Heart Vessels (2012) 27:559–567
DOI 10.1007/s00380-011-0198-1

ORIGINAL ARTICLE

Coronary artery surgery in octogenarians: evolving strategies for the improvement in early and late results

Francesco Nicolini · Alberto Molardi · Danilo Verdichizzo · Maria Cristina Gallazzi · Igino Spaggiari · Flavio Cocconcelli · Alessandro Maria Budillon · Bruno Borrello · Davide Rivara · Cesare Beghi · Tiziano Gherli

Received: 18 April 2011 / Accepted: 30 September 2011 / Published online: 2 November 2011

Abstract The purpose of this study was to investigate retrospectively early and late outcomes of coronary artery bypass grafting (CABG) in a large series of octogenarians. We retrospectively reviewed the data of 241 octogenarian patients who underwent CABG between April 2002 and April 2009 at our institution. Mean age was 84.7 ± 1.8 years. Patients affected by concomitant coexistent organic aortic, mitral, or tricuspid valve disease were excluded from the study. Patients with functional secondary ischemic mitral incompetence were included in the study. The majority of the patients were male. Angina pectoris functional class III/IV accounted for 164 patients (68%). Left ventricular ejection fraction ≤35% was diagnosed in 38 patients (15.8%). Early mortality rate was 5.8% (14 patients). Causes of death were cardiac related in 10 patients. Preoperative independent predictors of in-hospital mortality obtained with multivariate analysis were extracardiac arteriopathy, New York Heart Association class III/IV, and previous percutaneous transluminal coronary angioplasty (PTCA). The overall mean follow-up was 41.6 ± 25.9 months (range 1–87.6 months). Among the 222 contacted survivors, there were 16 (7.2%) deaths during the follow-up. The actuarial survival was 91.9% at 1 year and 83.5% at 5 years. On multivariate analysis, time to late death was adversely affected by preoperative extracardiac arteriopathy and previous PTCA. Advanced age alone should not be a deterrent for CABG if it has been determined that the benefits outweigh the potential risk. A careful selection of optimal candidates, based on the evaluation of their systemic comorbidities, appears mandatory in order to obtain the greatest benefit for these high-risk patients.

Keywords Coronary artery bypass grafting · Elderly patient · Surgery

Introduction

An increasing number of octogenarians are undergoing coronary artery bypass grafting (CABG) surgery. Despite recent advances in surgical technology, pharmacotherapy, and intensive care unit (ICU) management, leading to improved outcomes in this group of patients, they remain at higher risk of mortality and morbidity after CABG in comparison with younger patients [1]. On the other hand, recent reports suggest that aggressive revascularization strategies in older patients with coronary artery disease obtain the relief of symptoms and the improvement of quality of life [2–4].

Most clinical series have reported early results [5, 6], and few studies have been published with the aim of examining long-term outcome and its predictors in octogenarian patients undergoing CABG surgery [7–10].

The purpose of the current investigation was to examine early mortality and morbidity after CABG, to determine predictors of late mortality in a single-center series of octogenarians who underwent surgical coronary revascularization, and to discuss potential strategies to improve early and long-term outcomes.

F. Nicolini (✉) · A. Molardi · D. Verdichizzo · M. C. Gallazzi · I. Spaggiari · F. Cocconcelli · A. M. Budillon · B. Borrello · D. Rivara · C. Beghi · T. Gherli
Heart Surgery Section, University of Parma Medical School, Via A. Gramsci 14, 43100 Parma, Italy
e-mail: francesco.nicolini@unipr.it

Patients and methods

Population

We retrospectively reviewed the data of 241 octogenarian patients who underwent CABG between April 2002 and April 2009 at our institution. Mean age was 84.7 ± 1.8 years. Patients affected by concomitant coexistent organic aortic, mitral, or tricuspid valve disease were excluded from the study. Patients with functional secondary ischemic mitral incompetence were included in the study.

The majority of the patients were male. Canadian Cardiovascular Society (CCS) functional class III/IV accounted for 164 patients (68%). Left ventricular ejection fraction (LVEF) ≤35% was diagnosed in 38 patients (15.8%). The European System for Cardiac Operative Risk Evaluation (EuroSCORE) was calculated for every patient as predictor of perioperative mortality [11]. Mean additive EuroSCORE was 8.7 ± 2.6. Details of preoperative demographic and cardiovascular characteristics are reported in Table 1.

The study complies with the Declaration of Helsinki, the local ethics committee approved the research protocol, and informed consent was obtained from the subjects.

Perioperative management

Coronary artery disease was diagnosed on the basis of symptoms and noninvasive tests, and was confirmed in all patients by coronary angiography. Coronary artery bypass grafting was performed whenever coronary angiography showed stenosis greater than 70% on the major epicardial vessels. Patients with mitral valve insufficiency with an echocardiographic effective regurgitant orifice (ERO) ≥0.2 cm^2 were considered for annuloplasty [12]. Severely depressed myocardial function detected by echocardiography was defined as an LVEF ≤35%. All patients had preoperative epiaortic vessel echography and aortic echography, used in order to detect the sites of severe atherosclerotic disease and to perform safe aortic cannulation and manipulation during the operation.

