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Predictors of prolonged ICU stay after on-pump versus off-pump coronary artery bypass grafting

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Abstract *Objective:* To define predictors for prolonged ICU stay in order to improve patient outcome and reduce costs. *Patients and methods:* Prospective data on 10,759 patients undergoing coronary artery bypass grafting with and without use of cardiopulmonary bypass (coronary artery bypass grafting, CABG; *n*=8,917; off-pump coronary artery bypass grafting, OPCAB; *n*=765; minimally invasive direct coronary artery bypass grafting, MIDCAB; *n*=1,077) between April 1996 and August 2001 were subjected to univariate and, consecutively, to multivariate logistic regression analysis. Prolonged ICU stay was defined as intensive care treatment for three postoperative days and longer. *Measurements and results:* Mean duration of ICU stay was 3.8±6.9 days; overall prevalence of prolonged ICU stay was 37.1%. The hospital mortality was 3.5% (ICU ≥3 days: 5.9%; ICU <3 days: 2.0%). Out of 39 selected pre- and intraoperative patient- and treatment-related variables, by univariate analysis, 32 variables having a high association with prolonged ICU stay were identified. Using a stepwise logistic regression model, 20 variables were shown to be independent predictors for prolonged ICU stay. Both OPCAB and MIDCAB surgery were identified as having a significantly lower association with prolonged ICU stay. *Conclusion:* As prolonged ICU stay is associated with poor patient outcome and increased costs it is of utmost importance to identify patients at a high risk for prolonged ICU stay. More frequent off-pump CABG may optimize patient outcome.

Keywords Cardiac surgery · CABG · Beating heart surgery · Intensive care unit

Introduction

Despite refinements in perioperative management, prolonged intensive care unit (ICU) stay is still associated with poor patient outcome and increased costs [1, 2, 3]. Due to improvements in medical treatment, such as off-pump coronary artery bypass grafting (OPCAB) and recent trends in interventional cardiology, the profile of patients referred to cardiac surgery has altered substantially. There is a growing number of elderly patients carrying substantial additional risk factors as well as those requiring repeat cardiac surgery. This has led to an increased proportion of high-risk patients in recent years resulting in impaired patient outcome and increasingly expensive care [4, 5].

While several studies have used multivariate analysis to predict the risk of death after cardiac surgery and to develop scoring systems to identify patients at high risk for intra- and postoperative mortality, there is little data regarding predictors for postoperative morbidity and prolonged ICU stay especially after coronary artery bypass surgery with and without cardiopulmonary bypass (CPB). The value of mortality as the sole end-point in the evaluation of clinical trials has been questioned. Instead, morbidity has been suggested as a valid end-point [6]. In 1990, Hammermeister and associates conducted a study to identify risk factors predisposing towards major complications after cardiac surgery. They found older age, congestive heart failure, vascular disease, higher serum creatinine, and previous cardiac surgery to be risk factors for the development of renal failure, low cardiac output, and requirement for prolonged mechanical support [7].

However, new therapeutic strategies, such as off-pump CABG, may be beneficial with regard to postoperative morbidity and the need for intensive care treatment even in high-risk subgroups.

The aim of the present study was to systematically investigate the prevalence and possible predictors of prolonged ICU stay, as well as variables leading to a prolonged ICU stay, after coronary artery bypass grafting in the era of new, less invasive surgical techniques.

