ± 1.2	0.255
Peripheral vascular disease, n (%)	8 (13.3%)	7 (17.0%)	0.777	6 (15.0%)	7 (17.5%)	0.765
History of cerebrovascular accident, n (%)	10 (16.6%)	5 (12.1%)	0.373	7 (17.5%)	4 (10.0%)	0.336
Preoperative AF, n (%)	4 (6.6%)	7 (17.0%)	0.094	3 (7.5%)	7 (17.5%)	0.181
Serum Cr level (mg/dL), mean ± SD	2.1 ± 2.5	2.5 ± 3.0	0.418	2.0 ± 2.2	2.4 ± 3.0	0.467
Serum TG level (mg/dL), mean ±	118.0 ± 59.4	111.8 ± 46.2	0.576	115.0 ± 56.9	112.9 ± 46.2	0.857

SD						
Serum LDL cholesterol level (mg/dL), mean ± SD	102.8 ± 38.8	100.8 ± 29.7	0.787	93.6 ± 36.4	100.5 ± 30.0	0.363
Serum HDL cholesterol level (mg/dL), mean ± SD	43.1 ± 11.3	43.6 ± 12.3	0.914	44.4 ± 11.9	43.4 ± 12.5	0.727
BNP (pg/mL), mean ± SD	760.8 ± 1512.6	613.2 ± 781.0	0.574	504.7 ± 568.6	613.2 ± 781.0	0.480
LVEF (%), mean ± SD	41.1 ± 13.2	37.6 ± 16.5	0.251	37.5 ± 11.2	34.8 ± 14.5	0.382
EuroSCORE II (%), mean ± SD	6.8 ± 8.6	7.5 ± 6.9	0.699	5.9 ± 7.7	7.5 ± 6.9	0.365
Japan SCORE (%), mean ± SD	5.6 ± 11.9	7.5 ± 12.2	0.497	5.5 ± 13.1	7.5 ± 12.2	0.516

Table 2. Baseline characteristics of patients undergoing CABG alone vs. CABG + MVs

AF, atrial fibrillation; BNP, brain natriuretic peptide; Cr, creatinine; HbA1c, hemoglobin A1c; LVEF, LV ejection fraction; TG, triglycerides

	CABG (N=40)	**CABG + MVs (N=40)**	**p-value**
Preoperative IABP, n (%)	2 (5.0%)	1 (2.5%)	0.556
Number of grafts selected, mean ± SD	2.7 ± 0.7	2.4 ± 0.7	0.142
Left internal thoracic artery, n (%)	39 (97.5%)	35 (87.5%)	0.090
Bilateral internal thoracic artery, n (%)	30 (75.0%)	19 (47.5%)	0.012
Radial artery, n (%)	3 (7.5%)	2 (5.0%)	0.644
Gastroepiploic artery, n (%)	20 (50.0%)	17 (40.2%)	0.501
Saphenous vein graft, n (%)	16 (40.0%)	25 (60.2%)	0.044
Number of distal anastomoses, mean ± SD	3.7 ± 1.4	3.6 ± 1.7	0.725
Off-pump surgery	38 (95%)	0 (0.0%)	
Operation time duration (min), mean ± SD	300.3 ± 74.4	468.2 ± 124.2	< 0.001
Aorta cross clump time (min), mean ± SD	-	105.8 ± 51.2	
Cardiopulmonary bypass (min), mean ± SD	159.0 ± 14.1	188.3 ± 76.0	0.586

Table 3. Operative data of patients undergoing CABG alone vs. CABG + MVs

IABP, intra-aortic balloon pump

Procedure	CABG + MVs (N=40)
Mitral annuloplasty (MAP) alone, n (%)	17 (42.5%)
MAP + Procedure of MV leaflet or subvalvular apparatus, n (%)	19 (47.5%)
Leaflet edge-to-edge repair, plication, chordal cutting, n (%)	7 (17.5%)
Chordal cutting, n (%)	5 (12.5%)
Papillary muscle approximation (PMA), n (%)	10 (25.0%)
LV reconstruction, n (%)	5 (12.5%)
Mitral valve replacement, n (%)	4 (10.0%)