All patients were treated in the perioperative period with intravenous (i.v.) vancomycin associated with cefotaxime. The i.v. vancomycin protocol was as follows. A loading dose of 15 mg/kg i.v. was infused almost 1 h before anesthesiologic induction or surgical maneuvers. Maintaining doses of 12.5 mg/kg i.v. were administered at the arrival in ICU after surgery and consequently at a rate adjusted according to the estimated vancomycin clearance based on the daily vancomycin serum levels. Cefotaxime was administered at a dose of 2 g i.v. every 6 h for 3 days, or until the removal of central venous catheters and chest tubes.

Table 1 Demographic and preoperative clinical characteristics

Variables	No. of patients	%
Age (mean ± SD)	84.7 ± 1.8	
Gender		
Male	139	57.7
Female	102	42.3
Hypertension	192	79.7
Diabetes	51	21.2
History of smoking	115	47.7
COPD	17	7.1
Hypercholesterolemia	105	43.6
Peripheral arterial vascular disease	73	30.3
Vascular neurologic disease	5	2.1
Creatinine serum level >2 mg/dl	6	2.5
Previous AMI	127	53
HF history	25	10.4
Previous PTCA	16	6.6
CCS class III	105	43.6
CCS class IV	59	24.5
NYHA class III	74	30.7
NYHA class IV	19	7.9
LVEF (%) ± SD	50.3 ± 12.6	
LVEF ≤35%	38	15.8
Emergency	11	4.6
Mean EuroSCORE (range)	8.7 ± 2.6	6–13
EuroSCORE >9	81	33.6

COPD chronic obstructive pulmonary disease, *AMI* acute myocardial infarction, *HF* heart failure, *CABG* coronary artery bypass grafting, *PTCA* percutaneous transluminal coronary angioplasty, *CCS* Canadian Cardiovascular Society, *NYHA* New York Heart Association, *LVEF* left ventricular ejection fraction

All patients received premedication with morphine sulfate (0.1 mg/kg body weight) and scopolamine (0.01 mg/kg body weight) intramuscularly 60 min before transfer to the operating room. Anesthesia was induced with midazolam (0.05 mg/kg), etomidate (0.3 mg/kg), and fentanyl. Neuromuscular block was obtained by cisatracurium besylate i.v. Anesthesia was maintained with fentanyl, sevoflurane, and cisatracurium besylate. A full intravenous heparin dose was administered (3 mg/kg) in the case of standard cardiopulmonary bypass (CPB).

Heart surgery was performed using CPB at 34°C systemic temperature in all patients, except those who were operated on for off-pump coronary artery revascularization. The extracorporeal circulation management was based on an optimal flow rate of 2.4 l/min/m^2 and mean systemic perfusion pressure of 60 mmHg. Perfusion pressure >70 mmHg during CPB was maintained in all patients with a documented associated cerebrovascular disease.

Antegrade warm blood intermittent cardioplegia or anteretrograde warm blood continuous cardioplegia were used

at the discretion of the operating surgeon. Myocardial revascularization was obtained by suturing the left internal mammary artery as first-choice arterial conduit on the left anterior descending coronary artery whenever possible, and by using segments of saphenous vein or other arterial conduits on the other vessels. In the case of concomitant ischemic mitral regurgitation, normothermic CPB was started via aorto-bicaval cannulation. After performing posterior wall bypass grafts with saphenous vein segments, the mitral valve was exposed by a transseptal incision and repaired according to the Bolling annuloplasty technique [13] using a Cosgrove band (Edwards Lifesciences, Irvine, CA, USA), sutured on the posterior leaflet.

Off-pump beating heart revascularization was performed only in patients affected by systemic comorbidities such as severe epiaortic vessel obstructive disease, chronic obstructive pulmonary disease, or porcelain aorta, which are all mandatory contraindications to traditional on-pump CABG. Off-pump coronary revascularization was performed with the use of Octopus 3 Tissue Stabilizer and the insertion of intracoronary Clearview shunts (Medtronic, Minneapolis, MN, USA). After the operation, the assessment of cardiac output, cardiac index, systemic vascular resistance index, and pulmonary vascular resistance index was made by Swan–Ganz catheter insertion.

Definition of the complications

All of the preoperative variables included in the EuroSCORE system were defined with the same criteria reported in the score system [11]. Postoperative CABG-related myocardial infarction was diagnosed in the case of the elevation of cardiac biomarker values more than five times the 99th percentile of the normal reference range during the first 72 h following CABG, when associated either with the appearance of new pathologic Q-waves or new left bundle branch block, or with angiographically documented new graft or native coronary artery occlusion, or with evidence of new loss of viable myocardium. Diagnosis of postoperative low cardiac output syndrome was made if a patient required either intra-aortic balloon counterpulsation and/or dopamine support greater than 5 μg/kg/min for more than 24 h in the ICU to obtain a systolic blood pressure greater than 90 mmHg and a cardiac index greater than 2.0 l/min/m^2 despite an adequate preload. Stroke was defined as any neurologic deficit longer than 24 h confirmed by clinical findings or computed tomographic scan. Bleeding was defined as a re-exploration owing to excessive mediastinal bleeding or a cardiac tamponade. Respiratory failure was defined as a requirement for mechanical ventilatory support for more than 2 days in the intensive care unit.

