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ORIGINAL ARTICLE

Short-term and long-term outcomes of octogenarians after off-pump coronary artery bypass surgery

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Abstract
Purpose. Off-pump coronary artery bypass has been reported to be associated with reduced morbidity and mortality after surgical coronary revascularization, especially in high-risk patients. The aim of this study was to clarify the efficacy of off-pump coronary artery bypass for the very elderly patients.
Methods. We compared the outcomes of octogenarians (n = 28, 82 ± 2 years) undergoing off-pump coronary artery bypass and those of the patients <80 years of age (n = 315, 67 ± 9 years) during short- and long-term periods.
Results. There was no difference in hospital mortality between octogenarians and the younger cohort (3.8% vs. 0.6%; $P = 0.11$). A high rate of postoperative complications (e.g., pneumonia, transient renal dysfunction, ventricular arrhythmia) were observed in the octogenarians. The long-term survival (81% at 5 years) and the rate of freedom from cardiac death (92% at 5 years) and from cardiac events (85% at 5 years) were excellent in the octogenarians; they appeared less favorable, however, when compared with the younger group (95%, 98%, and 94% at 5 years, respectively). Most of the cardiac adverse events, including unexplained sudden death, occurred 6 months after the surgery in octogenarians.
Conclusion. Off-pump coronary artery bypass can be performed safely in octogenarians, with excellent early and late outcomes. Careful postoperative follow-up is required to reduce postoperative long-term adverse events. Off-pump coronary artery bypass is a feasible modality of coronary revascularization for octogenarians.

Key words Off-pump coronary artery bypass · Octogenarian · Clinical outcome

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Introduction

Life expectancy has increased in developed countries, with a growing number of elderly patients who are referred to surgery for coronary artery disease. Such elderly patients have considerable risks for morbidity and mortality following coronary artery bypass surgery (CABG). Off-pump coronary artery bypass (OPCAB) has been reported to be associated with reduced morbidity and mortality after coronary artery bypass surgery, especially in high-risk patients including the elderly.[1–3] However, there are few data regarding short- and long-term clinical outcomes for octogenarians after OPCAB surgery in the literature. Since 1999, we have employed a systematic OPCAB strategy, seeking complete revascularization with our decision-making algorithm.[4] Consequently, more than 98% of CABGs annually were performed with the off-pump technique including octogenarians.

The aim of this study was to clarify the efficacy of this off-pump procedure for very elderly patients. For this purpose, we compared the outcomes of octogenarians undergoing OPCAB and those of patients <80 years of age in short- and long-term periods.

Patients and methods

Patients

This study analyzed the data of patients undergoing OPCAB surgery over a 9-year period (January 2001 to December 2009) at Fukushima Medical University Hospital. During this period, 343 patients (259 men, 84 women; mean age 68 ± 2 years) underwent OPCAB surgery. The OPCAB/total CABG ratio in our practice exceeded 98% over those years.

Decision-making algorithm for routine OPCAB

All major coronary arteries with proximal stenosis (>75%), a considerable perfusion area, and adequate diameter (>1.0 mm) at the target anastomosis site were selected to be revascularized. We have constructed a decision-making algorithm for routine OPCAB to seek the best benefit of OPCAB with complete coronary revascularization by all means.[4] Briefly, the patients with preoperative hemodynamic instability or ventricular arrhythmia underwent on-pump CABG without cardiac arrest. Other patients with stable hemodynamic were candidates for OPCAB surgery. Among them, patients with severe left main trunk disease (stenosis >95%) or poor left ventricular function (ejection fraction <0.35) were subjected to preoperative intraaortic balloon pumping (IABP) under fluoroscopy in the operating room before tracheal intubation. During OPCAB surgery, patients with consistent elevation of the ST segment on electrocardiography (ECG) or pulmonary artery pressure (PAP) were subjected to IABP through the arterial pressure monitoring line in the femoral artery. The patients with hypotension and pulmonary artery pressure (PAP) elevation or ventricular fibrillation were converted to on-pump beating CABG to seek complete coronary artery revascularization.