Material and methods

Study population

Ten thousand seven hundred and fifty-nine consecutive adult patients undergoing coronary artery bypass surgery between April 1996 and August 2001 were included in this study. As shown in Table 1, conventional CABG surgery with cardiopulmonary bypass was performed (Conv-CABG) in 8,917 patients, and 1,842 patients underwent CABG on the beating heart without cardiopulmonary bypass (CPB) either through a median sternotomy (off-pump coronary artery bypass grafting, OPCAB; n=765) or through a left lateral minithoracotomy (minimally invasive direct coronary artery bypass grafting, MIDCAB; n=1,077) (Table 1). Patients were assigned to one of the surgical techniques according to clinical indications (e.g., MIDCAB approach in patients with one-vessel disease). Throughout this study the choice of performing conventional or off-pump CABG was up to the individual surgeon. Initially, only selected patients were considered candidates for off-pump revascularization, whereas after an initial period of 6–12 months it was performed much more frequently. From the middle of 1997 onwards two out of nine staff surgeons used the off-pump technique whenever feasible; from 1998 onwards this increased to three staff surgeons; and from 2000 onwards four staff surgeons used this techique when feasible. Thirty-one patients, who initially had beating heart operations (either OPCAB or MIDCAB approach) had to be converted to a conventional strategy with cardiopulmonary bypass, intraoperatively. Intraoperative conversion was necessary in cases of hemodynamic instability, inability to expose the native coronary vessel with mechanical stabilizers on the beating heart, intramural course of the native coronary vessels or inability to anastomose the bypass vessel in cases in which the target coronary vessel was too small to perform a safe anastomosis on the beating heart. These patients were excluded from the beating heart groups and assigned to the Conv-CABG group.

Definition of prolonged ICU stay

Postoperative prolonged ICU stay was defined as intensive care treatment either at the intensive care unit or the intermediate care unit (without mechanical ventilation) lasting for 3 days and longer. Patients requiring intensive care treatment on at least three non-consecutive days were also assigned to the group with prolonged ICU stay as they suffered from severe postoperative complications, possibly associated with one of the analyzed pre- and intraoperative variables. Patients only temporarily readmitted to the intermediate care unit for electrical cardioversion or pleurocentesis, for example, were not assigned to the group with prolonged ICU stay. In cases of readmitted patients staying on the ICU for 1 day and more, these days were added to the initial number of days on the ICU. If the total number reached or exceeded 3 days, those patients were included in the group of patients with prolonged ICU stay.

Data collection

Perioperative data were recorded prospectively using an online database system as described previously (Medwork database software, Lenz + Partner, Germany) [8]. All variables analyzed were entered prospectively to achieve a complete and valid data set for each patient. The validity of the data was routinely ensured by using this information for generating text documents, thus resulting in a meticulous confirmation of the data entered by the user. The pre- and intraoperative risk factors that were included in a univariate analysis and consecutively in a stepwise logistic regression model are listed in Table 2.

Statistical analysis

Continuous variables are expressed as mean±standard deviation, and categorical data as proportions. Continuous variables between patients with and without prolonged ICU stay were compared using the student's unpaired t-test or analysis of variance (ANOVA), with the appropriate correction for multiple comparisons. Categorical variables were compared by χ^2 analysis. Univariate analysis of risk factors was performed calculating odds ratios (OR) with a 95% confidence interval. Variables with a P-value less than 0.05

Table 1 Preoperative patient characteristics. (*Conv-CABG* conventional coronary artery bypass grafting, *B.h.* beating heart surgery, *OPCAB* off-pump coronary artery bypass grafting, *MIDCAB* minimally invasive direct coronary artery bypass grafting, *LVEF* left ventricular ejection fraction, *NYHA* New York Heart Association heart failure classification, *CCS* Canadian Cardiovascular Society angina classification, *Prior CABG* prior coronary artery bypass grafting)

	n	Age (years)	Gender Male (%)	CCS ≥3 (%)	NYHA ≥3 (%)	LVEF (%)	No. of CABGs	Prior CABG (%)
Total	10,759	65.0±9.5	8,289 (77.0)	36.7	78.4	53.5±20.6	2.3±0.9	3.4
Conv-CABG	8,917	65.4±9.2	6,887 (77.2)	36.0	79.9	53.0±20.6	2.5±0.8	3.2
B.h.	1,842	63.1±10.6	1,402 (76.1)	39.6	71.4	55.9±20.7	1.3±0.6	4.2
OPCAB	765	64.4±10.5	613 (80.1)	44.6	74.5	54.4±20.2	1.7±0.8	4.8
MIDCAB	1,077	62.2±10.6	789 (73.3)	36.1	69.3	57.0±21.1	1.0±0.3	3.8

