Determinants of operative mortality in elderly patients undergoing coronary artery bypass grafting

Emphasis on the influence of internal mammary artery grafting on mortality and morbidity

Coronary artery bypass grafting has been performed for elderly patients (≥ 70 years) with increasing frequency. From January 1986 through June 1993, 1399 elderly patients underwent isolated coronary bypass grafting. Of these patients, 823 had saphenous vein grafts alone and 576 had internal mammary artery grafting, including unilateral ($n = 546$) and bilateral ($n = 28$). Overall operative mortality was 8.86%. Operative mortality for unilateral internal mammary artery grafting (6.41%) was lower than for saphenous vein grafting only (9.96%, $p = 0.021$) and bilateral internal mammary artery grafting (21.43%, $6/28$, $p = 0.018$). Fewer patients undergoing internal mammary artery grafting had postoperative complications (low cardiac output, intraaortic balloon pumping, and neurologic complications) than patients having saphenous vein grafting only. To determine risk factors for mortality and the influence of internal mammary artery grafting on the outcome, we analyzed 55 variables (27 preoperative, 15 intraoperative, and 13 postoperative) by univariate analysis. Significant variables (age, gender, height, weight, surface area, diabetes, obesity, body mass index, history of congestive heart failure, myocardial infarction, or arrhythmia, functional class, left ventricular ejection fraction, stenosis of the left anterior descending or right coronary artery, emergency operation, reoperation, number of grafts, perfusion time, and bilateral or right internal mammary artery grafting) were included in a stepwise multiple logistic regression analysis. The logistic regression demonstrates that those preoperative (history of congestive heart failure or myocardial infarction, low ejection fraction, female gender, and old age), intraoperative (long cardiopulmonary bypass time, emergency operation, reoperation, and use of right internal mammary artery grafting), and postoperative (postoperative complications) variables are independently associated with higher mortality. This study reveals the high-risk groups in elderly patients undergoing coronary bypass and suggests that a left internal mammary artery graft in combination with saphenous vein grafting may achieve a lower operative mortality and morbidity than other procedures in selected elderly patients undergoing coronary artery bypass grafting. (*J THORAC CARDIOVASC SURG* 1994;108:73-81)

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Coronary artery bypass grafting (CABG) has been performed for elderly patients (≥ 70 years) with increasing frequency because of the increasing number of elderly patients in the general population, the increasing safety of CABG in general, the increasing prevalence of coronary artery disease, and the higher mortality rate after acute myocardial infarction.^{1, 2} The operative mortality and morbidity for patients older than 70 years of age undergoing isolated CABG are higher than those in younger patients.³⁻¹² A large experience from the Cleve-

Table I. Characteristics for elderly patients (≥ 70 years) having IMA grafting or having saphenous vein grafting only