Surgical technique

The surgical technique has been quite consistent through this study period. All OPCAB procedures were performed under general anesthesia with PAP and transesophageal echocardiography monitoring. Median sternotomy was used in 89% of the patients. Other approaches included left anterior small thoracotomy for a single left internal thoracic artery to left anterior descending artery bypass (7%), and left lateral thoracotomy with/without a transdiaphragmatic upper median abdominal approach for redo OPCAB (4%).

Nicorandil, a potassium channel opener, and landiolol, a ultra-short-acting selective β1-adrenergic receptor blocker,[5,6] were continuously infused. Heparin sodium was administered periodically to keep the acting clotting time between 200 and 250 s. A suction type stabilizer (Octopus; Medtronic; Minneapolis, MN, USA) was used in all cases for coronary artery stabilization. Deep pericardial traction sutures, table titling, and apical suction device were used for inferior and lateral wall exposure.

A test cross-clamp was applied to the proximal coronary artery with surrounding fat tissue by a micro-bulldog clamp (Diethrich micro-bulldog clamp with 80 g of closing pressure, no. 20 to 0310; Geister Meditintechnik, Tuttlingen, Germany) for 1–2 min as ischemic preconditioning. After coronary arteriotomy, a flexible silicone-constructed intracoronary shunt (Clearview intracoronary shunt; Medtronic) was introduced immediately.[7] In most of the cases of multivessel coronary disease, anastomosis of the internal thoracic artery to the left anterior artery was performed first. We preferred to use in situ arterial grafts whenever applicable, rather than saphenous vein grafts especially for younger patients with long life expectancy. The arterial grafts were harvested in a skeletonized fashion with a Harmonic scalpel. When proximal anastomosis on the ascending aorta was necessary, periaortic echography was performed to assess the atheroma plaque on the aortic wall. For the proximal anastomosis, we used single lateral clamping of the ascending aorta or, since 2005, a clampless anastomosis assist device (Enclose II; Novare Surgical System, Cupertino, CA, USA).[8] The distal anastomosis was constructed with a continuous running technique using 7-0 polypropylene suture in an end-to-side fashion. Sequential grafting using the saphenous vein or radial artery was utilized when applicable. The graft flow was confirmed with vascular echography and a transit-time flowmeter. Postoperatively, patients were given intravenous heparin (15 000 KIU/day) for 3 days and were maintained on oral aspirin (80 mg) for the first 3 months.

Clinical follow-up

All preoperative, intraoperative, and early postoperative data were gathered from the patients' charts. Perioperative myocardial infarction was defined as a new Q wave on ECG or a peak myocardial specific creatine kinase level >100 ng/ml after surgery. Clinical follow-up was completed by regular postoperative visits, telephone calls, and information from the attending doctors at the referral hospitals. All data were entered into the database. Cardiac death was defined as death caused by acute myocardial infarction, congestive heart failure, or fatal ventricular arrhythmias or unexplained sudden death. Cardiac adverse events were defined as follows: nonfatal myocardial infarction, recurrent angina, hospitalization for congestive heart disease, nonfatal arrhythmia, or repeat revascularization (surgery or percutaneous coronary intervention).

Statistical analysis

Data were expressed as the mean ± SD or absolute numbers. The difference between values was analyzed by the Mann-Whitney test. The categorical difference was analyzed by the χ^2 test or Fisher's exact test with Yates' correction, if appropriate. Actuarial survival was constructed using the Kaplan-Meier method. The difference between the two survival curves was analyzed by the log-rank test. Statistical analysis was performed using SPSS version 15 (SPSS, Chicago, IL, USA). $P < 0.05$ was considered statistically significant.

Results

During this study period, 346 patients underwent isolated coronary bypass surgery, among whom 3 patients (0.9%) underwent on-pump beating coronary artery bypass surgery because of preoperative hemodynamic instability. Consequently, 28 patients who were >80 years of age (group O) and 315 patients who were younger (group Y) underwent OPCAB. The mean follow-up was 3.5 ± 2.1 years (range 0.1–10.2 years. The follow-up was 98% complete.

