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Cardiac Surgery Fast-track Treatment in a Postanesthetic Care Unit

Six-month Results of the Leipzig Fast-track Concept

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Background: **The authors compared the safety and efficacy of a newly developed fast-track concept at their center, including implementation of a direct admission postanesthetic care unit, to standard perioperative management.**

Methods: **All fast-track patients treated within the first 6 months of implementation of our direct admission postanesthetic care unit were matched *via* propensity scores and compared with a historical control group of patients who underwent cardiac surgery prior to fast-track implementation.**

Results: **A total of 421 fast-track patients were matched successfully to 421 control patients. The two groups of patients had a similar age (64 ± 13 *vs.* 64 ± 12 yr for fast-track *vs.* control, $P = 0.45$) and European System for Cardiac Operative Risk Evaluation–predicted risk of mortality (4.8 ± 6.1% *vs.* 4.6 ± 5.1%, $P = 0.97$). Fast-track patients had significantly shorter times to extubation (75 min [45–110] *vs.* 900 min [600–1140]), as well as shorter lengths of stay in the postanesthetic or intensive care unit (4 h [3.0–5] *vs.* 20 h [16–25]), intermediate care unit (21 h [17–39] *vs.* 26 h [19–49]), and hospital (10 days [8–12] *vs.* 11 days [9–14]) (expressed as median and interquartile range, all $P < 0.01$). Fast-track patients also had a lower risk of postoperative low cardiac output syndrome (0.5% *vs.* 2.9%, $P < 0.05$) and mortality (0.5% *vs.* 3.3%, $P < 0.01$).**

Conclusion: **The Leipzig fast-track protocol is a safe and effective method to manage cardiac surgery patients after a variety of operations.**

RISING medical costs are causing clinicians and administrators to take a close look at current practices to assess the possibility of cost savings without comprising the quality of patient care. Numerous studies have previously shown that early extubation or "fast-track" treatment of cardiac surgery patients results in a decrease in intensive care unit (ICU) and hospital stays and subsequently a possible reduction of hospitalization costs.[1,2] The objectives of fast-track cardiac surgery include early extubation, reduction of length of stay in the ICU, and reduction of total length of stay in hospital. The use of short-acting hypnotic drugs and opioids greatly facilitates early extubation after cardiac surgery.[3]

The safety and convenience of early extubation and reduced mechanical ventilation is well documented. However, most fast-track treatment protocols for cardiac surgery patients have been implemented in the ICU.[4–12] In addition, ultra fast-track therapy with extubation in the operation room failed to reduce length of stay in ICU or in hospital even with the use of thoracic epidural analgesia.[11,12] We hypothesized that it may be possible to avoid ICU admission entirely in selected cardiac surgery patients by implementing a fast-track protocol with direct admission from the operating room to a postanesthestic care unit (PACU), without the use of epidural anesthesia. Implementation of a PACU staffed by anesthesiologists and anesthetic nurses may be more feasible than in the ICU, where staff are not necessarily trained in the methods of early extubation. For this purpose, we established a cardiac anesthesia PACU with three beds adjacent to the operating room that directly admits postoperative cardiac surgery patients.

The purpose of this study was to compare the safety and efficacy of a fast-track protocol implemented by anesthesiologists in a direct-admission PACU to standard perioperative management in a diverse population of cardiac surgery patients.

Materials and Methods

We opened a direct-admission PACU for cardiac surgery patients and implemented our fast-track protocol in November 2005. All fast-track patients operated on during the first 6 months of the program's inception (n = 433) were screened. Patients that were temporarily "parked" in the PACU because of a shortage of ICU beds (n = 9) or because they were awaiting an open operating theater (n = 3) were excluded from the study, resulting in a final sample size of 421. Fast-track patients were then matched in a 1:1 ratio using risk factors that are known to affect postoperative lengths of stay (see Statistical Analysis) to patients undergoing cardiac surgery during an 8-month period in 2004/2005; *i.e.*, before the PACU was opened (control, n = 421). Our study was performed in accordance with the principles outlined in the Declaration of Helsinki and was approved by the local ethics board (Ethical Review Board at the Medical Faculty of the University Leipzig, permit 66–2007).