	IMAG (n = 576)	SVG (n = 823)	p Value
Gender			
Male	422	472	
Female	154	351	0.000
Age (yr)	74.05 $\pm$ 0.13	75.89 $\pm$ 0.14	0.0001
Age ≥ 80 (yr)	26 (4.51%)	129 (15.67%)	0.000
Emergency operation	31/565 (5.5%)	87/799 (10.89%)	0.000
Mortality	42/576 (7.29%)	82/823 (9.96%)	0.084
Diabetes	112/576 (19.44%)	193/823 (23.45%)	0.074
Obesity	184/576 (31.94%)	221/823 (26.85%)	0.039
History of CHF	71/576 (12.33%)	153/823 (18.59%)	0.002
History of MI	279 (48.44%)	498 (60.51%)	0.000
NYHA			
I	5	6	
II	63	73	
III	258	380	
IV	177	268	0.56
Ejection fraction	53.88 $\pm$ 0.45	49.96 $\pm$ 0.46	0.0001
No. of vessels diseased			
Single	23	34	
Double	72	145	
Triple	443	541	0.006
Left main stenosis	61	81	0.648
No. of grafts			
1	20	36	
2	53	129	
3	208	379	
4	219	239	
5	71	38	
6	5	2	0.000
Mean	3.49 $\pm$ 0.04	3.15 $\pm$ 0.03	0.0001
Myocardial protection			
Cardioplegia			
Blood	64	134	
Crystalloid	506	677	
Oxygenated crystalloid	2	1	0.021
Aortic crossclamp time (min)	54.19 $\pm$ 0.73	44.84 $\pm$ 0.69	0.0001
Cardiopulmonary bypass time (min)	109.53 $\pm$ 2.33	101.97 $\pm$ 1.21	0.004
Postoperative complications*	221/575 (38.43%)	442/821 (53.84%)	0.000
Perioperative MI	10 (1.74%)	21 (2.55%)	0.308
Pulmonary complications	63/539 (11.69%)	126/776 (16.24%)	0.02
Ventilation >5 days	3 (0.52%)	18 (2.19%)	0.012
Renal	30/539 (5.57%)	65/776 (8.38%)	0.053
Low cardiac output	12 (2.08%)	59 (7.17%)	0.000
Insertion of IABP	35 (6.08%)	127 (15.43%)	0.000
Neurologic complications	30/539 (5.57%)	66/776 (8.51%)	0.044
Transient stroke	5 (0.87%)	19 (2.31%)	0.04
Permanent stroke	8 (1.39%)	24 (2.92%)	0.06
Sternal infection			
Deep	2 (0.35%)	6 (0.73%)	0.35
Superficial	3 (0.52%)	7 (0.85%)	0.47
Reoperation for bleeding	29 (5.03%)	62 (7.53%)	0.062
Requirement for blood transfusion			
Pack cell	263/539 (48.79%)	402/775 (51.87%)	0.377
FFP	(3.95 $\pm$ 0.22)	(4.35 $\pm$ 0.19)	0.17
Cryoprecipitate	136/512 (26.56%)	244/731 (33.38%)	0.01
Platelet	(3.63 $\pm$ 0.26)	(4.42 $\pm$ 0.31)	0.0486
	27/491 (5.5%)	61/664 (9.19%)	0.02
	(12.11 $\pm$ 1.46)	(13.89 $\pm$ 1.33)	0.43
	91/508 (17.91%)	180/707 (25.46%)	0.002
	(14.67 $\pm$ 1.09)	(15.04 $\pm$ 0.93)	0.8

IMAG, Internal mammary artery grafting; SVG, saphenous vein grafting only; CHF, congestive heart failure; MI, myocardial infarction; NYHA, New York Heart Association; IABP, intraaortic balloon pumping; FFP, fresh frozen plasma.

*Postoperative complications include any complications that occurred postoperatively: They are operative complications, infection, neurologic, pulmonary, renal, vascular, arrhythmia, postcardiotomy syndrome, anticoagulant complications, pericarditis, coagulopathy, multisystem failure, heart block, gastrointestinal complications, pneumothorax, thrombophlebitis, cardiac arrest, CHF, and tamponade.

Table II. Cause of operative mortality

Cause of death	No. of patients	Percentage
Cardiac	63	50.81
Pulmonary	20	16.13
Neurologic	9	7.26
Renal	12	9.68
Vascular	6	4.84
Infection	12	9.68
Other	2	1.61
Total	124	100

land Clinic identified that the risk factors for operative mortality are age 75 years or older, cigarette smoking, left ventricular impairment, and female gender.¹³ On the other hand, although superior patency rates and low mortality of internal mammary artery (IMA) grafting have promoted the use of left IMA grafting in either young patients or elderly patients, little has been known about the influence of IMA grafting, particularly the role of bilateral IMA grafting, on operative mortality and morbidity in the elderly.¹⁴ The present study was designed to investigate high-risk groups in elderly patients undergoing isolated CABG with emphasis on the influence of IMA grafting on outcome in these patients.