Preoperative patient demographics

The average ages were 82 ± 2 years and 67 ± 9 years in groups O and Y, respectively. Preoperative data are shown in Table 1. The prevalences of hypertension, hyperlipidemia, respiratory impairment, renal dysfunction, old cerebral infarction, aortic aneurysms, peripheral artery disease, and malignant neoplasm were not significantly different between the two groups. There was significantly more diabetes mellitus in the younger group than in the octogenarian group (37% vs. 17%: $P = 0.02$); and the octogenarians frequently had an impaired left ventricle with low ejection fraction (18% vs. 7%; $P = 0.03$). There was no significant difference in the prevalence of old myocardial infarction, acute myocardial infarction, or unstable angina between the two groups.

Table 1 Patient demographic data

Parameter	Group O (age ≥ 80 years)	Group Y (age < 80 years)	*P*
	No.	No.	
No.	28	315	
Female sex	8 (29%)	76 (24%)	0.60
Disease			
Diabetes	4 (14%)	115 (37%)	0.03*
Insulin-dependent diabetes	1 (4%)	53 (17%)	0.64
Hypertension	6 (21%)	84 (27%)	0.54
Hyperlipidemia	3 (11%)	66 (21%)	0.20
Chronic obstructive lung disease	3 (11%)	17 (5%)	0.25
Renal dysfunction (CRTN > 2.0 mg/dl)	7 (25%)	46 (15%)	0.14
Hemodialysis	0	16 (5%)	0.22
Old cerebral infarction	1 (4%)	55 (17%)	0.06
Thoracic aortic aneurysm	3 (11%)	34 (11%)	0.99
Abdominal aortic aneurysm	3 (11%)	12 (4%)	0.09
Peripheral artery disease	2 (7%)	23 (7%)	0.97
Cerebral artery disease	1 (3%)	13 (4%)	0.89
Malignant neoplasm	0	4 (1%)	0.55
Acute myocardial infarction	2 (7%)	9 (3%)	0.53
Unstable angina	17 (61%)	208 (66%)	0.91
Old myocardial infarction	10 (36%)	117 (37%)	0.69
Left main trunk disease (>75% stenosis)	12 (43%)	110 (35%)	0.38
Ejection fraction (<0.35)	5 (18%)	21 (7%)	0.03*
Treatment			
Urgent operation	7 (25%)	62 (20%)	0.66
Redo	2 (7%)	13 (4%)	0.68
Prior PCI	5 (18%)	63 (20%)	0.60

"Cerebral artery disease" represents cerebral artery occlusion or stenosis defined with magnetic resonance angiography. Left ventricular "ejection fraction" was assessed by echocardiography

PCI, percutaneous coronary intervention with either stents or balloon angioplasty; CRTN, serum creatinine

*$P < 0.05$

Table 2 Perioperative data

Parameter	Group O (age ≥ 80 years)	Group Y (age < 80 years)	P
No. of distal anastomoses (range)	2.4 ± 0.8 (1–4)	2.5 ± 1.0 (1–5)	0.51
Bypass conduit			0.0004*
All arterial graft	15 (54%)	233 (74%)	
Arterial + venous graft	9 (32%)	76 (24%)	
All venous graft	4 (14%)	6 (2%)	
Ascending aorta anastomosis	9 (32%)	154 (49%)	0.13
IABP usage			0.53
Preoperative	2 (7%)	9 (3%)	
Scheduled	2 (7%)	13 (4%)	
Intraoperative	3 (11%)	47 (15%)	
Incomplete revascularization	0	3 (0.9%)	0.88
Pump conversion	0	3 (0.9%)	0.88
Operating time (min)	257 ± 69	289 ± 77	0.06

Values are expressed as absolute numbers or the mean ± SD

"Incomplete revascularization" represents the case in which part of the planned revascularization was not performed owing to an intramyocardial coronary artery or severely calcified anastomosis site

IABP, intraaortic balloon pump

*$P < 0.05$

Perioperative data

Perioperative data are shown in Table 2. The average number of distal anastomoses was similar ($P = 0.51$). More vein grafts were selected for bypass conduits for the octogenarians than for the younger group ($P = 0.0004$). In this cohort, internal mammary arteries were selected in all patients when arterial bypass conduits were necessary. There was no significant difference in the prevalence of preoperative IABP use. Hemodynamic instability occurred in seven of the octogenarians and three of the younger patients, who were then subjected to intraoperative IABP. Three patients of the younger group were converted to on-pump beating coronary artery bypass surgery owing to refractory hemodynamic instability; they uneventfully underwent the procedure and were discharged with no complications. The complete revascularization rate was approximately 100% in both groups.