Table 2 Independent predictors of prolonged ICU-stay. (*LVEF* left ventricular ejection fraction, *IABP* intra-aortic ballon pump, *PM* pacemaker, *NYHA* New York Heart Association heart failure classification, *OPCAB* off-pump coronary artery bypass grafting, *MIDCAB* minimally invasive direct coronary artery bypass grafting)

	Odds-ratio	95% Confidence interval	*P*-value
Variables associated with *higher* prevalence of prolonged ICU-stay (analyzed by multivariate logistic regression analysis)			
Preoperative infection	2.0	1.29–3.12	0.0019
History of cerebrovascular disease	1.45	1.15–1.83	0.0014
History of pulmonary disease	1.4	1.18–1.66	0.0001
History of renal disease	2.1	1.65–2.56	<0.0001
History of embolism	1.30	1.01–1.68	0.0041
Atrial fibrillation	1.47	1.19–1.81	0.0003
Diabetes mellitus	1.29	1.19–1.41	<0.0001
Peripheral vascular disease	1.36	1.23–1.51	<0.0001
NYHA ≥3	1.12	1.01–1.25	0.029
LVEF ≤30%	1.38	1.18–1.62	<0.0001
Preoperative myocardial infarction	1.21	1.11–1.32	<0.0001
Age ≥70 and <80 years	1.32	1.26–1.45	<0.0001
Age ≥80 years	1.78	1.41–2.26	<0.0001
Preoperative cardiogenic shock	1.39	1.18–1.64	<0.0001
Urgent operation	1.52	1.37–1.69	<0.0001
Operation time ≥3 h	1.35	1.2–1.51	<0.0001
Perfusion time ≥2 h	1.59	1.33–1.91	<0.0001
Intraoperative hemofiltration	1.26	1.05–1.49	0.009
Intraoperative PM-stimulation	1.3	1.15–1.46	<0.0001
Intraoperative IABP-support	1.69	1.25–2.28	0.0006
Variables associated with *lower* prevalence of prolonged ICU-stay (analyzed by multivariate logistic regression analysis)			
OPCAB	0.62	0.52–0.74	<0.0001
MIDCAB	0.5	0.42–0.59	<0.0001

were consecutively subjected to a multivariate logistic regression model to assess the independent impact of the risk factors on prolonged ICU stay. A stepwise procedure (backward Wald) was used. A P-value less than 0.05 was used to enter and eliminate variables [9]. All statistical analyses were performed using the SPSS statistical package 9.0 (SPSS, Birmingham, Ala., USA).

Results

Patient characteristics are shown in Table 1. The mean age of the study population was 65.0±9.5 years. Patients aged over 70 years constituted 34.8% of the study population (age 70–79 years 31.7% and age over 80 years 3.1%, respectively). Most of the patients in the study population were male (77.0%). Patients in the MIDCAB group were significantly younger than both the Conv-CABG and the OPCAB group, respectively (P<0.0001). The age within the OPCAB group was significantly lower than the Conv-CABG group (P =0.022). With regard to preoperative left ventricular ejection fraction (LVEF), patients in the MIDCAB group had a higher LVEF than patients both in the Conv-CABG and in the OPCAB group (P<0.0001 vs Conv-CABG and P=0.021 vs OPCAB, respectively). Prevalence of impaired NYHA-classification (≥3) was significantly higher in the Conv-CABG group than both the MIDCAB and the OPCAB group (P<0.0001 vs MIDCAB and P=0.003 vs OPCAB, respectively), whereas the prevalence in the OPCAB group was significantly higher compared to the MIDCAB group (P=0.039). However, the prevalence of impaired CCS-classification (≥3) was found to be highest in the OPCAB group, being significantly different in comparison to the Conv-CABG (P<0.0001) and the MIDCAB group (P=0.001). No differences with regard to the CCS-classification were found between the Conv-CABG and the MIDCAB group (P=n.s.). The number of coronary bypass grafts in the Conv-CABG group was significantly higher than the OPCAB and the MIDACB group (P<0.0001, respectively). Furthermore, patients undergoing MIDCAB surgery received a significantly lower number of bypass grafts than the OPCAB group (P<0.0001). Prevalence of previous coronary bypass grafting was significantly higher in the OPCAB than the Conv-CABG group (P=0.048). No significant differences have been found between the MIDCAB and the Conv-CABG group and between both beating heart groups (P=n.s.)

