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Readmission to the Intensive Care Unit after Fast-Track Cardiac Surgery: An Analysis of Risk Factors and Outcome according to the Type of Operation

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ABSTRACT

Introduction: In the present study, we investigated risk factors for intensive care unit (ICU) readmission after fast-track cardiac surgery and analyzed outcome data according to the type of surgical procedure.

Methods: Between 1999 and 2008, we prospectively enrolled 4270 consecutive patients who underwent isolated coronary artery bypass grafting (CABG) (CABG group, n = 3754), isolated valve surgery (valve group, n = 353), or combined CABG and valve surgery (CABG + valve group, n = 163) in the study.

Results: Ninety-eight patients (2.2%) were readmitted to the ICU. Of these patients, 73 were in the CABG group (1.9% of this group), 16 were in the valve group (4.5%), and 9 were in the CABG + valve group (5.5%). The main reason for ICU readmission in all groups was respiratory distress. A multivariate analysis showed that the independent risk factors for ICU readmission in the CABG group were an age >65 years (odds ratio [OR], 2.9; 95% confidence interval [CI], 1.5-5.4; P = .001), peripheral arterial disease (OR, 2.7; 95% CI, 1.2-6.1; P = .016), and drainage >500 mL (OR, 2.5; 95% CI, 1.2-5.1; P = .009). The independent risk factors for the valve group included only preoperative congestive heart failure (OR, 3.9; 95% CI, 1.3-11.7; P = .01). No independent risk factor was defined for the CABG + valve group. Mortality was significantly higher among the readmitted patients in all groups.

Conclusions: The risk factors for readmission after cardiac surgery with fast-track recovery may differ according to the type of operation. A strict control of volume balance and blood transfusion may further help prevent the occurrence of the most frequent cause of readmission, respiratory failure.

INTRODUCTION

The development of new methods of anesthesia and postoperative care protocols, such as fast-track recovery (FTRC), has contributed to significant reductions in postoperative mechanical ventilation time, intensive care unit (ICU) stay, and length of hospital stay following cardiac surgical procedures [Higgins 1992, 1995; Engelman 1994; Karski 1995; Marquez 1995; Cheng 1998; Alhan 2003; Celkan 2005]. This method generally targets the patient for extubation within 6 to 8 hours of the completion of the cardiac procedure, an ICU length of stay of <24 hours, and a total hospital length of stay of 4 to 6 days. It has been used successfully for both low- and high-risk patients [Konstantakos 2000; Capdeville 2001; Lazar 2001].

The FTRC steps of primary focus include an earlier extubation and a shorter ICU stay. The ICU readmission rate, which is one of the most accurate quality indicators, has usually been given less concern [Bardell 2003; Toraman 2005]. Thus, an appropriate analysis related to the heterogeneity of the patient groups undergoing different types of cardiac surgery has not yet been undertaken. In the present study, we investigated ICU readmission and outcome data according to the type of surgical procedure.

METHODS

Between 1999 and 2008, we prospectively enrolled 4270 consecutive patients who underwent isolated coronary artery bypass grafting (CABG) (CABG group, n = 3754), isolated valve surgery (valve group, n = 353), or combined CABG and valve surgery (CABG + valve group, n = 163) in the study. None of the patients were excluded for any reason. A single surgical and anesthesia team performed all of the operations, and the same physician provided postoperative care to all of the patients.

Anesthesia and Operative Technique

On the night before the operation, all patients received 0.5 mg alprazolam by mouth. Midazolam (125 µg/kg) was administered intramuscularly 30 minutes before the operation. $MgSO_4$ was infused for prophylaxis of atrial fibrillation 1 day before the operation and 4 more days postoperatively. A 16-gauge intravenous cannula was inserted in all patients in the operating room. The patients' NaCl drip was 100 mL/hour. Anesthesia induction consisted of 50 µg/kg midazolam, 0.15 mg/kg pancuronium, and 25 to 35 µg/kg fentanyl.