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Fast-track Protocol

Our fast-track protocol consisted of oral premedication with dipotassium clorazepate the evening before and clonidine on the day of surgery. Anesthetic induction was performed with propofol (1–2 mg/kg), sufentanil (0.5–1 μg/kg), and rocuronium (0.6 mg/kg). For maintenance of anesthesia during the pre- and postcardiopulmonary bypass period, a continuous infusion of remifentanil (0.2 μg · kg · min) and sevoflurane (0.8–1.1% minimum alveolar concentration) was used. During cardiopulmonary bypass, a continuous propofol infusion (3 mg · kg · h) also was administered. A recruitment maneuver was carried out prior to weaning from cardiopulmonary bypass to prevent atelectasis. An external convective warming system with an underbody blanket (Bairhugger®; Arizant Healthcare, Eden Prairie, MN) was used after weaning from cardiopulmonary bypass to ensure a core temperature of 36°C. For early postoperative analgesia, 1 g paracetamol was administered systemically to each patient before skin closure.

After surgery, patients were admitted to the PACU if they were in stable hemodynamic condition without inotropic support, without excessive bleeding, and with a core temperature of at least 36°C. Only patients scheduled for elective cardiac surgery were admitted to the PACU. Postoperative analgesia consisted of a bolus of piritramide (0.1 mg/kg) as required and paracetamol (1 g every 6 h) to achieve a pain score between 2 to 4 on an analogue pain scale from 0 to 10. Immediately after extubation, all patients underwent a noninvasive ventilation period of 1 h (Elisee 350®, Saime, France). The PACU operated daily Monday to Friday from 10:00 AM to 6:30 PM.

Conventional Treatment (Control)

Conventional treatment control patients underwent cardiac surgery during a 6-month period prior to implementation of the fast-track protocol. Conventional treatment consisted of premedication with dipotassium clorazepate the evening before and midazolam on the day of surgery. Anesthetic induction was performed with midazolam (5 mg), propofol (1–2 mg/kg), sufentanil (0.5–1 μg/kg), and pancuronium (0.1 mg/kg). Maintenance of anesthesia was performed with continuous sufentanil (1–2 μg · kg · h) and propofol infusions (3 mg · kg · h). All control patients were admitted to the ICU from the operating room. The continuous sufentanil infusion was stopped when the patient was hemodynamically stable, without significant bleeding (< 100 ml/h chest tube drainage) and normothermic. The weaning from volume-controlled ventilation to pressure-support ventilation and subsequent extubation was performed under the direction of ICU nurses and staff. The ICU was staffed by an ICU attending physician along with cardiology and cardiac surgery residents.

All patients (fast track and control) were sent to the intermediate care unit prior to being discharged to the regular nursing ward. Inotropes and invasive ventilation were available only in the ICU and not in the intermediate care. Continuous telemetry monitoring was available in the intermediate care unit, but not on the ward. Intermediate care unit patients were discharged to the nursing ward when they had a stable rhythm and were able to mobilize independently. Staff in the intermediate care unit were aware of which patients underwent fast-track treatment, whereas staff on the nursing ward were not.

Statistical Analysis

Data are displayed throughout the manuscript as median and interquartile range for all nonnormally distributed continuous variables and mean and SD for normally distributed values. All fast-track patients from the first 6 months of implementation of the PACU (November 2005 to April 2006) were included in the study (n = 421). Control patients were identified through our database, having undergone surgery during an 8-month period (August 2004 to April 2005) 1 yr prior to implementation of the fast-track protocol. The control patients came from a sufficiently large cohort (n = 2266) to enable 1:1 propensity-score matching on many variables. The propensity score represented the probability of a patient being assigned to the fast-track group given the comorbidities of that patient. It was calculated for each patient using a logistic regression model that included variables known to affect postoperative lengths of stay, including type of surgery, coexisting diseases, left ventricular ejection fraction, and European System for Cardiac Operative Risk Evaluation score.[13,14] All covariables of the model, as well as the propensity score itself, were utilized for matching according to the methods of Rosenbaum and Rubin.[15] Matching was performed by selecting a patient randomly from the fast-track group and looking for a partner in the control group who had minimal Mahalanobis distance determined on the basis of the covariance matrix of all matching parameters.[16,17] To evaluate balance between study groups, comparisons were made with respect to the matching variables. All comparisons of binary traits were performed with the Fisher exact test and of continuous traits with the Kolmogorov–Smirnov test.