Early postoperative outcome

Early outcomes are shown in Table 3. The early patency of each bypass graft before discharge was similar in the two groups. During the postoperative course, pneumonia with/without tracheotomy, transient renal dysfunction with hemodialysis, and ventricular arrhythmia occurred more frequently in the octogenarian group than in the younger group. The duration of ventilator support, intensive care unit stay, and hospitalization after surgery were not significantly different. One patient in the octogenarian group died of a ruptured abdominal aortic aneurysm, and two in the younger group died of massive stroke and low output syndrome after emergency operation. Consequently, the overall hospital mortality was not significantly different between the two groups.

Late clinical outcome

Overall survival rate

Actual survival rates including hospital death were 97%, 95%, 95%, and 91% at 1, 3, 5, and 7 years after the operation in the younger group (group Y); they were 81%, 81%, 81%, and 81%, respectively, in the octogenarian group (group O), with a significant difference between the groups ($P = 0.0011$), as shown in Fig. 1. All late deaths in the octogenarian group occurred within 1 year after the operation. In the octogenarian group, the causes of five deaths were identified as cardiac related ($n = 4$) including three sudden unexplained deaths, and one ruptured abdominal aortic aneurysm. In the younger group, the causes of 16 deaths were as follows: cardiac related ($n = 4$), neurological ($n = 2$), aortic rupture ($n = 3$), cancer ($n = 2$), pneumonia ($n = 3$), and renal dysfunction ($n = 2$).

Cardiac-death-free survival

Cardiac death was defined as death caused by acute myocardial infarction, congestive heart failure, fatal

Table 3 Early postoperative outcome

Outcome	Group O (age ≥ 80 years)	Group Y (age < 80 years)	*P*
Graft patency at discharge			
Left internal thoracic artery	100%	98.1%	0.87
Right internal thoracic artery	N/A	100%	
Radial artery	100%	99.0%	0.88
Gastroepiploic artery	N/A	99.4%	
Saphenous vein graft	100%	94.4%	0.76
Ventilator support (h)	32 ± 76	17 ± 42	0.42
Stay in intensive care unit (days)	4.3 ± 4.3	2.3 ± 2.1	0.08
Hospital stay after operation (days)	29 ± 14	24 ± 21	0.89
Morbidity and mortality (no.)			
Atrial fibrillation	2 (7%)	21 (7%)	0.92
Ventricular tachycardia/fibrillation	3 (11%)	8 (3%)	0.02*
Perioperative myocardial infarction	0	6 (2%)	0.46
Low cardiac output syndrome	0	1 (0.3%)	0.88
Transient hemodialysis	2 (7%)	4 (1%)	0.02*
Pneumonia	2 (7%)	2 (0.6%)	0.002*
Tracheostomy (Minitrac)	3 (11%)	2 (0.6%)	<0.0001*
Reexploration for bleeding	0	1 (0.3%)	0.77
Surgical site infection	2 (7%)	12 (4%)	0.40
Transient neurological dysfunction	1 (3.8%)	1 (0.3%)	0.77
Stroke	0	3 (0.9%)	0.33
Hospital death	1 (3.8%)	2 (0.6%)	0.11