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Table 1. Demographics and Perioperative Data*

	Readmission		
	No	Yes	*P*
CABG group (n = 3754)			
Age, y	60.6 ± 9.6	65.7 ± 7.9	<.001
EuroSCORE, %	3.6 ± 2.5	4.9 ± 3.4	<.001
Preoperative hematocrit, %	41 ± 4.7	39.9 ± 6.1	NS
CPB time, min	58 ± 21	64 ± 22	.02
Cardiac arrest time, min	39 ± 6	33 ± 13	.007
Intubation time (first ICU stay), h	5.1 ± 13.9	9.2 ± 13.2	.01
ICU time (first ICU stay), h	22.5 ± 23.3	24.9 ± 11	NS
Postoperative drainage, mL	590 ± 330	770 ± 570	<.001
Distal anastomoses, n	3.07 ± 1.1	3.3 ± 1.1	NS
Blood transfusion, units/patient	0.6 ± 1.5	1.5 ± 1.8	<.001
Valve group (n = 353)			
Age, y	51.5 ± 14.7	60.7 ± 10.2	.01
EuroSCORE, %	5 ± 2.4	5.5 ± 2.1	NS
Preoperative hematocrit, %	38.5 ± 5.7	37.8 ± 5.9	NS
CPB time, min	66 ± 28	68 ± 24	NS
Cardiac arrest time, min	56 ± 23	54 ± 20	NS
Intubation time (first ICU stay), h	5.9 ± 8.8	7.7 ± 5.7	NS
ICU time (first ICU stay), h	21.9 ± 12.1	36.6 ± 54	.01
Postoperative drainage, mL	589 ± 444	712 ± 496	NS
Distal anastomoses, n	0	0	NS
Blood transfusion, units/patient	0.7 ± 1.5	2.1 ± 3.0	<.001
CABG + valve group (n = 163)			
Age, y	66.2 ± 9.6	69.6 ± 7.0	NS
EuroSCORE, %	6.9 ± 2.9	7.8 ± 3.4	NS
Preoperative hematocrit, %	39.1 ± 5.6	37.5 ± 5.5	NS
CPB time, min	102 ± 29	102 ± 22	NS
Cardiac arrest time, min	79 ± 21	78 ± 20	NS
Intubation time (first ICU stay), h	8.7 ± 9.3	12.5 ± 12.5	NS
ICU time (first ICU stay), h	41.7 ± 67.5	29.8 ± 18.8	NS
Postoperative drainage, mL	660 ± 387	1155 ± 1206	NS
Distal anastomoses, n	2.7 ± 1.2	2.7 ± 1.2	NS
Blood transfusion, units/patient	0.5 ± 1.1	1.5 ± 1.7	<.001

*CABG indicates coronary artery bypass grafting; NS, not statistically significant; CPB, cardiopulmonary bypass; ICU, intensive care unit.

After endotracheal intubation, 50% O_2, 50% N_2O, and 3% to 4% desflurane were used for all hemodynamically stable patients. Desflurane and N_2O were discontinued at times of hemodynamic instability. Maintenance anesthesia and muscle relaxation were accomplished with 8 to 10 µg/kg fentanyl per hour and with midazolam and vecuronium at 80 µg/kg per hour. Furosemide (0.5 mg/kg) was administered routinely. The priming solution for cardiopulmonary bypass (CPB) included 900 mL Ringer's lactate solution, 150 mL 20% mannitol, and 60 mL sodium bicarbonate (8.4%). During CPB, the hematocrit, mean arterial pressure, and pump flow were kept between 20% and 30%, 50 and 80 mm Hg, and 2.2 and 2.5 L/m^2, respectively. The adequacy of tissue perfusion was assessed by monitoring the arteriovenous partial carbon dioxide difference (Pv-aCO_2), the lactate level, the urine output, and the base deficit. Moderate hypothermia was used during CPB, and the midazolam and vecuronium dosage was decreased to 60 µg/kg per hour when the body temperature reached 32°C. Myocardial viability was preserved with antegrade cold hyperkalemic crystalloid cardioplegia (Plegisol®; Abbott Laboratories, Abbott Park, IL, USA), except in patients with a left ventricular ejection fraction <0.25. In these patients, antegrade and retrograde blood cardioplegia associated with terminal warm blood cardioplegia was used. During rewarming, the midazolam and vecuronium dosage was increased back to 80 µg/kg per hour.

After the termination of CPB, the midazolam and vecuronium dosage was decreased to 50 µg/kg per hour and discontinued at skin closure.