Patients and methods

From January 1986 through June 1993, a total of 6360 patients underwent isolated CABG. Of these patients, 1399 were elderly (≥ 70 years old) with a mean age of 75.13 ± 0.10 (range 70 to 93.0) years. Patients who had a concomitant valve operation or resection of ascending aortic aneurysm were excluded from this study. Among these patients, 823 had saphenous vein grafts alone and 576 had IMA grafting including unilateral ($n = 546$) and bilateral ($n = 28$) IMA grafting with or without additional saphenous vein grafting. A computerized cardiac surgery registry based on the Society of Thoracic Surgeons database provided the basis for this study. Operative death was defined as any in-hospital death (≤ 30 days and > 30 days within the hospital) and any death that occurred after discharge from the hospital but within 30 days after operation.

The clinical characteristics were recorded by cardiologists. The criterion of obesity was based on the body mass index. Body mass index was calculated by dividing measured body weight in kilograms by the height in meters squared. A body mass index greater than 27.5 kg/m^2 (over 120% "normal" body mass index) was considered as obesity.¹⁵ Perioperative myocardial infarction was defined as new Q waves and was diagnosed by cardiologists or surgeons.

Catheterization data. All patients underwent preoperative left-heart catheterization and coronary angiography. Patients were grouped into categories of single, double, and triple vessel disease. Significant coronary artery disease was defined as 70% or more stenosis in any view of the right, left anterior descending, or left circumflex artery or their major branches. Left main artery disease was defined as 50% or more stenosis. Left ventricular ejection fraction was calculated according to left ventriculography. Left ventricular function was classified as

Table III. Significant preoperative variables for operative mortality in elderly patients undergoing CABG according to univariate analysis

Variable	Mortality (%)	p Value
Sex		
Male	65/894 (7.27%)	0.005
Female	59/505 (11.68%)	
Age (yr)		
Survival (75.03 ± 0.11)		0.0055
Death (76.17 ± 0.39)		
Weight (kg)		
Survival (77.15 ± 1.13)		0.0002
Death (70.22 ± 1.42)		
Height (cm)		
Survival (171.09 ± 0.31)		0.0045
Death (168.14 ± 1.09)		
Surface area (m^2)		
Survival (1.91 ± 0.01)		0.0002
Death (1.82 ± 0.02)		
Body mass index (kg/m^2)		
Survival (0.002612)		0.0052
Death (0.002472)		
Diabetes		
Yes	36/305 (11.80%)	0.065
No	88/1094 (8.04%)	
History of CHF		
Yes	43/224 (19.20%)	0.000
No	81/1175 (6.89%)	
History of MI		
Yes	91/777 (11.71%)	0.000
No	33/622 (5.31%)	
History of arrhythmia		
Yes	51/460 (11.09%)	0.041
No	73/939 (7.77%)	
NYHA class		
I	0/11 (0%)	0.000
II	4/136 (2.94%)	
III	42/638 (6.58%)	
IV	64/445 (14.38%)	
I/II	4/147 (2.72%)	
III/IV	106/1083 (9.79%)	0.005
Ventricular function		
Normal	40/733 (5.46%)	0.000
Mild dysfunction	28/287 (9.76%)	
Moderate dysfunction	21/165 (12.73%)	
Severe dysfunction	20/67 (29.85%)	
Ejection fraction		
Survival (52.22 ± 0.34)		0.0001
Death (44.97 ± 1.26)		
LAD stenosis		
0%-50%	2/6 (33.33%)	0.024
51%-70%	4/55 (7.27%)	
71%-90%	21/332 (6.33%)	
91%-99%	48/583 (8.23%)	
100%	33/273 (12.09%)	

CABG, Coronary artery bypass grafting; CHF, congestive heart failure; MI, myocardial infarction; NYHA, New York Heart Association; LAD, left anterior descending coronary artery.

normal (ejection fraction $\geq 50\%$) and mild (ejection fraction 40% to 50%), moderate (ejection fraction 30% to 39%), or severe (ejection fraction $<30\%$) dysfunction. Stenosis of the left anterior descending or the right main coronary artery was classified as 0% to 50%, 51% to 70%, 71% to 90%, 91% to 99%, and 100% stenosis.