* $P < 0.05$

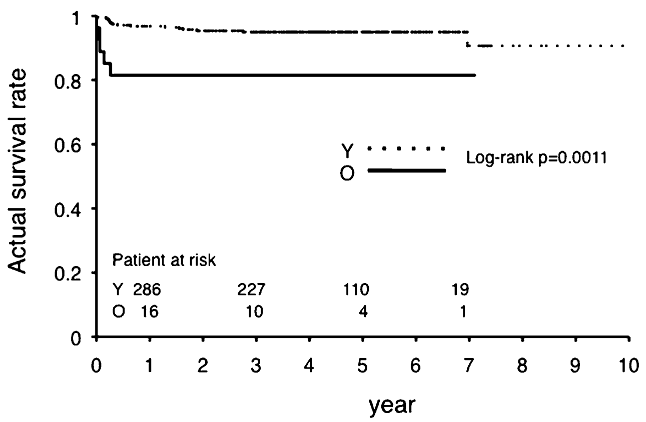

Fig. 1 Actuarial survival curve. Groups *O* (octogenarian) and *Y* (non-octogenarian) are compared using the Kaplan-Meier method

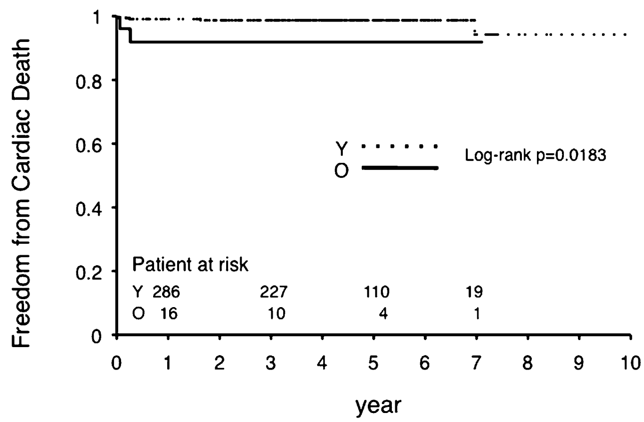

Fig. 2 Freedom from cardiac deaths. Groups *O* and *Y* are compared using the Kaplan-Meier method. Cardiac death includes death caused by acute myocardial infarction, congestive heart failure, or fatal ventricular arrhythmias as well as unexplained sudden death

arrhythmia, or sudden unexplained death. The rates of freedom from cardiac death were 99%, 98%, 98%, and 94% at 1, 3, 5, and 7 years, respectively, in the younger group (group Y) and 96%, 92%, 92%, and 92%, respectively, in the octogenarian group (group O), as shown in Fig. 2. Although there was a significant difference between the two groups (p = 0.0183), the cardiac-death-free survivals were excellent.

Cardiac-event-free survival

Cardiac event was defined as recurrence of angina, nonfetal arrhythmia, percutaneous coronary intervention, and redo coronary artery bypass surgery. In the octogenarian group (group O), nonfatal ventricular arrhythmia occurred in two patients within 6 months after the operation, producing an 85% freedom-from-cardiac-events rate for the long-term periods (1, 3, 5, and 7 years), as shown in Fig. 3. The rates of freedom from cardiac events were 95%, 94%, 94%, and 89% at 1, 3, 5, and 7 years in the younger group (group Y). There was a significant difference between the two groups ($P = 0.0482$).

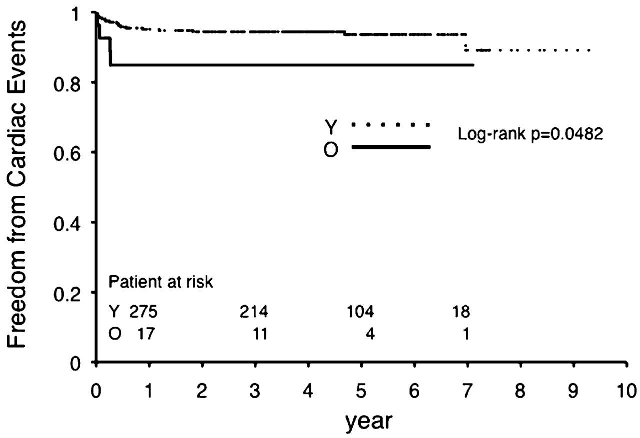

Fig. 3 Freedom from cardiac events. Groups *O* and *Y* are compared using the Kaplan-Meier method. Cardiac events include nonfatal myocardial infarction, recurrent angina, hospitalization for congestive heart disease, nonfatal arrhythmia, and repeat revascularization (surgery or percutaneous coronary intervention)