Postoperative Clinical Management

On arrival in the ICU, patients were placed on mechanical ventilation. The ventilator mode was switched to synchronized intermittent mandatory ventilation plus pressure support, and ventilator settings were adjusted as follows: respiratory rate, 12/min; tidal volume, 8 to 10 mL/kg; fraction of inspired oxygen (FIO_2), 0.6; positive end-expiratory pressure, 0 to 5 mm Hg; pressure support, 10 mm Hg; and trigger sensitivity, –2 cm H_2O. All patients were warmed by forced-air warming until the rectal temperature reached 37°C. The basic fluid substitution during the first 20 postoperative hours was 40 mL/kg per day. Six hundred to 800 mL of this solution was the autologous blood derived from the CPB circuit, and the rest was balanced crystalloid solution. Intravenous meperidine (0.4 mg/kg, to a total dose of 50 mg over 6 hours) was used to treat shivering. All patients were evaluated for extubation every half hour. As soon as spontaneous breathing resumed, the respiratory rate was gradually decreased to 4/min, and pressure support was reduced to 4 mm Hg. If there were no contraindications for the use of beta-blockers, metoprolol was used intravenously to control hypertension. All hemodynamically stable patients who had no excessive chest tube drainage, a $PaCO_2$ value <48 mm Hg, a pH >7.30, and a PaO_2/FIO_2 ratio >250 were extubated. After the patient was extubated, 40% to 50% oxygen was administered by face mask. Oxygen saturation of hemoglobin and the respiratory rate were monitored continuously. Arterial blood gas measurements were obtained at 30, 60, and 120 minutes after extubation. Repeated intramuscular doses of diclofenac sodium (1.25 mg/kg) were used for postoperative analgesia. Patients >70 years of age with a hemoglobin value <8 g/dL and patients ≤70 years of age with a hemoglobin value <7 g/dL received packed red blood cells. Patients with a tendency to bleed were treated by transfusion with fresh frozen plasma. Inotropes were used only when hemodynamic stabilization could not be achieved by fluid administration or when there was other evidence of impaired contractility. In the case of an insufficient response to inotropes, intra-aortic balloon counterpulsation was initiated. All patients were evaluated for discharge from the ICU on the morning after the operation, regardless of their operation type and time. Patients were not transferred from the ICU if they were considered at clinically high risk, with signs of inadequate tissue perfusion (lactate >4 mmol/L, mixed venous oxygen saturation <50%, urine output <0.5 mL/kg per hour, cardiac index <2 L/min per square meter), requiring inotropes other than low-dose dopamine (3 µg/kg per minute), significant hemodynamic instability, requiring the use of an intra-aortic balloon pump, or needing circulatory support.

Table 2. Reasons for Intensive Care Unit Readmission*

CABG group	Readmitted Patients, n
Total readmission rate	73/3754 (1.9%)
Respiratory distress	42 (57.5%)
Atrial fibrillation	8 (11%)
Stroke	8 (11%)
Ventricular fibrillation/arrest	6 (8%)
Low cardiac output	5 (7%)
Cardiac tamponade	2 (2.7%)
Other	2 (2.7%)
Valve group	
Total readmission rate	16/353 (4.5%)
Respiratory distress	9 (56.25%)
Ventricular fibrillation/arrest	4 (25%)
Atrial fibrillation	1 (6.25%)
Stroke	1 (6.25%)
Cardiac tamponade	1 (6.25%)
CABG + valve group	
Total readmission rate	9/163 (5.5%)
Respiratory distress	4 (44.4%)
Cardiac tamponade	2 (22.2%)
Low cardiac output	1 (11.1%)
Ventricular fibrillation/arrest	1 (11.1%)
Other	1 (11.1%)

*CABG indicates coronary artery bypass grafting.

We aimed to discharge all patients on the fifth postoperative day. The decision to discharge was based on a satisfactory routine checkup on day 4, which consisted of a clinical examination; a complete blood cell count, measurements of blood urea nitrogen, creatinine, and electrolyte levels; an electrocardiogram; and a chest radiograph. If the patient was medically unfit on day 5, the hospitalization was prolonged, and further investigations were performed, depending on the patient's clinical status. Because the objective of our FTRC program was to extubate the patients within 6 hours of the completion of the cardiac procedure, to discharge from the ICU within 24 hours, and to discharge from the hospital on fifth postoperative day, these time points were taken as references in this study.