Follow-up

Follow-up was obtained using telephone interviews. All survivors were questioned on their health status, and the presence or absence of angina pectoris and dyspnea, to identify their postoperative CCS and New York Heart Association (NYHA) functional classes.

The SF-36 Quality of Life questionnaire was used preoperatively and in the follow-up to compare the self-reported changes in the functional status in all surviving patients. The questionnaire contains 36 questions covering eight different health dimensions: physical functioning, role limitations caused by impaired physical health, bodily pain, general health, vitality, social functioning, role limitations caused by emotional difficulties, and mental health. For each dimension, scores are calculated and converted into a scale of 0–100, that is, from the worst to the best possible status.

Follow-up was 98% complete for the patient population discharged from hospital.

Statistical analysis

Normally distributed continuous variables were expressed as mean ± standard deviation (SD) and were analyzed using Student's *t* test. Dichotomous variables were compared using the χ^2 test, or Fisher's exact test when appropriate. The "*t* test" for paired groups was used to compare population means. The association of potential risk factors with in-hospital mortality was assessed by univariate analysis; factors with a *P* value less than or equal to 0.2 were included in a stepwise logistic regression analysis model. A *P* value of 0.05 or less was considered significant. Survival was analyzed by the Kaplan–Meier method. A log-rank test was used to analyze the impact of preoperative and operative variables on the outcome at follow-up. The Cox proportional hazards method was used to evaluate the influence of pre- and postoperative variables on time to death. Statistical analysis was performed with SPSS 15 statistical software (SPSS, Chicago, IL, USA).

Results

Among our patients, 211 (87.5%) underwent conventional on-pump coronary revascularization, whereas the remaining 30 patients had off-pump beating-heart surgery. The majority of patients (69%) received the left internal mammary artery graft on the left descending artery. The mean number of grafts was 2.2 ± 1.5. Mitral valve annuloplasty was performed in 10 patients, due to severe secondary ischemic mitral regurgitation. Mean CPB time was

Table 2 Operative data

Procedures	No. of patients	%
Off-pump procedures	30	12.5
Number of grafts (mean ± SD)	2.2 ± 1.5	
Use of left internal mammary artery	166	68.9
Use of right internal mammary artery	2	0.8
Use of radial artery	4	1.7
Mitral valve annuloplasty	10	4.1
Cardiopulmonary bypass time (min) (mean ± SD)	98 ± 39	
Aortic cross clamp time (min) (mean ± SD)	80 ± 41	

98 ± 39 min and mean aortic cross-clamp time was 80 ± 41 min. Operative details are reported in Table 2.

In-hospital mortality rate was 4.6% (11 patients). Causes of death were cardiac related in 7 patients: 4 patients died of unresponsive low cardiac output syndrome, 1 of sudden death, 1 of major arrhythmias, and 1 of perioperative myocardial infarction. Noncardiac-related deaths accounted for 4 patients: 2 had untreatable respiratory failure due to postoperative pulmonary infection and 2 died of multiorgan failure. Three other patients (1.2%) died within 30 days outside the hospital: 1 of untreatable heart failure, 1 of sudden death, and 1 of major arrhythmia.

Low cardiac output syndrome occurred in 23 patients (9.5%), although only 11 patients required intra-aortic balloon counterpulsation (IABP). Four patients experienced perioperative myocardial infarction (1.7%), and major ventricular arrhythmia episodes were reported in 23 patients (9.5%). Thirty-nine patients (16.2%) experienced postoperative atrial fibrillation. Respiratory failure requiring prolonged mechanical ventilation affected 22 patients (9.1%), which in 2 of these patients was caused by acute pneumonia. Acute renal failure occurred in 23 patients (9.5%), requiring transient renal dialysis in 5. Repeat thoracotomy due to bleeding was necessary in 4 patients (1.7%). We reported a very low incidence of stroke, which occurred in only 1 patient (0.4%), whereas 2 patients (0.8%) reported transient ischemic attacks. Five patients (2.1%) had subcutaneous presternal wound infection that did not require repeat thoracotomy. No mediastinitis occurred. Mean ICU stay was 3.13 ± 4.04 days.

Table 3 shows the relationship between preoperative and operative variables and 30-day mortality. The univariate statistical analysis confirmed that previous stroke ($P = 0.02$), extracardiac arteriopathy ($P = 0.05$), previous PTCA ($P = 0.004$), CCS class III or IV ($P = 0.02$), NYHA functional class III or IV ($P = 0.002$), emergency surgery ($P = 0.0002$), and EuroSCORE >9 ($P = 0.0007$) were

Table 3 Relationship between preoperative and operative variables and in-hospital mortality: univariate analysis