Operative technique. A similar operative technique was used throughout this experience. For patients undergoing IMA grafting, after the sternotomy, the left IMA was mobilized from the chest wall. Low-voltage electrocoagulation was used to avoid thermal damage to the IMA. The IMA was mobilized from its origin to the distal end close to the bifurcation. The IMA pedicle was then wrapped with a gauze swab immersed in papaverine solution. In patients undergoing bilateral or right IMA grafting, the right IMA was then mobilized by means of a similar technique. After heparinization, the IMAs were divided distally and free flow was examined. The decision of grafting diseased coronary arteries with which IMA or saphenous vein grafts was made according to the individual surgeon's preference. Coronary anastomosis was performed with continuous 8-0 Prolene suture (Ethicon, Inc., Somerville, N.J.) for IMA grafting and 7-0 suture for saphenous vein grafting using magnification. Moderate systemic hypothermia was used. Myocardial protection was achieved by antegrade and/or retrograde infusion of cardioplegic solution and topical cooling. The proximal anastomosis was performed on bypass for saphenous vein grafting. The sternum was closed with interrupted 18-gauge stainless steel wires. The fascial tissue and subcutaneous tissue were closed with running absorbable suture and the skin was closed with continuous subcuticular suture.

Indications for IMA grafting. Left IMA, as the primary arterial conduit, was used for left coronary branches, particularly for the left anterior descending artery. In general, selection of patients for a second IMA graft was primarily preferred for younger patients with good ventricular function. Thus there were only 28 patients who underwent bilateral IMA grafting (2.0%) throughout this experience. In these patients, a right IMA would be grafted to the mid or distal right coronary artery or alternatively be placed on a large obtuse marginal artery or left anterior descending artery. Use of the distal branch of the IMA was avoided if possible. Free right IMAs were used to graft onto the distal right coronary artery or obtuse marginal branch of the left coronary artery in three patients.

Statistical analysis. The correlation between preoperative, intraoperative, and postoperative variables and operative mortality was tested by univariate analysis; the comparison of operative mortality and morbidity between the patients having IMA grafting and saphenous vein grafting were also analyzed. After the univariate analysis, logistic regression was used to further test significant variables in a multivariate situation. Univariate testing of discrete variable comparisons was performed with χ^2 analysis or Fisher's exact test. The unpaired *t* test was used on continuous variable comparisons. Stepwise multiple logistic regression analysis was then used to further test significant variables in a multivariate situation.¹⁶⁻²² Any variables that had trends to be associated with operative mortality ($p < 0.2$) were also included in stepwise multiple logistic regression analysis. To investigate the influence of IMA grafting on the operative mortality, we included IMA grafting, unilateral, bilateral, and right IMA grafting in the logistic regression model to test the significance. The univariate analysis and the logistic regression were performed with the SAS program (SAS Institute Inc., Cary,

N.C.) in an IBM-compatible personal computer linked with a VAX computer (Digital Equipment Corp., Maynard, Mass.). A *p* value of less than 0.05 was considered significant.

Results

Mortality. Overall operative mortality was 8.86%. Operative mortality for unilateral IMA grafting (6.41%) was lower than that for saphenous vein grafting (9.96%, $p = 0.021$) and bilateral IMA grafting (21.43%, 6/28, $p = 0.018$). Table I lists the characteristics for patients receiving IMA and saphenous vein grafts. The causes of death are listed in Table II.

Univariate analysis. To determine the risk factors correlated to the operative mortality in the elderly patients, we performed univariate analysis for 55 variables including 27 preoperative, 15 intraoperative, and 13 postoperative variables (see appendix). Tables I, III, and IV list the significant variables for the operative mortality. The average age of operative survivors (75.03 ± 0.11 years) was younger than that of deceased patients (76.17 ± 0.39 years, $p = 0.0055$), although the higher mortality in the patients older than 80 years (20/155, 12.9%, versus 104/1244, 8.36%) did not reach statistical significance ($p = 0.061$). Female patients had higher mortality (11.68%) than male patients (7.27%, $p = 0.005$). Other preoperative variables associated with the operative mortality were weight, height, surface area, body mass index, diabetes, history of congestive heart failure, myocardial infarction or arrhythmia, New York Heart Association class, left ventricular ejection fraction, and stenosis of the left anterior descending coronary artery. Perioperative (intraoperative and postoperative) variables associated with the operative mortality were emergency operation, reoperation, number of grafts, use of bilateral IMA grafting, use of right IMA grafting, perfusion time, intraaortic balloon pumping, postoperative complications (including any of the postoperative complications listed under Table I), postoperative low cardiac output, reoperation for bleeding, perioperative myocardial infarction, neurologic complications (transient or permanent stroke), and stroke (permanent).