With regard to the postoperative need for rethoracotomy defined as chest reopening due, in almost all cases, to bleeding the prevalence was highest within the MIDCAB group (8.0%) reaching statistical significance as compared to the Conv-CABG group (6.8%; P=0.036), whereas there were no statistically significant differences between both beating heart groups (OPCAB: 7.2%; P=n.s.) and between the OPCAB and the Conv-CABG group (P=n.s.).

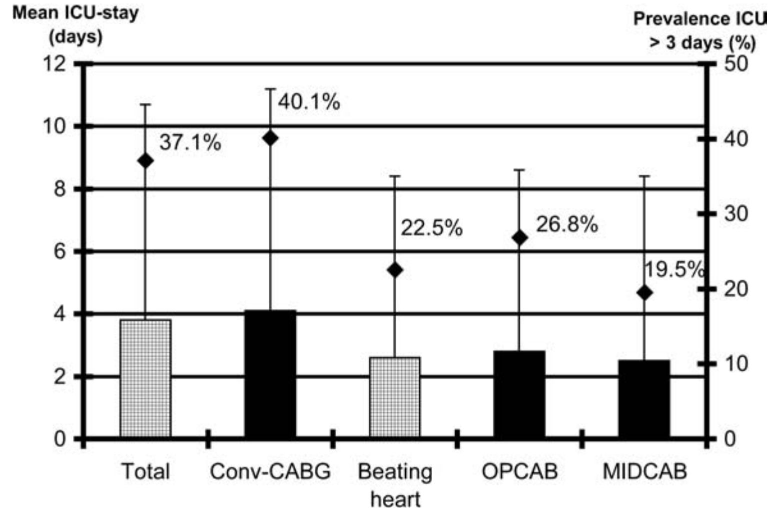

Fig. 1 Mean ICU stay and prevalence of prolonged ICU stay (≥3 days) according to the type of coronary artery bypass grafting. ICU-stay expressed as mean and standard deviation. *Error bars* represent standard error of the mean. (*Rhomb* prevalence of prolonged ICU-stay according to the type of coronary artery bypass grafting, *Conv-CABG* conventional coronary artery bypass grafting, *OPCAB* off-pump coronary artery bypass grafting, *MIDCAB* minimally invasive direct coronary artery bypass grafting)