Variable	Mortality (%)	*P* value
Gender		
Male	8/139 (5.8)	
Female	6/102 (5.9)	0.92
Hypertension		
Yes	13/192 (6.8)	
No	1/49 (2.04)	0.36
Diabetes		
Yes	4/51 (7.8)	
No	10/190 (5.3)	0.72
Previous stroke		
Yes	2/5 (40)	
No	12/236 (5.1)	0.02
Extracardiac arteriopathy		
Yes	8/73 (10.9)	
No	6/168 (3.6)	0.05
COPD		
Yes	1/17 (5.9)	
No	13/224 (5.8)	0.90
Previous PTCA		
Yes	4/16 (25)	
No	10/225 (4.4)	0.004
Previous AMI		
Yes	9/127 (7.1)	
No	5/114 (4.4)	0.5
HF history		
Yes	1/25 (4)	
No	13/216 (6)	0.9
CCS		
I	1/46 (2.2)	
II	1/31 (3.2)	
III	4/105 (3.8)	
IV	8/59 (13.6)	0.02
NYHA		
I	0/71 (0)	
II	4/77 (5.2)	
III	7/74 (9.5)	
IV	3/19 (15.8)	0.002
Cardiogenic shock		
Yes	1/2 (50)	
No	13/239 (5.4)	0.24
LVEF < 35%		
Yes	2/37 (5.4)	
No	12/204 (5.9)	0.78
Left main stem disease		
Yes	5/92 (5.4)	
No	9/149 (6)	0.9

Table 3 continued

Variable	Mortality (%)	*P* value
Emergency surgery		
Yes	4/11 (36.3)	
No	10/230 (4.3)	0.0002
EuroSCORE >9		
Yes	11/81 (13.6)	
No	3/160 (1.9)	0.0007
Mitral valve surgery		
Yes	0/10 (0)	
No	14/231 (6.1)	0.44
ECC		
Yes	11/211 (5.2)	
No	3/30 (10)	0.53

COPD chronic obstructive pulmonary disease, *AMI* acute myocardial infarction, *HF* heart failure, *PTCA* percutaneous transluminal coronary angioplasty, *CCS* Canadian Cardiovascular Society, *NYHA* New York Heart Association, *LVEF* left ventricular ejection fraction, *ECC* extracorporeal circulation

significant determinants of 30-day mortality. The relationship between postoperative morbidity and in-hospital mortality is reported in Table 4: univariate analysis showed that the use of IABP for low cardiac output syndrome ($P = 0.0002$), and prolonged mechanical ventilation ($P = 0.03$) were the only postoperative predictors of early mortality. Preoperative independent variables were analyzed in a stepwise multiple logistic regression analysis, showing that extracardiac arteriopathy (odds ratio (OR) 3.4911, 95% confidence interval (CI) 1.0992–11.0881, $P = 0.03$), NYHA III/IV (OR 3.8501, 95% CI 1.1284–13.1374, $P = 0.03$), and previous PTCA (OR 6.5720, 95% CI 1.6394–26.3450, $P = 0.08$) were significant predictors of 30-day mortality.

The overall mean follow-up was 41.6 ± 25.9 months (range 1–87.6 months). Five patients were lost at follow-up. Among the 222 contacted survivors there were 16 deaths (7.2%) during the total follow-up period. Cardiovascular diseases caused 11 deaths (69%). The cause of death was refractory heart failure in 4 patients, sudden death in 2 patients, pulmonary embolism in 2, acute myocardial infarction in 1, stroke in 1, sequelae of inferior limbs ischemia in 1, ruptured abdominal aortic aneurysm in 1, sepsis after fracture of thighbone in 1, pulmonary neoplasia in 1, pancreas neoplasia in 1, and bladder neoplasia in 1 patient.

The actuarial survival was 91.9% at 1 year and 83.5% at 5 years (Fig. 1). The mean NYHA functional class improved in survivors from 2.13 ± 1 to 1.8 ± 0.8 ($P = 0.0078$), and the mean CCS class improved from 2.7 ± 1.1 to 0.91 ± 0.87 ($P < 0.0001$). Functional status derived from SF-36 questionnaire markedly and significantly improved after surgery, as reported in Table 5.

Table 4 Relationship between perioperative morbidity and in-hospital mortality: univariate analysis

Variable	Mortality (%)	*P* value
IABP		
Yes	4/11 (36.3)	
No	10/230 (4.3)	0.0002
Blood transfusions		
Yes	9/200 (4.5)	
No	5/41 (12.2)	0.12
Surgical revision for bleeding		
Yes	1/4 (25)	
No	13/237 (5.5)	0.56
Perioperative AMI		
Yes	1/4 (25)	
No	13/237 (5.5)	0.56
Prolonged mechanical ventilation		
Yes	4/22 (18.2)	
No	10/219 (4.6)	0.03
Acute renal failure		
Yes	2/23 (6.1)	
No	12/208 (5.7)	0.42
Atrial fibrillation		
Yes	1/39 (2.6)	
No	13/202 (6.4)	0.56