Multivariate analysis. Significant preoperative variables (gender, age, height, weight, surface area, diabetes, obesity, body mass index, history of myocardial infarction, history of congestive heart failure and arrhythmia, New York Heart Association class, left ventricular function, ejection fraction, left anterior descending artery stenosis, and right coronary artery stenosis) and intraoperative variables (emergency operation, reoperation, number of grafts, bilateral or right IMA grafting, and perfusion time) were included in the multiple logistic regression analysis for the operative mortality. The post-

Table IV. Significant perioperative variables for operative mortality in the elderly patients undergoing CABG by univariate analysis

Variable	Mortality	p Value
Emergency operation		
Yes	26/118 (22.03%)	0.000
No	95/1246 (7.62%)	
Reoperation		
Yes*	22/125 (17.60%)	0.000
No	102/1274 (8.01%)	
No. of grafts		
Survival (n = 1275)		0.03
3.31 ± 0.03		
Death (n = 124)		
3.11 ± 0.08		
IMAG	42/576 (7.29%)	0.084
SVG only	82/823 (9.96%)	
Details of IMAG		
LIMA (±SVG)	33/533 (6.19%)	0.003
BIMA (±SVG)	6/28 (21.43%)	
RIMA (±SVG)	2/13 (15.38%)	
SVG only	82/823 (9.96%)	
UIMAG versus SVG only		
UIMAG	35/546 (6.41%)	0.021
SVG only	82/823 (9.96%)	
BIMAG versus UIMAG/SVG		
BIMAG	6/28 (21.43%)	0.018
UIMAG/SVG	118/1371 (8.61%)	
RIMAG versus other		
RIMAG	8/41 (19.51%)	0.015
Other	116/1358 (8.54%)	
Perfusion time (min)		
Survival (n = 1268)		0.0000
103.10 ± 1.23		
Death (n = 122)		
125.68 ± 4.46		
IABP		
Yes	63/162 (38.89%)	0.000
No	61/1237 (4.93%)	
Operative complications†		
Yes	69/198 (34.85%)	0.000
No	49/1117 (4.39%)	
Postoperative low cardiac output		
Yes	45/71 (63.38%)	0.000
No	79/1308 (5.95%)	
Reoperation for bleeding		
Yes	20/91 (21.98%)	0.000
No	104/1308 (7.95%)	
Perioperative myocardial infarction		
Yes	11/31 (35.48%)	0.000
No	113/1368 (8.26%)	

CABG, Coronary artery bypass grafting; IMAG, internal mammary artery grafting; SVG, saphenous vein grafting; LIMA, left internal mammary artery; BIMA (G), bilateral internal mammary artery (grafting); RIMA (G), right internal mammary artery (grafting); UIMAG, unilateral internal mammary artery grafting; IABP, intraaortic balloon pumping.

*In 125 patients who had reoperation, 7 had second reoperation and 2 of them died.

†Operative complications include reoperation for bleeding, graft occlusion, or other reasons, perioperative myocardial infarction, and low cardiac output.

‡Neurologic complications include transient or permanent stroke.

Table IV. Cont'd.