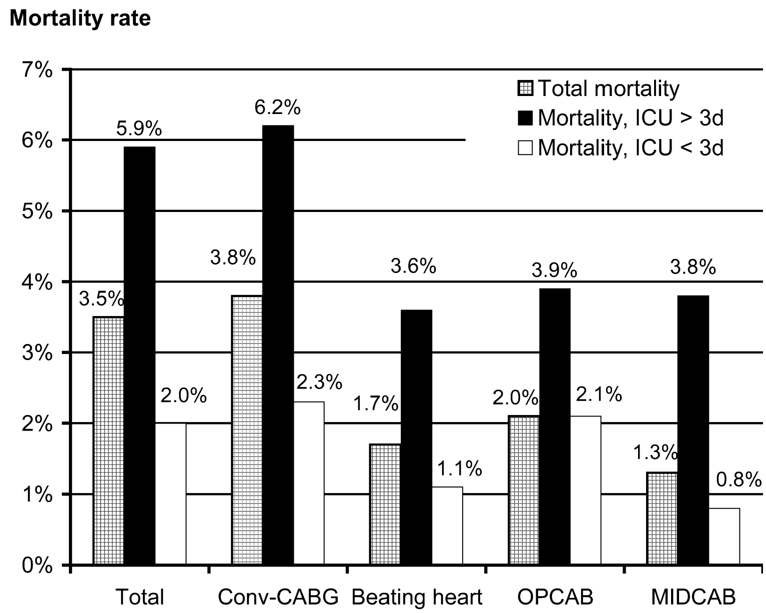

Fig. 2 Postoperative (30 day) mortality in relation to the type of coronary artery bypass grafting and the duration of ICU stay. (*Conv-CABG* conventional coronary artery bypass grafting, *OPCAB* off-pump coronary artery bypass grafting, *MIDCAB* minimally invasive direct coronary artery bypass grafting)

Patients with prolonged ICU stay were significantly older (66.6±9.3 years vs 64.0±9.4 years; $P<0.0001$) and had a significantly lower preoperative left ventricular ejection fraction (50.7%±21.2 vs 55.2%±20.1; $P<0.0001$) as compared to patients with a normal ICU stay. The majority of patients both with and without prolonged ICU stay were male gender (76.2% vs 77.5%; *P*=n.s.). The mean duration of ICU stay in all patients was 3.8±6.9 days and the overall prevalence of prolonged ICU stay was 37.1%.

The prevalence of prolonged ICU stay varied among the different surgical procedures as shown in Fig. 1. The highest prevalence was found in the Conv-CABG group as compared to both the OPCAB and the MIDCAB group ($P<0.0001$ for both groups). Within the beating heart group the prevalence in the MIDCAB group was significantly lower than the OPCAB group [($P=0.004$); Fig. 1]. The mean duration of postoperative ICU stay in patients with prolonged intensive care treatment was 7.7±10.2 days.

By using univariate analysis, 32 out of 39 variables were identified as having a high association with prolonged ICU stay (see table in Appendix).

By stepwise logistic regression analysis, 20 variables were identified as independent predictors of ICU stay for 3 postoperative days and longer, as well as two variables that were found to be associated with a significantly lower prevalence of prolonged ICU stay (Table 2). Prevalence and statistically significant differences of independent predictors as related to the different surgical procedures are shown in Table 3.

Table 3 Prevalence of independent predictors of prolonged ICU-stay according to the type of coronary artery bypass grafting. (*LVEF* left ventricular ejection fraction, *IABP* intra-aortic ballon pump, *PM* pacemaker, *NYHA* New York Heart Association heart failure classification, *Conv-CABG* conventional coronary artery bypass grafting, *OPCAB* off-pump coronary artery bypass grafting, *MIDCAB* minimally invasive direct coronary artery bypass grafting)

	Total	Conv–CABG	B.h.	OPCAB	MIDCAB
Variables associated with *higher* prevalence [independent predictors (multivariate logistic regression analysis)]	Prevalence (%)				
Preoperative infection	0.9	0.9	1.0	0.9	1.0
History of cerebrovascular disease	3.4	3.4	3.1	4.2	2.3
Pulmonary disease ***	11.3	12.4	5.9	9.3	3.5
Renal disease	3.9	3.9	3.5	3.4	3.5
History of embolism	6.3	6.5	5.6	7.3	4.5
Atrial fibrillation	4.1	4.2	3.3	3.1	3.4
Diabetes mellitus *,**,***	39.2	41.2	29.4	32.5	27.1
Peripheral vascular disease **,***	20.5	21.8	14.7	20.0	10.9
NYHA ≥3 *,**,***	78.4	79.9	71.4	74.5	69.3
LVEF ≤30% **,***	7.9	8.3	6.1	9.3	3.8
Preoperative myocardial infarction *,**,***	61.2	63.6	49.6	52.5	47.4
Age ≥70 and <80 years *,**	31.7	32.9	25.6	28.5	23.6
Age ≥80 years	3.1	3.0	3.3	3.9	2.9
Preoperative cardiogenic shock**,***	9.8	10.1	8.5	13.2	5.1
Urgent operation *,**,***	20.4	22.0	12.9	17.3	9.7
Operation time ≥3 h *,**,***	19.3	19.4	18.8	23.3	15.7
Perfusion time ≥2 h	7.9	7.9			
Intraoperative hemofiltration	7.4	7.4			
Intraoperative PM–stimulation *,**	14.3	16.7	3.0	3.5	2.7
Intraoperative IABP–support *,**	2.3	2.6	0.6	0.5	0.6
Variables associated with *lower* prevalence [independent predictors (multivariate logistic regression analysis)]					
OPCAB	7.1	∅	41.5	∅	∅
MIDCAB	10.0	∅	58.5	∅	∅