IABP intra-aortic balloon counterpulsation, *AMI* acute myocardial infarction

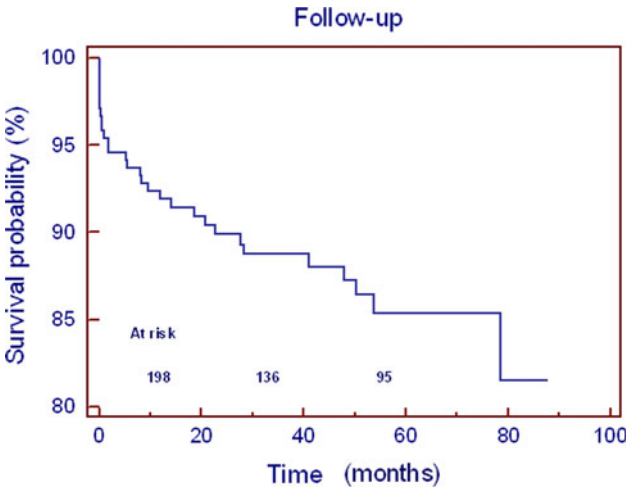

Fig. 1 Actuarial overall survival

Preoperative and operative variables were analyzed in a multivariate model with Cox proportional hazards regression analysis, showing that extracardiac arteriopathy (hazard ratio 0.7197, 95% CI 1.0048–4.1985, $P = 0.04$) and previous PTCA (hazard ratio 1.1497, 95% CI

Table 5 SF-36 scores preoperatively and at follow-up

Variable	Preoperatively Mean ± SD	Follow-up Mean ± SD	*P*
SF-36 domains			
Physical function	45.61 ± 31.15	52.94 ± 28.26	NS
Role physical	45.52 ± 50.11	38.24 ± 41.85	NS
Bodily pain	48.27 ± 36.29	66.68 ± 29.84	0.001
General health	40.71 ± 28.66	56.15 ± 17.48	<0.001
Vitality	42.8 ± 28.82	53.97 ± 18.9	0.002
Social functioning	58.29 ± 32.53	71.82 ± 24.87	0.004
Role emotional	50.87 ± 54.23	59.59 ± 38.23	NS
Mental health	52.33 ± 29.79	70.71 ± 17.16	<0.001

SF-36 Short-Form 36, *NS* not significant

1.2133–8.2162, $P = 0.01$) were significant predictors of late mortality.

Discussion

Elderly patients who underwent CABG have a relatively greater prevalence of cerebrovascular disease, diabetes mellitus, chronic obstructive pulmonary disease, peripheral vascular disease, and left ventricular dysfunction. Moreover, age has been shown to decrease maximal heart rate, to prolong the PR interval, to increase the incidence of atrial fibrillation, and to alter the homogeneity of ventricular repolarization, which may contribute to the cardiac mortality in the elderly population [14]. Not unexpectedly, significant mortality, increased resource utilization, and a high rate of complications have been reported in elderly high-risk surgical candidates [1, 15]. Catabolic response to stress is of great concern in the elderly, because of the limited muscle mass of many older people before surgery [16]. Hormonal dysregulation (decline in anabolic hormones) and postoperative systemic inflammation, often through a synergistic interaction, play a fundamental role in the pathogenesis of the so-called geriatric frailty syndrome [17]. In the elderly, CABG with cardiopulmonary bypass can trigger an acute inflammatory response and hormonal changes that have been related to hemodynamic and metabolic effects [18]. Nevertheless, recent reports suggest that aggressive surgical coronary revascularization in the elderly relieves angina effectively and improves quality of life [2, 3].

The main finding of this study is that CABG can be performed in octogenarians with acceptable in-hospital results. The 30-day mortality rate in our study was 5.8%, comparing well with the results of other single-center experiences reporting early mortalities of less than 10% [7–9, 15, 19]. Continued refinements in surgical technique, cardiac anesthesia, myocardial protection, and postoperative respiratory fast-track weaning may be determinants leading to an improved outcome for elderly patients.

Although saphenous vein grafts have been traditionally used as the bypass conduits in CABG, it is well recognized that vein graft atherosclerosis is the "Achilles heel" of surgical coronary revascularization. In elderly patients, left internal mammary artery grafts, along with vein grafts, have resulted in improved long-term outcomes [20]: in fact, we used the left internal mammary artery in the majority of patients (68.9%), with a percentage of 90% in the second half of the study period. Several studies supported survival benefits of arterial revascularization in elderly patients [21, 22]. Our strategy involved the use of the right internal mammary or the radial artery as second-choice arterial conduit only in the case of poor quality of the left internal mammary artery.

Off-pump CABG has become an option in the treatment of patients with coronary artery disease, especially those with associated systemic disease or functional impairment of various organs, in patients with technical obstacles to on-pump surgery caused by severe aortic calcifications, and also in patients with depressed ventricular function [23]. It is significant that in elderly patients, coronary artery disease is often very severe and is characterized by diffuse calcifications in comparison with the younger population, making off-pump multivessel complete revascularization in these patients very difficult. Moreover, recent studies have confirmed that complete revascularization improves long-term cardiac survival and functional status [24]. In consideration of these findings, a rigorous selection of potential candidates for off-pump technique appears mandatory, particularly in the setting of high-risk patients. Even though consensus has been reached on the possibility of performing complete revascularization with the off-pump technique, we believe that beating-heart coronary surgery can be performed with success only by an experienced surgeon. We do not perform off-pump surgery routinely, reserving this technique for selected patients in whom coronary artery disease is limited to the left ventricle anterior wall and when there are mandatory contraindications to CPB such as porcelain aorta.