Variable	Mortality	p Value
Neurologic complications‡		
Yes	18/96 (18.75%)	0.000
No	100/1219 (8.20%)	
Stroke (permanent)		
Yes	11/32 (34.38%)	0.000
No	113/1367 (8.27%)	
Pulmonary complications		
Yes	46/189 (24.34%)	0.000
No	72/1126 (6.39%)	
Ventilation >5 days		
Yes	5/21 (23.81%)	0.015
No	119/1378 (8.64%)	
Renal failure		
Yes	42/93 (45.16%)	0.000
No	82/1306 (6.28%)	

operative complications, as a single variable, were also included in the logistic regression analysis. Those variables (age ≥80 years, obesity, and IMA grafting) that had a trend to correlate with the operative mortality ($p < 0.2$) in the univariate analysis were also included. Smoking history was included in the logistic regression analysis because of its important influence on operative mortality in the elderly according to the literature.¹³ The logistic regression analysis demonstrated that postoperative complications, long perfusion time, history of congestive heart failure, emergency operation, left ventricular ejection fraction, reoperation, history of myocardial infarction, use of right IMA grafting, female gender, and old age were independently associated with increased operative mortality (Table V).

Morbidity. Postoperative morbidity is listed in Tables I and IV. Table I compares the morbidity between the patients having IMA grafting and those having saphenous vein grafting only. The patients undergoing IMA grafting had fewer postoperative complications, such as low cardiac output, insertion of an intraaortic balloon pump, pulmonary complications, ventilatory support for more than 5 days, and neurologic complications. However, no difference in the prevalence of perioperative myocardial infarction, sternal infection, requirement for blood transfusion, or reoperation for bleeding was noted.

Discussion

High mortality has been reported in elderly patients undergoing coronary artery bypass grafting.^{3,4} Therefore, to identify risk factors for operative mortality in elderly patients is important to improve operative results. Despite the fact that in some studies old age is defined as 65 years or older,^{9,13} we used 70 years or older as the definition in the present study, because it is used in most

studies.^{3, 4, 6, 11, 12} Although IMA grafting has become a routine procedure for CABG, few reports on its effects on operative mortality in elderly patients have been published.^{13, 14} In addition, although left IMA grafting in elderly patients has been reported to have superior results,¹⁴ to our knowledge the role of bilateral IMA grafting in elderly patients has not been fully studied. A recent report²³ has suggested that the operative mortality for bilateral IMA grafting (3.1%) is lower than that for unilateral IMA grafting (6.4%), but the study did not compare the operative mortality and morbidity between patients having IMA and saphenous vein grafting. In a previous study, we²⁴ have investigated the effect of bilateral IMA grafting on operative mortality in patients having CABG and found that old age (≥ 70 years) is a risk factor for operative mortality in patients having bilateral IMA grafting. Therefore, we designed the present study to retrospectively investigate the risk factors for operative mortality in elderly patients having CABG with emphasis on the influence of IMA grafting on operative mortality and morbidity.

In the present study, the overall operative mortality of 8.86% was comparable with that in other studies.^{14, 23} The operative mortality in the patients having unilateral IMA grafting (6.41%) was significantly lower than that in patients having bilateral IMA grafting (21.43%, $p = 0.018$) or saphenous vein grafting only (9.96%, $p = 0.021$). Although from some aspects patients having IMA grafting were in better preoperative condition (fewer patients had congestive heart failure, myocardial infarction, or emergency operation, and ejection fraction was higher), no difference in functional class, diabetes, and left main stenosis was observed. On the other hand, more patients having IMA grafting were obese. Also, longer aortic crossclamp and cardiopulmonary bypass times in patients undergoing IMA grafting reflect a more complicated operative technique and more grafts performed (3.49 ± 0.04 versus 3.15 ± 0.03 , $p = 0.0001$). Despite these risk factors, fewer patients undergoing IMA grafting had operative or postoperative complications, such as postoperative low cardiac output, neurologic complications, or pulmonary complications, and fewer required intraaortic balloon pumping or ventilatory support for longer than 5 days. These are the major postoperative complications. Therefore, the lower operative mortality and postoperative morbidity in this study support the use of unilateral IMA grafting in elderly patients although the patient selection was not randomized. In this study, the elderly patients undergoing bilateral IMA grafting had a high operative mortality. However, the number of this subgroup is small (28 patients) and this

reflects our attitude in the use of bilateral IMA grafting in elderly patients. Like others, we do not choose bilateral IMA grafting as the primary operation for elderly patients because the major benefit of this procedure is high long-term patency rates and this is obviously less important in elderly subjects. Therefore, from this study, we cannot simply conclude that bilateral IMA grafting increases operative mortality in elderly persons, but we do address its possibility, even though in our total patient population of 6360 patients who underwent isolated CABG during the same time frame selected bilateral IMA grafting does not increase the operative mortality.²⁴