Our primary events of interest were extubation times and postoperative lengths of stay in the PACU/ICU, intermediate care unit, and hospital. In addition, we recorded and compared the number of readmissions to the ICU and intermediate care, as well as morbidity and mortality. Mortality was defined as any death that occurred within 30 days of surgery. Statistical comparisons of primary outcomes were carried out using the Wilcoxon rank sum test if testing between matched cohorts and the Mann–Whitney U test for other comparisons.

Table 1. Demographics and Operation-related Data

	Fast Track	Control	*P* Value
No.	421	421	
Male sex (%)*	279 (66)	285 (70)	0.71
Age, yr*	64 ± 13	64 ± 12	0.45
Ejection fraction, %*	63 ± 11	62 ± 12	0.78
EuroSCORE, %*	4.8 ± 6.1	4.6 ± 5.1	0.97
Procedure performed (%):*			
CABG	189 (44.9)	193 (45.8)	0.84
Valve	188 (44.7)	191 (45.4)	0.89
Valve and CABG	25 (5.9)	24 (5.7)	1
Others	19 (4.5)	13 (3.1)	0.37
Recent myocardial infarction*	98 (23.3)	96 (22.8)	0.94
Preoperative stroke*	18 (4.3)	19 (4.5)	1
Renal insufficiency*	33 (7.8)	30 (7.1)	0.79
COLD*	32 (7.6)	30 (7.1)	0.90
Diabetes mellitus*	115 (27.3)	113 (26.8)	0.94
Previous cardiac surgery*	7 (1.7)	7 (1.7)	1
Hypertrophic cardiomyopathy*	10 (2.4)	5 (1.2)	0.30
Neurologic deficit*	13 (3.1)	13 (3.1)	1
Pulmonary hypertension*	3 (0.7)	3 (0.7)	1
Peripheral vascular disease*	30 (7.1)	29 (6.9)	1
CPB time, min	85 ± 54	87 ± 56	0.88
XCL time, min	55 ± 38	56 ± 39	0.88
Operative time, min	174 ± 50	179 ± 72	0.2

Continuous variables are expressed as mean ± SD. "Other" operations included aortic surgery, atrial septal defect repair, and sternal debridement.

* Used for propensity matching.

CABG = coronary artery bypass grafting; COLD = chronic obstructive lung disease; CPB = cardiopulmonary bypass; EuroSCORE = European System for Cardiac Operative Risk Evaluation; XCL = aortic cross clamp.

Comparisons of morbidity and mortality were performed with the Fisher exact test. A probability of $P < 0.05$ was considered significant. All calculations were performed using the statistical software package R.[18]††

We determined the mean and standard deviations for lengths of stay with conventional perioperative management from prior analyses. We estimated that fast-track treatment would reduce time to extubation by 75%, PACU/ICU length of stay by 50%, and hospital length of stay by 10%. Based on the sample size, we calculated the power of the study to be 83% for the comparison of time of extubation, 94% for the comparison of lengths of stay in the PACU and/or ICU, and 77% for the comparison of length of hospital stay.

Results

A total of 421 patients were treated in the PACU within the first 6 months of its inception and were matched 1:1 with historical controls. There were no significant differences between the two groups with respect to demographics and/or operation-related data (table 1). In particular, there was no significant difference in age, European System for Cardiac Operative Risk Evaluation predicted risk of mortality, or type of operative procedure performed.