Table 4. Details of mitral valve procedures

	CABG (N=40)	CABG + MVs (N=40)	p-value
Left atrial diameter (mm), mean ± SD	44.7 ± 6.7	47.3 ± 8.8	0.192
Mitral annulus diameter (mm), mean ± SD	34.1 ± 5.5	31.5 ± 3.8	0.105
LV diastolic dimension (mm), mean ± SD	58.5 ± 7.3	59.2 ± 7.7	0.735
LV systolic dimension (mm), mean ± SD	48.6 ± 10.0	47.6 ± 11.5	0.720
LV EDVI (mL/m^2), mean ± SD	101.9 ± 38.0	110.7 ± 41.3	0.388
LV ESVI (mL/m^2), mean ± SD	64.6 ± 31.5	74.6 ± 39.8	0.278
ERO (PISA), mean ± SD	0.26 ± 0.06	0.26 ± 0.08	0.827
RV (PISA) (mL), mean ± SD	39.3 ± 10.8	42.5 ± 15.7	0.443
Tenting height (mm), mean ± SD	10.8 ± 2.3	9.8 ± 2.0	0.178
LVEF (%), mean ± SD	37.5 ± 11.2	34.8 ± 14.5	0.382

Table 5. Preoperative echocardiography of patients undergoing CABG alone vs. CABG + MVs

Dd, diastolic dimension; Ds, systolic dimension; EDVI, end-diastolic volume index; ERO, effective regurgitant orifice; ESVI, end-systolic volume index; LV, left ventricular; LVEF, LV ejection fraction; RV, regurgitant volume

A	CABG (N=40)	CABG + MVs (N=40)	p-value
In-hospital death, n (%)	0 (0.0%)	1 (2.5%)	0.314
Postoperative AF, n (%)	15 (37.5%)	25 (62.5%)	0.025
Postoperative stroke, n (%)	1 (2.5%)	1 (2.5%)	1.0
Respiratory failure / Pleural effusion, n (%)	6 (15.0%)	12 (30%)	0.108
Acute kidney injury, n (%)	3 (7.5%)	6 (15.0%)	0.288
Blood transfusion, n (%)	16 (40.0%)	30 (75%)	0.002
Re-exploration for bleeding, n (%)	0 (0.0%)	0 (0.0%)	
Length of ICU stay (day), mean ± SD	3.2 ± 4.1	6.0 ± 9.3	0.089
Length of hospital stay (day), mean ± SD	13.6 ± 8.9	18.1 ± 9.6	0.035

B	CABG (N=60)	CABG + MVs (N=41)	p-value
In-hospital death, n (%)	3 (5.0%)	2 (%)	0.676
Postoperative AF, n (%)	22 (36.6%)	26 (63.4%)	0.007
Postoperative stroke, n (%)	1 (1.6%)	1 (2.4%)	0.650
Respiratory failure / Pleural effusion, n (%)	13 (21.6%)	13 (31.7%)	0.183
Acute kidney injury, n (%)	6 (10.0%)	6 (14.6%)	0.343
Blood transfusion, n (%)	25 (41.6%)	31 (75.6%)	0.001
Re-exploration for bleeding, n (%)	0 (0.0%)	1 (2.4%)	0.406
Length of ICU stay (day), mean ± SD	3.2 ± 3.5	5.8 ± 9.2	0.089
Length of hospital stay (day), mean ± SD	13.4 ± 8.4	17.7 ± 9.8	0.021

Table 6. Hospital outcomes of patients undergoing CABG alone vs. CABG + MVs

A) Matched patients; B) All 101 patients

Abbreviations: AF, atrial fibrillation; LVEF, left ventricular ejection fraction

	Hazard ratio	95% confidence interval	p-value
All-cause death	1.20	0.39 – 2.37	0.96
Cardiac death	1.69	0.30 – 9.28	0.53
MACCEs	0.90	0.36 – 2.23	0.82

Table 7. Hazard ratios for all-cause mortality, cardiac death, and MACCE

Hazard ratios use the CABG alone group as the control.

Abbreviations: MACCEs, major adverse cardiac and cerebrovascular events