Discussion

This report describes the short- and long-term outcomes of nonselected elderly patients who underwent OPCAB surgery in comparison with the younger age group. The main findings in this study were as follows: (1) Low cardiac function as a preoperative risk was more frequently seen in octogenarians, suggesting inclusion of a significant number of high-risk patients in this cohort. (2) Vein grafts were utilized more in the octogenarians. (3) Although hospital mortality was low in both groups (without a significant difference), postoperative complication rates such as pneumonia, transient renal dysfunction, and ventricular arrhythmia were higher in octogenarians. (4) Although the long-term survival and the rates of freedom from cardiac death and from cardiac events were less favorable in octogenarians, the long-term outcomes of both groups were excellent. (5) Most of the cardiac adverse events, including unexplained sudden death, occurred within 6 months after surgery in the octogenarians.

Very elderly patients undergoing coronary artery bypass surgery experience considerable morbidity and mortality.[9,10] Recent reports have shown that mortality for elderly patients who underwent OPCAB was more than twice that for younger patients,[9] with a substantial early complication rate.[10] Postoperative complication is a stronger risk factor for hospital death than preoperative co-morbidity or procedure variables among elderly patients; it is also a risk factor for long-term survival.[10] OPCAB has been reported to be associated with reduced morbidity and mortality after coronary revascularization surgery,[1–3] especially in high-risk patients including the very elderly population.[11–13] These clinical observation studies showed reduced in-hospital mortality and fewer postoperative complications (e.g., neurological dysfunction, prolonged intubation) in octogenarians.[11–13] Li and colleagues recently analyzed 447 patients >65 years old who underwent OPCAB and reported an in-hospital mortality of 1.3% in this elderly cohort.[14]

In this study, we found more postoperative complications, including pneumonia with/without tracheotomy, renal dysfunction with transient hemodialysis, and ventricular arrhythmia, in the octogenarians. However, these complications were not related to hospital deaths in this cohort. The only cause of death in the octogenarian herein was postoperative rupture of an abdominal aortic aneurysm, which had been scheduled for the second operation. Interestingly, the rate of neurological dysfunction was low in both age groups in this study, with no significant difference. Current clinical strategy, including echographic assessment of the ascending aorta, a clampless aortic anastomotic device, and intense perioperative anticoagulation therapy may contribute to this low stroke rate after OPCAB surgery.

Recently, Likosky and associates reported a surprisingly good long-term results among octogenarians after coronary artery bypass surgery relative to the general population,[15] suggesting that surgical revascularization should be suitable option for elderly patients. More recently, Rohde and colleagues analyzed 606 octogenarians undergoing coronary artery bypass surgery and demonstrated that cardiopulmonary bypass time is a strong risk factor for long-term survival.[16] In this study, we found that the long-term survival and the rates of freedom from cardiac death and cardiac events were satisfactory in octogenarians after OPCAB surgery.

Naughton and associates conducted a large database study and concluded that co-morbidities such as renal impairment, cardiac dysfunction, arrhythmia, and arteriopathy were significant risk factors for late mortality in the very elderly patient after coronary artery bypass surgery.[9] Therefore, they suggested a need for effective long-term strategies in the management of chronic heart and renal disorders. Our study showed that most of the adverse cardiac events, including death, occurred within 6 months after surgery in the octogenarians. These events included nonfatal ventricular arrhythmia and unexplained sudden death probably due to arrhythmia. Based on these results, it is clear that close follow-up with medical support during the recovery period of a few months after surgery is needed to achieve good long-term outcomes.

This study has limitations. This database analysis study was conducted as a single center study with possible referral bias. Nonetheless, the institution in this study was a major referral center in this area with an aged population, suggesting inclusion of a considerable number of high-risk elderly patients in this cohort.

Conclusions

Off-pump coronary artery bypass can be performed safely in octogenarians followed by satisfactory long-term outcomes. Careful postoperative follow-up is required to reduce the number of postoperative long-term adverse events. Off-pump coronary artery bypass is a feasible modality for coronary revascularization in octogenarians.

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