We used only flexible annuloplasty rings for the mitral valve reconstruction in the case of chronic mitral regurgitation secondary to coronary artery disease. We believe that this approach is easy and safe. It is confirmed by the current best available evidence that the use of flexible bands permits more physiologic geometric changes, preserves left ventricular function during stress, and is associated with lower postoperative mitral valve gradients [25, 26].

Attention to intraoperative myocardial protection appears mandatory in these high-risk patients, and the use of antegrade and retrograde normothermic blood cardioplegia should be encouraged mainly for coronary revascularization [27]. The benefits in the prevention of systemic inflammatory response syndrome after ischemia–reperfusion injury due to CPB have recently been demonstrated [28]. Although transient low-output syndrome occurred in 23 of our patients (9.5%), IABP was required only in 4.6% of our patients. This was similar to what has been reported in the literature [9, 15].

Another important issue to consider is careful hemostasis management and the use of antifibrinolytic agents during CPB, which can minimize excessive postoperative bleeding and the need for re-exploration, as well as helping to realize an effective respiratory fast-track weaning. In fact in the present study, this postoperative complication was reported only in 4 patients (1.7%).

The overall neurologic complications rate in our patient population was 1.2%. In particular, the stroke incidence (0.4%) was lower than that reported in other studies [8, 15], which may be linked to the routine use of preoperative epiaortic vessels Doppler echography and intraoperative transesophageal aortic echography. We believe that it is necessary to maintain a perfusion pressure >70 mmHg during CPB in all patients with a documented associated cerebrovascular disease in order to minimize the risks of perioperative stroke.

Age is considered a significant risk factor for the development of acute renal failure in postanesthesia care unit patients, particularly after cardiac surgery [29], which has a serious impact on in-hospital stay and mortality. In this study, this postoperative complication was not a risk factor for increased early and long-term mortality at univariate and multivariate analysis, although it remains a relatively frequent complication, occurring in 23 of our patients (9.5%), and requiring transient renal dialysis in 5 of them. Several new technical and pharmacologic approaches have been proposed to reduce the incidence of postoperative acute renal failure after cardiac surgery. In a recent study, Presta et al. [30] demonstrated that pulsatile CPB seems to preserve renal function better than standard CPB, also in elderly patients. A recent meta-analysis provided evidence that fenoldopam may confer significant benefits in preventing the need for renal replacement therapy and reducing mortality in patients undergoing cardiovascular surgery [31], whereas the impact of nesiritide on renal protection after cardiac surgery remains a matter of debate [32, 33]. In this setting of high-risk patients, the assessment of novel renal biomarkers for the early detection of postoperative acute renal failure constitutes an important area of research [34].

All of these considerations suggest that although refinements in perioperative management have led to improved outcome of elderly patients, focused efforts are required to optimize prevention and treatment of postoperative systemic and specific organ dysfunctions. Surgical stress after CABG is usually followed by increased inflammation and hormonal dysregulation, superimposed on the already altered hormonal assessment and preoperative proinflammatory state and sarcopenia. It has been suggested that hormonal therapy together with nutritional supplementation and exercise could be a potential strategy to prevent the catabolic response and improve physical well-being after surgery [16].

In the meantime, prediction of outcome in elderly patients based on preoperative risk factors appears to be mandatory for the optimal selection of surgery candidates. Several studies have reported that renal failure, peripheral vascular disease, the use of IABP, longer CPB time, and emergency procedures occur frequently in elderly people after cardiac surgery, and predict adverse outcomes [8, 10, 35]. In our study, multivariate analysis was used to evaluate 30-day death risk for patients after surgery: extracardiac arteriopathy (OR = 3.4911), NYHA III–IV (OR = 3.8501), and previous PTCA (OR = 6.5720) proved to be independent predictive factors of perioperative mortality. These results suggest that early intervention may be warranted in this high-risk population in order to avoid the worsening of heart functional class and the onset of symptoms of heart failure.

In the current study, survival estimates at 1 and 5 years were 91.9% and 83.5%, respectively. These results compare well with other single-center and registry studies, and confirm good long-term survival despite advanced age [7, 10, 36, 37]. The results obtained in our series of patients demonstrate not only an extended life expectancy, but also a significant improvement in the NYHA functional class and the relief of angina. Cox proportional hazards analysis showed that time to late death was adversely affected by preoperative extracardiac arteriopathy and previous PTCA. These variables may represent markers for major postoperative morbidity with a strong negative impact on life expectancy, and should probably be considered in the preoperative evaluation of optimal candidates for surgery and for the development of a risk model for this high-risk group of patients.

The limitations of this study should be noted. This is a single-center retrospective analysis of elderly patients who

underwent CABG. Given that the study did not compare outcomes in elderly patients with coronary disease who underwent medical therapy or percutaneous coronary interventions in the same period, the conclusions have limited application. Finally, due to the retrospective design of the study, it proved impossible to collect data about preoperative objective "frailty" criteria in order to define their prognostic significance, as reported by other authors [17].

Which types of elderly patients are ideal candidates for CABG is not an easy question to answer. An elderly person with few background illnesses and a good expected quality and length of life would probably stand to benefit from surgery. Discrepancies between chronological age and biological age must be dealt with, and the risk–benefit analysis needs to be tailored to each patient.