Data Source and Definitions

Our clinical database was used for outcomes analysis. It is a prospectively collected record containing relevant patient

Table 3. Risk Factors for Readmission to the Intensive Care Unit (Univariate Analysis)*

	Readmission, %		
Risk Factor	No	Yes	*P*
CABG group (n = 3754)			
CHF	1.8	5.5	.048
Hypertension	48.1	58.4	.08
Hypothyroidism	1.9	8.2	.02
Chronic obstructive lung disease	15.3	27.2	.04
Peripheral arterial disease	5.5	14.4	.03
Left main coronary disease	4.9	11.0	.015
Preoperative IV nitrates	5.8	11.0	.01
Nonelective operation	11.2	28.8	.001
NYHA class III-IV	8.1	16.4	.01
Age >65 y	36.5	61.6	.001
EuroSCORE >5	21.3	39.7	.001
Cross-clamp time >40 min	23.3	37.7	.005
CPB time >60 min	43.0	61.4	.002
ICU stay >24 h	4.8	17.1	.001
Red blood cell transfusion	30.2	56.2	.001
Postoperative drainage >500 mL	9.3	26.8	<.001
Valve group (n = 353)			
CHF	11	37.5	.002
Beta-blocker use	15.1	31.3	.008
Preoperative IV nitrate use	0.6	6.3	.01
Preoperative diuretic drug use	36.8	62.5	.03
EuroSCORE >5	35.9	56.3	.09
Red blood cell transfusion	35.9	62.5	.03
CABG + valve group (n = 163)			
Female sex	30.3	66.7	.02
CHF	6.6	33.3	.004
Preoperative heparin use	0.7	11.1	.006
NYHA class III-IV	24.3	55.6	.03
Red blood cell transfusion	55.5	88.9	.04

*CABG indicates coronary artery bypass grafting; CHF, congestive heart failure; IV, intravenous; NYHA, New York Heart Association; CPB, cardiopulmonary bypass.

demographic data, comorbidities, intraoperative variables, and postoperative outcomes, including postoperative drainage, ventilation time, length of ICU stay, length of hospital stay, transfusion rate, new-onset postoperative renal failure, postoperative stroke, rate of readmission to the ICU, rate of readmission to the hospital, and mortality. Hospital mortality included all deaths within 30 days of the operation, irrespective of where the death occurred, and all deaths in the hospital after 30 days among patients who had not been discharged after their operation. Postoperative blood loss was defined as the total volume of the chest tube drainage. Renal complications included acute renal failure, which was defined as the requirement of hemodialysis or an elevated creatinine level (>200 µmol/L). Stroke included postoperative permanent and temporary neurologic dysfunction.

Statistical Analysis

Data are reported as a percentage or as the mean ± SD. Univariate comparisons were evaluated by means of the χ^2 test or the Fisher exact test for categorical variables and by Student *t* tests for continuous variables. Any factor with a *P* value <0.1 in the univariate analysis was entered into the multiple logistic regression analysis. Statistical analysis was performed with SPSS statistical software (version 11.0; SPSS, Chicago, IL, USA). Variables were considered significant at *P* values <.05.

RESULTS

Demographic and perioperative data and demographics for the entire group are presented in Table 1. Ninety-eight patients (2.2%) were readmitted to the ICU. Of these patients, 73 were in the CABG group (1.9% of this group), 16 were in the valve group (4.5%), and 9 were in the CABG + valve group (5.5%). The main reason for ICU readmission in all groups was respiratory distress (Table 2).