Table 2. Postoperative Data for the Entire Group

	Fast Track	Control	*P* Value
No.	421	421	
Time to extubation, min	75 [45–110]	900 [600–1,140]	< 0.01
PACU/ICU, h	4 [3–5]	20 [16–25]	< 0.01
Intermediate care, h	21 [17–39]	26 [19–49]	< 0.01
Hospital, days	10 [8–12]	11 [9–14]	< 0.01
Intermediate care readmission (%)	61 (14.5)	42 (9.7)	0.6
LOS for intermediate care readmission, h	18 [7–33]	14 [5–25]	0.23
ICU readmission (%)	24 (5.7)	32 (7.6)	0.33
LOS for ICU readmission, h	25 [13–53]	19 [10–120]	0.75
Myocardial infarction (%)	1 (0.2)	4 (1.0)	0.37
Low cardiac output (%)	2 (0.5)	12 (2.9)	< 0.05
Renal failure (%)	4 (1.0)	9 (2.1)	0.25
Stroke (%)	5 (1.2)	10 (2.4)	0.30
Mediastinitis (%)	1 (0.2)	2 (0.5)	0.88
Mortality (%)	2 (0.5)	14 (3.3)	< 0.01

All times are expressed as median and interquartile range.

ICU = intensive care unit; LOS = length of stay; PACU = postanesthetic care unit.

Table 2 shows the postoperative results of the 421 fast-track patients in comparison to the control group. Fast-track patients had significantly shorter times to extubation, as well as postoperative lengths of stay in the PACU or ICU, intermediate care unit, and hospital. There was no significant difference between groups with regards to readmission to the intermediate care unit or the ICU and the number of hours spent in these units during readmission. There were no significant differences between groups with regards to morbidity, with the exception of a lower rate of postoperative low cardiac output syndrome in the fast-track group. Fast-track patients had a significantly lower mortality than controls.

A total of 360 fast-track patients (86%) were transferred directly from the PACU to the intermediate care without an intermediary stay in the ICU. Table 3 shows the results for these 360 fast-track patients in comparison to their matched controls. The fast-track patients had significantly shorter time to extubation and length of stay in the intermediate care unit, as well as shorter postoperative hospital length of stay. The readmission rates to the intermediate care and ICU were similar between the two groups of patients. The fast-track patients had a significantly lower incidence of low cardiac output syndrome and mortality compared with their matched controls.

Sixty-one fast-track patients (14%) had to be transferred from the PACU to the ICU for a variety of reasons. Twenty-five of these patients were extubated and were transferred because of a shortage of beds in the intermediate care unit after closure of the PACU (*i.e.*, after 6:30 PM). Eleven extubated patients were transferred to the

†† R is freeware under the terms of the Free Software Foundation. Available at: www.r-project.org. Accessed March 6, 2008.

Table 3. Postoperative Outcomes for Fast-track Patients Who Were Discharged Directly from the Postanesthetic Care Unit to the Intermediate Care Unit, along with Their Respective Matched Controls

	Fast Track	Control	*P* Value
Number	360	360	
Time to extubation, min	75 [40–105]	840 [600–1,140]	< 0.01
PACU/ICU, h	4 [3–5]	20 [16–24]	< 0.01
Intermediate care, h	21 [17–38]	26 [18–49]	< 0.01
Hospital, days	10 [8–12]	11 [9–13]	< 0.01
Intermediate care readmission (%)	35 (9.7)	36 (10.0)	1
LOS for intermediate care readmission, h	17 [7–26]	13 [4.8–22]	0.26
ICU readmission (%)	17 (4.7)	26 (7.2)	0.21
LOS for ICU readmission, h	22 [9–37]	18 [10–128]	0.87
Myocardial infarction (%)	1 (0.3)	3 (0.8)	0.62
Low cardiac output (%)	0	9 (2.5)	< 0.01
Renal failure (%)	3 (0.8)	8 (2.2)	0.22
Stroke (%)	3 (0.8)	8 (2.2)	0.22
Mediastinitis (%)	1 (0.3)	2 (0.6)	0.90
Mortality (%)	1 (0.3)	11 (3.1)	< 0.01

All times are expressed as median and interquartile range.