However, our study shows that advanced age alone should not be a deterrent to CABG. Despite a trend toward continued improvement in the perioperative management and consequent lower perioperative morbidity, a careful selection of optimal candidates, based also on the evaluation of their systemic comorbidities, appears mandatory to obtain the greatest benefit for these high-risk patients.

Further prospective studies need to be addressed to determine the independent prognostic effect of rules-based frailty criteria in the older candidates for CABG.

Acknowledgments We thank Lois Clegg, English Language Teacher, University of Parma, for her assistance in the revision of the manuscript.

Conflict of interest None declared.

References

1. Chee JH, Filion KB, Haider S, Pilote L, Eisenberg MJ (2004) Impact of age on hospital course and cost of coronary artery bypass grafting. Am J Cardiol 93:768–771
2. Graham MM, Ghali WA, Faris PD, Galbraith PD, Norris CM, Knudtson ML, Alberta Provincial Project for Outcomes Assessment in Coronary Heart Disease (APPROACH) Investigators (2002) Survival after coronary revascularization in the elderly. Circulation 105:2378–2384
3. TIME Investigators (2001) Trial of invasive versus medical therapy in elderly patients with chronic symptomatic coronary artery disease (TIME): a randomized trial. Lancet 358:951–957
4. Shirasawa K, Hwang M, Sasaki Y, Takeda S, Inenaga-Kitaura K, Kitaura Y, Kawai C (2011) Survival and changes in physical ability after coronary revascularization for octa-nonagenarian patients with acute coronary syndrome. Heart Vessels 26:385–391
5. Baskett R, Buth K, Ghali W, Norris C, Maas T, Maitland A, Ross D, Forgie R, Hirsch G (2005) Outcomes in octogenarians undergoing coronary artery bypass grafting. CMAJ 172: 1183–1186
6. Gopaldas RR, Chu D, Dao TK, Huh J, Lemaire SA, Coselli JS, Bakaeen FG (2009) Predictors of surgical mortality and discharge status after coronary artery bypass grafting in patients 80 years and older. Am J Surg 198:633–638
7. Kozower BD, Moon MR, Barner HB, Moazami N, Lawton JS, Pasque MK, Damiano RJ Jr (2005) Impact of complete revascularization on long-term survival after coronary artery bypass grafting in octogenarians. Ann Thorac Surg 80:112–117
8. Filsoufi F, Rahmanian PB, Castillo JG, Chikwe J, Silvay G, Adams DH (2007) Results and predictors of early and late outcomes of coronary artery bypass graft surgery in octogenarians. J Cardiothorac Vasc Anesth 21:784–792
9. Likosky DS, Dacey LJ, Baribeau YR, Leavitt BJ, Clough R, Cochran RP, Quinn R, Sisto DA, Charlesworth DC, Malenka DJ, MacKenzie TA, Olmstead EM, Ross CS, for the Northern New England Cardiovascular Disease Study Group (2008) Long-term survival of the very elderly undergoing coronary artery bypass grafting. Ann Thorac Surg 85:1233–1238
10. Rohde SL, Baker RA, Tully PJ, Graham S, Cullen H, Knight JL (2010) Preoperative and intraoperative factors associated with long-term survival in octogenarians cardiac surgery patients. Ann Thorac Surg 89:105–111
11. Nashef SA, Roques F, Michel P, Gauducheau E, Lemeshow S, Salamon R (1999) European system for cardiac operative risk evaluation (EuroSCORE). Eur J Cardiothorac Surg 16:9–13
12. Grigioni F, Enriquez-Sarano M, Zehr KJ, Bailey KR, Tajik AJ (2001) Ischemic mitral regurgitation: long-term outcome and prognostic implications with quantitative Doppler assessment. Circulation 103:1759–1764
13. Badwar V, Bolling SF (2002) Mitral valve surgery in the patient with left ventricular dysfunction. Semin Thorac Cardiovasc Surg 14:133–136
14. Huang J-H, Lin Y-Q, Pan N-H, Chen Y-J (2010) Aging modulates dispersion of ventricular repolarization in the very old of the geriatric population. Heart Vessels 25:500–508
15. Scott BH, Seifert FC, Grimson R, Glass PSA (2005) Octogenarians undergoing coronary artery bypass graft surgery: resource utilization, postoperative mortality, and morbidity. J Cardiothorac Vasc Anesth 19:583–588
16. Wolfe RR (2006) Optimal nutrition, exercise, and hormonal therapy promote muscle anabolism in the elderly. J Am Coll Surg 202:176–180
17. Fried L, Walston J (2003) Frailty and failure to thrive. In: Hazzard WR, Blass JP, Ettinger WH Jr, Halter JB, Ous-lander J (eds) Principles of geriatric gerontology, 5th edn. McGraw Hill, New York, pp 1487–1502
18. Maggio M, Ceda GP, De Cicco G, Cattadori E, Visioli S, Ablondi F, Beghi C, Gherli T, Basaria S, Ceresini G, Valenti G, Ferrucci L (2005) Acute changes in circulating hormones in older patients with impaired ventricular function undergoing on-pump coronary artery bypass rafting. J Endocrinol Invest 28:711–719
19. Zingone B, Gatti G, Rauber E, Tiziani P, Dreas L, Pappalardo A, Benussi B, Spina A (2009) Early and late outcomes of cardiac surgery in octogenarians. Ann Thorac Surg 87:71–78
20. Kurlansky PA, Williams DB, Traad EA, Carrillo RG, Schor JS, Zucker M, Singer S, Ebra G (2003) Arterial grafting results in reduced operative mortality and enhanced long-term quality of life in octogenarians. Ann Thorac Surg 76:418–427
21. Onorati F, Santarpino G, Leone MA, Impiombato B, Mastroroberto P, Renzulli A (2008) Intraoperative behavior of arterial grafts in the elderly and the young: a flowmetric systematic analysis. Heart Vessels 23:316–324
22. Santarpino G, Onorati F, Scalas C, De Gori M, Cristodoro L, Zofrea S, Renzulli A (2009) Radial artery achieves better flowmetric results than saphenous vein in the elderly. Heart Vessels 24:108–115
23. Emmert MY, Salzberg SP, Theusinger OM, Rodriguez H, Sündermann SH, Plass A, Starck CT, Seifert B, Baulig W,