To further study whether increased operative mortality is correlated to the use of the bilateral IMA or simply correlated to the use of right IMA grafting, we investigated the effects of right IMA grafting in elderly subjects by including both bilateral and single right IMA grafting in the multiple logistic regression analysis. The logistic regression identified that right, but not bilateral, IMA grafting is an independent risk factor. An important factor in our patients having right IMA grafting (including bilateral and single right IMA grafting) is that seven of those 41 patients received a right IMA for their reoperations and four of them died (4/7 versus 4/34, $p = 0.006$). Two of them died of a cardiac cause, one of pulmonary complications, and one of infection. In the other four patients having right IMA grafting who died after the first operation, the causes were cardiac in one, pulmonary complications in one, and other causes in two. Thus, in this subgroup of 41 patients undergoing right IMA grafting, four of eight patients in whom operative mortality occurred underwent reoperation. In these reoperative patients, the right IMA was used as a "secondary choice" because of lack of grafting conduits. For those patients having right IMA grafting as a "primary choice" ($n = 34$) for their first operation, the operative mortality (11.76%, 4/34) was not significantly different from that in patients having unilateral IMA or saphenous vein grafting (8.61%, $p = 0.52$). As mentioned earlier, in our patients younger than 70 years, bilateral IMA grafting does not increase operative mortality. This also suggests that in our study group of patients aged 70 years or more, use of right IMA grafting, although not as favorable as it is in younger patients, only increases operative mortality in reoperative patients. However, further study on this is necessary because of the rather small number of the right IMA grafting subgroup and the preselection as determined by the surgeon.

Among the risk factors correlating to the operative mortality, identified by the stepwise multiple logistic regression analysis (Table V), history of congestive heart

Table V. Stepwise multiple logistic regression for operative mortality in the elderly patients undergoing CABG

Variables	Regression coefficient	Standard error	Odds ratio	Score χ^2	p Value
Postoperative complications	1.9053	0.2616	6.722	76.0444	0.0001
Perfusion time	-0.00620	0.00197	0.994	28.8417	0.0001
History of CHF	0.7900	0.2321	2.203	25.6205	0.0001
Emergency operation	-0.7410	0.2839	0.477	14.8588	0.0001
Ejection fraction	0.0234	0.00838	1.024	9.7685	0.0018
Reoperation	-0.7643	0.2708	0.466	7.5804	0.0059
History of MI	0.6283	0.2369	1.874	5.5385	0.0186
RIMAG	1.1613	0.4934	3.194	6.5951	0.0102
Gender	-0.5173	0.2149	0.596	6.0812	0.0137
Age	-0.0508	0.0253	0.950	4.0400	0.0444

CABG, Coronary artery bypass grafting; CHF, congestive heart failure; MI, myocardial infarction; RIMAG, right internal mammary artery grafting.

failure or myocardial infarction and low ejection fraction refer to detrimental reserve of the heart and reflect damaged cardiac function. Interestingly, New York Heart Association functional class did not enter the regression model. This obviously suggests that the ejection fraction is a more important index than functional class.

Another variable correlated to operative mortality was cardiopulmonary bypass time. Despite the fact that unilateral IMA grafting had longer cardiopulmonary bypass time but lower operative mortality, long cardiopulmonary bypass time is the strongest risk factor among the preoperative and intraoperative variables ($p = 0.0001$, Table V). A long cardiopulmonary bypass time is related to (1) long aortic crossclamp time and (2) long reperfusion time. Usually, a long aortic crossclamp time reflects the complexity of the operation and a long reperfusion time implies in part that the heart requires longer support by cardiopulmonary bypass. Therefore, long cardiopulmonary bypass time may more importantly reflect the cardiac functional status after ischemia. As seen in the present study, aortic crossclamp time was not correlated to operative mortality even in the univariate analysis. In our previous studies on the risk factors for operative mortality in patients having bilateral IMA grafting²⁴ and aortic valve replacement,²⁵ we also found that long cardiopulmonary bypass time was either a stronger predictor than long aortic crossclamp time²⁵ or the variable entered into the logistic regression model rather than crossclamp time.²⁴ Therefore, we believe that in predicting operative mortality, long cardiopulmonary bypass time is more important than aortic crossclamp time.