**P* <0.05 between CABG and OPCAB; ***P*<0.05 between CABG and MIDCAB; ****P*<0.05 between OPCAB and MIDCAB

Perioperative (30 day) mortality was 3.5%. Mortality in the prolonged ICU group was significantly higher than patients with normal ICU stay [(5.9% vs 2.0%; *P*<0.0001); Fig. 2]. The highest mortality rate was found in the Conv-CABG group for patients with prolonged ICU stay as well as for those with normal ICU stay, which was the lowest in the MIDCAB group for both subgroups (Fig. 2).

Discussion

Quantification of operative risk is a major problem in contemporary cardiac surgery especially with the background of an increasing number of high-risk patients. Although considerable information has been published on preoperative predictors of mortality after cardiac surgery, only a few studies have assessed such predictors of major complications resulting in prolonged ICU stay after cardiac surgery. A reliable yet simple global evaluation of the cardiac surgical patient's preoperative condition will improve assessment of the effects of surgical, anesthetic, and intensive care management. There is a clear relationship between the presence of co-morbidities and duration of ICU stay, suggesting that preoperative prediction of postoperative morbidity is important for assessment of expected length of stay, estimation of projected costs, and resource utilization [2].

Prolonged intensive care treatment in this series was intentionally defined as an ICU stay for 3 days and more. This relatively broad time-frame includes almost all patients suffering from postoperative complications after cardiac surgery leading to an increased requirement for intensive care treatment. Excluding those patients from the study would have biased the impact of the analyzed potential risk factors on patient outcome. It is probably due to this underlying definition of prolonged ICU stay that an unexpectedly large number of pre- and intraoperative predictors have been significantly associated with prolonged intensive care treatment in this series.

As reported in other series, a significant relationship was found between the presence of severe heart failure [NYHA ≥3 (OR: 1.12); LVEF ≤30% (OR: 1.38)] frequently resulting in the need for urgent operation (OR: 1.52), cardiogenic shock (OR: 1.39), preoperative myocardial infarction (OR: 1.21), and prolonged intensive care treatment in this series. In addition, advanced patient age [age ≥70 and <80 years (OR: 1.32) and age

≥80 years (OR: 1.78)] is a significant predictor of prolonged ICU stay as reported previously [2, 10]. Elderly patients constitute an increasing fraction of the cardiac surgical population and advanced age is known to be a significant risk factor, especially for non-cardiac morbidity such as renal and neurologic complications or multisystem organ failure after cardiac surgery [4, 5, 11, 12, 13, 14]. Furthermore, age-related losses of physiological reserves affect different organ systems to varying degrees and contribute to the increased morbidity observed in the elderly cardiac surgical patient.

Several concomitant diseases associated with vascular alterations such as atherosclerosis have been found to be significant predictors of prolonged ICU stay in this series. Not surprisingly, diabetes mellitus as one of the well-known risk factors of artherosclerotic disease has been found to be independently associated with prolonged intensive care treatment (OR: 1.29) [15, 16, 17]. In addition, peripheral vascular disease as a systemic disorder, was significantly associated with prolonged ICU stay as well (OR: 1.36). In this context, the association of a history of cerebrovascular disease (OR: 1.45), such as TIA, PRIND, or manifest stroke, and history of embolism (OR: 1.30) with a prolonged need for intensive care treatment was not an unexpected finding. The first denotes the existence of pathologic conditions within the cerebrovascular system and/or underlying stenoses of one or both carotid arteries. Other investigators have demonstrated a 7–13% incidence of postoperative stroke for patients with a history of previous neurologic events, leading to a prolonged requirement for mechanical ventilation and a delayed postoperative mobilization with a subsequent demand for intensive care treatment in most cases [18, 19]. The latter, as well as a history of atrial fibrillation as another significant risk factor (OR: 1.47), has a well-recognized association with the recurrent risk of thromboembolization and, subsequently, with a higher risk of intraoperative cerebral embolization during cardiac surgery, possibly leading to postoperative neurobehavioral deficits as described previously [20, 21].