ICU = intensive care unit; LOS = length of stay; PACU = postanesthetic care unit.

ICU because they required ongoing noninvasive ventilation. Twenty-five intubated patients were transferred to the ICU because of problems with oxygenation in 13 patients, focal neurologic problems in 2 patients, decreased level of consciousness in 6 patients, hemodynamic instability in 3 patients, and postoperative bleeding in 1 patient. Table 4 shows the results of these 61 fast-track patients. The mean length of ICU stay was significantly shorter than in the respective matched controls (16 h [11–19] *vs.* 20 h [17–32], $P < 0.01$). However, the mean length of stay in the intermediate care unit was similar to the control group (25 h [15–51] *vs.* 26 [21–56], $P = 0.36$). The readmission rate to the intermediate care unit was 8.2% for the fast-track patients and 9.8% for the control group, and the readmission rate to the ICU was 11.5% and 9.8%, respectively, which was not significantly different (both, $P = 1$).

Discussion

Modern cardiac surgery perioperative management is faced with the challenge of finding a balance between patient safety and economic restrictions, despite an ever increasing patient age and risk profile. To address this problem, we developed a fast-track process that included the implementation of a direct-admit PACU. The fast-track protocol was applied to a wide variety of cardiac surgery patients undergoing simple and complex operations. We staffed our PACU with anesthesiologists and anesthesia nursing staff, because we felt these personnel had more experience in the methods of rapid extubation than ICU personnel. For a new patient treatment protocol to be truly beneficial, however, it must be both effective and safe. Therefore, in the current study we compared extubation times, postoperative lengths of stay, morbidity, and mortality between our fast-track patients and a matched group of historical controls. We found significantly shorter intubation times and lengths of stay in the fast-track group, despite a similar risk profile. In addition, we found a decreased rate of postoperative low cardiac output syndrome and mortality in the fast-track group.

Although our study was retrospective in nature, we achieved comparable patient cohorts by a thorough matching process with respect to left ventricular ejection fraction, European System for Cardiac Operative Risk Evaluation score, type of surgery, and comorbidities. Such factors previously have been described as predictors of postoperative length of stay in cardiac surgery patients.[13,14] We were able to achieve balance for these possible confounders with our propensity matching process, as can be seen in table 1. Our propensity-matching approach has been recommended in the literature to generate quasirandomized experimental conditions and to minimize study bias.[15–17,19,20]

Our PACU is managed by the anesthesia team and is adjacent to the operating room with open hours from 10 AM to 6:30 PM during regular working days. In contrast to other fast-track protocols from other centers, we com-

Table 4. Results for the 61 Patients That Had to Be Transferred from the PACU Directly to the ICU

	Extubated	Noninvasive	Intubated
No.	25*	11*	25
Time to extubation, min	100 [55–176]	105 [55–160]	960 [660–1,620]
ICU time, h	14 [6–17]	16 [13–19]	16 [13–23]
Intermediate care, h	34 [17–58]	24 [12–27]	28 [15–63]
Hospital, days	11 [9–14]	11 [8–14]	13 [10–21]
Intermediate care readmission (%)	1 (4.0)	0	4 (16.0)
LOS for intermediate care readmission, h	33	—	12 [4.3–33]
ICU readmission (%)	3 (12.0)	2 (18.2)	2 (8.0)
LOS for ICU readmission, h	193	24	567

All times are expressed as median and interquartile range.

* Patients that were extubated in the PACU and secondarily transferred to the ICU.

ICU = intensive care unit; LOS = length of stay; PACU = postanesthetic care unit.

pletely separated fast-track patients from the ICU.[4–12] This was done to save ICU capacity for more acute patients, as well as to minimize the possible tendency of ICU staff to keep patients asleep who are stable enough to be extubated. Although a small number of studies have described cardiac surgery patient management with immediate extubation in the operating room, most using additional thoracic epidural anesthesia,[11,12] patients were transferred to the ICU for postoperative care. We therefore believe our fast-track protocol is unique.