Emergency status is a widely recognized risk factor associated with the operative mortality in previous studies.^{6,26} In the present study, this variable is also a strong independent risk factor for elderly patients undergoing CABG ($p = 0.0001$, Table V). The operative mortality

was 22.03% (26/118) in the patients who had emergency CABG compared with 7.62% ($p < 0.001$) in the patients treated electively.

Another factor independently correlated to operative mortality is reoperation (Table V). As shown in Table IV, operative mortality was significantly higher in patients who had reoperations than in those who did not (8.01% versus 17.60%, $p < 0.001$). As aforementioned, the influence of reoperation is particularly important in patients having right IMA grafting. However, even in patients having left IMA or saphenous vein grafting only, reoperation carries a higher operative mortality. Overall, 22 of 125 patients who had reoperation died. Operative mortality was particular high (2/7) in the patients who had a second reoperation.

A less important factor for operative mortality in elderly persons undergoing CABG is female gender (operative mortality was 11.68% versus 7.27% in the male, $p = 0.005$). This variable entered into the regression model as an independent factor. However, this is a rather weak predictor ($p = 0.0137$) compared with other factors (Table V). Similar to the Cleveland Clinic experience,¹³ we also found the influence of age on operative mortality in elderly subjects as an independent but weak factor ($p = 0.044$ in the regression model). This is also indicated by the fact that the operative mortality (12.9%) for the patients older than 80 years was not significantly higher than that for the patients whose age was between 70 and 80 years (8.36%, $p = 0.061$).

In conclusion, the present study identifies various preoperative (history of congestive heart failure or myocardial infarction, low ejection fraction, female gender, and old age), intraoperative (long cardiopulmonary bypass time, emergency operation, reoperation, and use of right IMA grafting), and postoperative (postoperative complications) variables as risk factors for elderly patients (≥ 70

years) undergoing isolated CABG. Therefore, the present study suggests that in the elderly patients with those risk factors, particular care should be taken to reduce cardiopulmonary bypass time and postoperative complications. In patients with the aforementioned risk factors and the likely inability to mitigate long cardiopulmonary bypass time or complications, the surgeon may be wise to reassess the presumed benefit of CABG for each patient. A left IMA grafting in combination with saphenous vein grafting may achieve a lower operative mortality and morbidity than other procedures in selected elderly patients undergoing CABG.

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Appendix

Variables examined by univariate analysis for operative mortality in elderly patients undergoing isolated CABG. Sex, age, age ≥ 80 years, weight, height, body surface area, smok-

ing history, family history of coronary artery disease, diabetes, obesity, body mass index, hypercholesterolemia, hypertension, chronic obstructive pulmonary disease, history of myocardial infarction, history of congestive heart failure, history of arrhythmia, angina, New York Heart Association functional class, ejection fraction, left ventricular function (classified by ejection fraction), number of vessels diseased, left main disease, right main artery disease, conduit on right coronary artery, left anterior descending stenosis, left anterior descending distal disease, conduit on left anterior descending, previous percutaneous transluminal coronary angioplasty, emergency operation, reoperation, individual surgeons, Aortic crossclamp time, cardio-

pulmonary bypass time, number of grafts, graft to left anterior descending, type of cardioplegia, route of cardioplegia, IMA grafting, unilateral IMA grafting, bilateral IMA grafting, right IMA grafting versus others, right IMA grafting versus other IMA grafting, left ventricular aneurysmectomy, postoperative complications, operative complications, postoperative low cardiac output, perioperative myocardial infarction, infectious complications, sternal infection, neurologic complications, permanent stroke, intraaortic balloon pumping, reoperation for bleeding, blood transfusion, pulmonary complications, and renal failure.

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