Preoperative renal disease (OR: 2.1) has been shown to be significantly associated with postoperative renal failure leading to a prolonged intensive care treatment by some [22, 23]. Furthermore, Anderson and associates found renal failure as a predisposing factor for several adverse outcomes, including neurologic deficits, in patients undergoing coronary bypass surgery [24]. Several previous studies as well as our study revealed preoperative pulmonary disease (OR: 1.4) as an important predictor for postoperative morbidity and/or mortality [22, 23, 25].

Five intraoperative variables [operation time ≥3 h (OR: 1.35); perfusion time ≥2 h (OR: 1.59); intraoperative hemofiltration (OR: 1.26); intraoperative pacemaker stimulation (OR: 1.3); intraoperative IABP-support (OR: 1.69)] have been found to be independent predictors of prolonged ICU stay. All of them often denote technical difficulties in executing the planned operation due to unfavorable anatomy or intraoperative complications. Intraoperative hemofiltration possibly reflects a preoperatively existing renal insufficiency requiring additional treatment.

Both beating heart approaches, MIDCAB and OPCAB, have been shown to be significantly associated with a lower prevalence of prolonged ICU stay as confirmed by previous investigators [26, 27, 28, 29, 30]. However, preoperative patient characteristics in the beating heart group revealed a younger mean age and higher left ventricular ejection fraction both in the OPCAB and the MIDCAB group than in the Conv-CABG group. In addition, prevalence of severe clinical symptoms (NYHA and CCS classification ≥3) was significantly higher in the Conv-CABG group as compared to both beating heart groups. In contrast to these findings, prevalence of prior coronary artery bypass grafting was higher in both beating heart groups compared to the Conv-CABG group. These differences may reflect a selection bias, with lower-risk patients being referred for beating heart surgery, as we did not follow a randomized protocol. However, it is important to note that both beating heart groups did not have the lowest prevalence of all independent predictors for prolonged ICU stay (Table 3).

In summary, in this series of patients—after coronary artery bypass surgery either with cardiopulmonary bypass or on the beating heart—several pre- and intraoperative patient- or treatment variables have been shown to be significantly associated with prolonged ICU stay. Understanding the multivariate regressions presented in this study and their analysis should enable identification of a high-risk subset of patients undergoing coronary artery bypass surgery. The lower prevalence of prolonged ICU stay in both beating heart groups seems to argue for a benefit of eliminating CPB in patients undergoing coronary bypass surgery.

Appendix

The following table shows peroperative variables analyzed by univariate analysis (factors that had a statistically significant association with prolonged ICU-stay are printed in bold)

CABG coronary artery bypass grafting, OPCAB off-pump coronary artery bypass grafting, MIDCAB minimally invasive direct coronary artery bypass grafting, RBC red blood cells, LVEF left ventricular ejection fraction, PTCA percutaneous transluminal coronary angioplasty, CPB cardiopulmonary bypass, IABP intraaortic ballon pump, ECMO extracorporal membrane oxygenation