In the CABG group, the univariate analysis defined the following risk factors for ICU readmission: congestive heart failure (*P* = .048), hypertension (*P* = .08), hypothyroidism (*P* = .02), chronic obstructive lung disease (*P* = .04), peripheral arterial disease (*P* = .03), left main disease (*P* = .015), preoperative intravenous nitrates (*P* = .01), operative priority (*P* = .001), New York Heart Association (NYHA) class III to IV (P = .01), age >65 years (*P* = .001), a EuroSCORE >5 (*P* = .001), cross-clamp time >40 minutes (P = .005), pump time >60 minutes (*P* = .002), ICU stay >24 hours (*P* = .001), postoperative drainage >500 mL (*P* <.001), and transfusion of red blood cells (*P* = .001). The univariate risk factors for readmission to the ICU in the valve group were congestive heart failure (*P* = .002), beta-blocker use (*P* = .008), preoperative intravenous nitrates (P = .01), diuretic drug use (*P* = .03), a EuroSCORE >5 (P = .09), and transfusion of red blood cells (*P* = .03). In the CABG + valve group, female sex (P = .02), congestive heart failure (*P* = .004), preoperative heparin use (*P* = .006), NYHA class III to IV (*P* = .03), and perioperative transfusion of red blood cells (*P* = .04) were the univariate risk factors for ICU readmission (Table 3). A multivariate analysis (Table 4) showed that the independent risk factors for ICU readmission in the CABG group were an age >65 years (odds ratio [OR], 2.9; 95% confidence interval [CI], 1.5-5.4; *P* = .001), peripheral arterial disease (OR, 2.7; 95% CI, 1.2-6.1; *P* = .016), and drainage >500 mL (OR, 2.5; 95% CI, 1.2-5.1; *P* = .009). Independent risk factors for the valve group included only preoperative congestive heart failure (OR, 3.9; 95% CI, 1.3-11.7; *P* = .01). No independent risk factor was defined for the CABG + valve group. The mortality rates were significantly higher for the readmitted patients in all groups (Table 5).

Table 4. Risk Factors for Readmission to the Intensive Care Unit (Multivariate Analysis)*

	Odds Ratio (95% CI)	P
CABG group		
Age >65 y	2.9 (1.5-5.4)	.001
PAD	2.7 (1.2-6.1)	.016
Drainage >500 mL	2.5 (1.2-5.1)	.009
Valve group		
CHF	3.9 (1.3-11.7)	.01
CABG + valve group		
None	—	—

*CI indicates confidence interval; CABG, coronary artery bypass grafting; PAD, peripheral arterial disease; CHF, congestive heart failure.

Table 5. Intensive Care Unit (ICU) Readmission and Outcomes*

	ICU Readmission		
Group	No	Yes	P
CABG			
Mortality, %	0.7	19.2	.001
Second ICU stay, h	—	151 ± 254	NA
Valve			
Mortality, %	1.5	12.5	.035
Second ICU stay, h	—	105 ± 131	NA
CABG + valve			
Mortality, %	5.3	33	.001
Second ICU stay, h	—	230 ± 392	NA
Total			
Mortality, %	0.9	19.3	0.001
Second ICU stay, h	—	147 ± 244	NA

*CABG indicates coronary artery bypass grafting; NA, not applicable.

DISCUSSION

The overall ICU readmission rate in the study was 2.2% after FTRC. The rate was higher in the valve group (4.5%) and in the CABG + valve group (5.5%) than in the CABG group (1.9%). The ICU readmission rate is accepted as a quality indicator, and the risk of such complications as stroke, reoperation, prolonged mechanical ventilation, prolonged hospitalization, and mortality have been found to be higher in readmitted patients [Bardell 2003]. The literature has reported this rate to be in the range of 3.6% to 5.5% after traditional cardiac surgical care [Cohn 1999; Bardell 2003] and is reportedly lower for FTRC [Kogan 2003]. Our results of a 2.2% overall readmission rate also imply that FTRC may offer a postoperative course at least as safe as traditional postoperative care.

The risk factors for readmission have been identified as a longer initial ICU length of stay, poor left ventricle function, a history of congestive heart failure, a longer initial intubation time, renal failure, and prolonged initial mechanical ventilation [Cohn 1999; Bardell 2003]. Prolonged ventilation, which may be associated with a low preoperative ejection fraction, renal failure, chronic obstructive pulmonary disease (COPD), age, sex, and unstable angina, was shown in these studies to be one of the strongest predictors of a return to the ICU; however, this was not the case for FTRC, which usually aims for a limited period of mechanical ventilation. Thus, the previously defined relationship of ICU readmission to prolonged ventilation in reality may be associated with an underlying cause, such as a low preoperative ejection fraction, renal failure, COPD, or age.