Hoerstrup SP, Jacobs S, Grünenfelder J, Falk V (2011) Off-pump surgery for the poor ventricle? Heart Vessels (Epub ahead of print). doi:10.1007/s00380-011-0146-0
24. Kleisli T, Cheng W, Jacobs MY, Mirocha J, Derobertis MA, Kass RM, Blanche C, Fontana GP, Raissi SS, Magliato KE, Trento A (2005) In the current era, complete revascularization improves survival after coronary artery bypass surgery. J Thorac Cardiovasc Surg 129:1283–1291
25. Sharony R, Saunders PC, Nayar A, McAleer E, Galloway AC, Delianides J, Schwartz CF, Applebaum RM, Kronzon I, Colvin SB, Grossi EA (2004) Semirigid partial annuloplasty band allows dynamic mitral annular motion and minimizes valvular gradients: an echocardiographic study. Ann Thorac Surg 77:518–522
26. Chee T, Haston R, Togo A, Raja SG (2008) Is a flexible mitral annuloplasty ring superior to a semi-rigid or rigid ring in terms of improvement in symptoms, survival? Interact Cardiovasc Thorac Surg 7:477–484
27. Nicolini F, Beghi C, Muscari C, Agostinelli A, Budillon AM, Spaggiari I, Gherli T (2003) Myocardial protection in cardiac surgery: current options and future challenges. Eur J Cardiothorac Surg 24:986–993
28. Enc Y, Karaca P, Ayoglu U, Camur G, Kurc E, Cicek S (2006) The acute cardioprotective effect of glucocorticoid in myocardial ischemia-reperfusion injury occurring during cardiopulmonary bypass. Heart Vessels 21:152–156
29. Abelha FJ, Botelho M, Fernandes V, Barros H (2009) Determinants of postoperative acute kidney injury. Crit Care 13:R79
30. Presta P, Onorati F, Fuiano L, Mastroroberto P, Santarpino G, Tozzo C, Andreucci M, Renzulli A, Fuiano G (2009) Can pulsatile cardiopulmonary bypass prevent perioperative renal dysfunction during myocardial revascularization in elderly patients? Nephron Clin Pract 111:c229–c235
31. Landoni G, Biondi-Zoccai GG, Marino G, Bove T, Fochi O, Maj G, Calabrò MG, Sheiban I, Tumlin JA, Ranucci M, Zangrillo A (2008) Fenoldopam reduces the need for renal replacement therapy and in-hospital death in cardiovascular surgery: a meta-analysis. J Cardiothorac Vasc Anesth 22:27–33
32. Salzberg SP, Emmert MY, Vassalotti J, Nandiwada DR, Adams DH (2009) Impact of preoperative nesiritide on renal function after mitral valve surgery. Heart Surg Forum 12:E217–E218
33. Ejaz AA, Martin TD, Johnson RJ, Winterstein AG, Klodell CT, Hess PJ Jr, Ali AK, Whidden EM, Staples NL, Alexander JA, House-Fancher MA, Beaver TM (2009) Prophylactic nesiritide does not prevent dialysis or all-cause mortality in patients undergoing high-risk cardiac surgery. J Thorac Cardiovasc Surg 138:959–964
34. Haase M, Bellomo R, Devarajan P, Ma Q, Bennett MR, Mockel M, Matalanis G, Dragun D, Haase-Fielitz A (2009) Novel biomarkers early predict the severity of acute kidney injury after cardiac surgery in adults. Ann Thorac Surg 88:124–130
35. Bridges CR, Edwards FH, Peterson ED, Coombs LP, Ferguson TB (2003) Cardiac surgery in nonagenarians and centenarians. J Am Coll Surg 197:347–356
36. Akins CW, Daggett WM, Vlahakes GJ, Hilgenberg AD, Torchiana DF, Madsen JC, Buckley MJ (1997) Cardiac operations in patients 80 years old and older. Ann Thorac Surg 64:606–614
37. Kirsch M, Guesnier L, LeBesnerais P, Hillion ML, Debauchez M, Seguin J, Loisance DY (1998) Cardiac operations in octogenarians: perioperative risk factors for death and impaired autonomy. Ann Thorac Surg 66:60–67