	Patients with ICU–stay ≥3 days (*n*=3,988)	Patients with ICU–stay <3 days (*n*=6,771)	
Preoperative variables	Prevalence % (*n*)		*P*–value
Age			
Age <60 years	18.3% (730)	29.1% (1,973)	<0.0001
Age ≥70 and <80 years	37.2% (1,483)	28.4% (1,926)	<0.0001
Age ≥80 years	4.3% (171)	2.4% (161)	<0.0001
History of syncope	8.4% (336)	7.3% (494)	0.033
History of embolism	3.5% (138)	2.2% (148)	<0.0001
History of cardiogenic shock	11.1% (442)	5.2% (353)	<0.0001
Diabetes mellitus (glucose intolerance treated with diet, oral hypoglycemics or insulin)	41.2% (1,645)	33.1% (2,238)	<0.0001
Arterial hypertension (patient taking antihypertensive medication preoperatively)	75.8% (3,021)	72.3% (4,898)	<0.0001
History of renal disease (history of renal failure or pathological elevated serum creatinine treated medically without hemofiltration and/or dialysis)	6.4% (256)	2.3% (159)	<0.0001
Dialysis dependent renal insufficiency	1.1% (42)	0.3% (19)	<0.0001
Preoperative infection (infectious disease including endocarditis)	1.5% (59)	0.6% (42)	<0.0001
History of cerebrovascular disease (including stroke, TIA, and PRIND)	4.7% (186)	2.6% (178)	<0.0001
NYHA ≥3	81.8% (3,263)	76.4% (5,175)	<0.0001
LVEF ≤30% (assessed by angiography or 2D echocardiography)	11.1% (441)	6.1% (413)	<0.0001
History of peripheral vascular disease	26.2% (1,046)	17.2% (1,164)	<0.0001
Atrial fibrillation (history of preoperative atrial fibrillation)	5.9% (235)	3.0% (202)	<0.0001
Urgent operation	27.5% (1,097)	16.4% (1,100)	<0.0001
Emergency surgery (emergent surgery due to complications during coronary angiography and/or PTCA)	1.1% (42)	0.6% (39)	0.008
History of pulmonary disease (chronic pathologic pulmonary function test)	8.0% (320)	4.8% (325)	<0.0001
Prior myocardial infarction	58.5% (2,331)	51.4% (3,479)	<0.0001
CCS ≥3	37.8% (1,509)	35.9% (2,435)	0.05
Sex (male)	76.2% (3,039)	77.5% (5,250)	0.117
Hyperlipidemia	52.7% (2,100)	54.3% (3,679)	0.155
Prior cardiac surgery	4.4% (174)	3.7% (252)	0.102
Prior CABG	3.8% (150)	3.1% (213)	0.097
Prior aortic valve surgery	0.2% (9)	0.4% (26)	0.219
Prior mitral valve surgery	0.1% (6)	0.2% (16)	0.386
Intraoperative variables			
Duration of surgery ≥3 h	24.1% (961)	16.4% (1,113)	<0.0001
Total CPB time ≥2 h	10.9% (435)	4.3% (293)	<0.0001
Ischemic time ≥1 h	11.6% (462)	8.9% (607)	<0.0001
Intraoperative hemofiltration	9.2% (367)	4.7% (321)	<0.0001
Intraoperative hypothermia ≤32 °C	29.2% (1,166)	21.3% (1,439)	<0.0001
Intraoperative RBC transfusion ≥1,000 ml	2.9% (115)	1.0% (67)	<0.0001
Intraoperative low cardiac output	3.9% (154)	1.1% (75)	<0.0001
Intraoperative IABP–support	4.2% (168)	1.2% (78)	<0.0001
Intraoperative assist device (ECMO, Berlin heart)	1.4% (54)	0.4% (24)	<0.0001
Intraoperative need for pacemaker stimulation	19.5% (776)	11.3% (766)	<0.0001
Use of cardioplegia	76.3% (3,043)	69.6% (4,711)	<0.0001
Beating heart surgery	10.4% (415)	21.1% (1,427)	<0.0001
OPCAB	4.9% (194)	8.0% (544)	<0.0001
MIDCAB	5.3% (210)	12.8% (867)	<0.0001
Coronary bypass grafts ≥2	82.5% (3,290)	75.7% (5,127)	<0.0001
Intraoperative blood loss ≥500 ml	0.7% (26)	0.4% (26)	0.061

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