The primary interesting finding of the study is that the risk factors for readmission after cardiac surgery with FTRC may differ according to the type of operation. Defining such specific operation-related risk factors may be beneficial for optimizing risk stratification for a patient planned for FTRC. Although the clinical status at the time of readmission was uniform among all of the groups and primarily related to respiratory and rhythm disorders, the risk factors were quite different in the study. Independent risk factors in the CABG group were an age >65 years, peripheral arterial disease, and drainage >500 mL; however, the only independent risk factor defined in the valve group was preoperative congestive heart failure. We could not define any independent risk factors for the CABG + valve group. The number of patients in this group was 163, which was quite low for a multivariate analysis of risk factors; however, the leading reason for readmission in this group was also preoperative congestive heart failure, which may be determined to be a risk factor with a larger patient group.

The secondary finding of the study indicates that readmission to the ICU after FTRC is associated with a significantly prolonged ICU stay and an increased mortality rate. The ICU stay for readmitted patients was increased approximately 7-fold in the CABG group, 5-fold in the valve group, and 6-fold in the CABG + valve group. Moreover, the mortality rate was higher after readmission, approximately 27-fold in the CABG group, 8-fold in the valve group, and 6-fold in the CABG + valve group. This result implies that defining the high-risk group for readmission with perioperative risk factors may allow modification of the postoperative care, thereby preventing an unfavorable outcome.

Previous studies have demonstrated that FTRC is a safe and effective option for patients undergoing cardiac surgery, even for high-risk groups [Marquez 1995; Cheng 1998; Alhan 2003]. The primary objective criteria for FTRC are early extubation and early discharge from the ICU and the hospital. Early extubation and early discharge from the ICU and the hospital do not reflect the real success of FTRC, however. The real criterion for success should be the application of FTRC with acceptable rates of ICU and hospital readmissions. Although observed at a lower incidence compared with traditional postoperative care, readmission after FTRC is still an important indicator of a poor outcome [Kogan 2003].

Thus, further enhancement of this technique should focus on defining specific risk factors for operation types and modifying the perioperative care according to these factors. It has been pointed out, however, that the heterogeneity of the patients in these studies that investigated readmissions to the ICU makes it difficult to identify specific characteristics of the patient groups [Rosenberg 2000]. Thus, there is a knowledge gap in the literature regarding the investigation of readmission according to the type of cardiac operation.

Respiratory problems have been determined to be the leading reason for readmission to the ICU, both in our study and in the literature [Kogan 2003]. Interstitial edema related to increased permeability and volume overload following extracorporeal circulation may be considered primary. Although many reasons can exist for respiratory failure in patients readmitted to the ICU, such as underlying COPD, pneumonia, atelectasis, pneumothorax, pulmonary hypertension, mitral valve pathology, and the presence of enhanced permeability due to the extracorporeal circulation may further deteriorate this pathology. Thus, it is important to improve fluid management during this period. A total fluid balance >500 mL at the end of the operation has been reported to be a predictor of an increased rate of red blood cell transfusion, an increased rate of readmission to the ICU, and a longer hospital stay [Toraman 2004]. Besides the direct effect via the increase in the interstitial volume, an increased volume balance intensifies the need for blood transfusion, which may have an adverse event on respiratory function [Kuduvalli 2005; Surgenor 2006; Senay 2009]. On this basis, we have instituted a strict volume and transfusion policy perioperatively. A decreased effective plasma volume and an increased total body volume may lead to the deterioration of gas exchange, especially in female patients with a low body mass index and a preoperative hematocrit <30% [Toraman 2004]. For this group of patients, volume and blood loading can be avoided by using a 2-stage venous cannula even in isolated coronary procedures, elevation, and Trendelenburg positioning of the operating table in the event of venous-return difficulties in order to increase the return.

In conclusion, risk factors for readmission after cardiac surgery with FTRC may differ according to the type of operation. Identifying patients who have preoperative risk factors for ICU readmission according to the specific operation type and modifying the perioperative care on this basis may help reduce readmission rates and lead to a better outcome. Strict control of volume balance and blood transfusions may further help in preventing the occurrence of the most frequent cause of readmission, respiratory failure.

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