The development of short-acting and easily controllable anesthetic drugs has allowed patients to be extubated very quickly, particularly compared with earlier perioperative management protocols when high-dose sufentanil administration was routine. The use of short-acting drugs such as remifentanil in fast-track patients may have a major impact on extubation times as compared with the use of sufentanil, as was the case in our control group. The extubation time for fast-track patients in our study was 75 min (interquartile range, 45–110), which was significantly less than matched controls (median, 900 min). Such differences were even more pronounced when we excluded those patients who required transfer from the PACU to the ICU for a variety of reasons (table 4). In addition, our mean extubation time was shorter than published fast-track protocols that used remifentanil, but that were implemented in the ICU. For example, Lison *et al.*[3] extubated patients after an average of 386 min and Cheng *et al.*[21] 216 min following surgery. We therefore feel that the implementation of our fast-track protocol in the PACU under the supervision of an anesthetic team significantly contributed to our short intubation times. Several previous publications have determined that the time of extubation after cardiac surgery is the main key to shortening the length of stay in postoperative care units.[22–24] To achieve our short extubation times, we feel it is important to maintain adequate body temperature and to avoid ongoing postoperative sedation. We used underbody blankets for convective warming and heating of the operation theater at the end of cardiopulmonary bypass to avoid postoperative hypothermia.

Our significantly shorter intubation and ventilation times may be one important reason for the observed lower mortality in the fast-track group. Patients in the fast-track group may have been at lower risk for ventilator-related infections and sepsis. Although further studies will be required to confirm whether fast-track anesthesia with a PACU results in decreased mortality, we feel confident in saying that such fast-track treatment is at least as safe as conventional perioperative management.

In contrast to Horswell *et al.*,[22] we preferred extubation of the patient in the PACU and not in the operating room. We chose this approach mainly because we wanted to ensure that the patient was hemodynamically stable, had a core temperature of at least 36°C, a blood loss of less than 200 ml/h, and sufficient analgesia. Second, we wanted to shorten the turnover time for the next scheduled patient, because time in the operating theater is the most expensive time in hospital.[25] All patients received noninvasive positive pressure ventilation for 1-h postextubation in the current study, independent of blood gas analysis results. For this purpose, we used a ventilator that was originally developed for home ventilation in patients with pulmonary disease (Elisee 350®). We did not observe any problems with gastric distension in our patients during the noninvasive ventilation.

Many investigators previously have found that a significantly shorter stay in the ICU is associated with better patient outcomes. Chong *et al.*[26] reduced the duration of ventilation from 5 h to 1 h with no major postoperative complications. In the current study, we confirmed that decreasing the length of time spent in the ICU is safe. Our fast-track patients displayed a lower incidence of postoperative low cardiac output syndrome and mortality when compared with control patients, without an increased risk for other measures of morbidity (*e.g.*, myocardial infarction, stroke, renal failure, or mediastinitis). We feel patient safety in the early postoperative phase is enhanced with an experienced anesthesiologist and an experienced anesthetic nurse, with a favorable staff-to-patient ratio in the PACU. The high staff-to-patient ratio (1 physician for 3 patients) may be one reason that decisions regarding extubation and other clinical factors are shorter in the PACU than in the ICU, where one physician has to care for 12 patients. The significant reduction in intermediate care length of stay for the fast-track group also may reflect that patients treated with the fast-track protocol arrived in better condition than those treated conventionally. In addition, we observed comparable readmission rates for the intermediate care unit and the ICU for both groups of patients.

We also observed a shorter total length of hospital stay in the fast-track group as compared with the control group. One possible explanation is that the staff in the intermediate care unit were not blinded to the treatment protocol and therefore management bias occurred, but we feel this is unlikely. It is interesting to note that our lengths of stay are longer than those found in most studies in the literature. For example, Cheng *et al.*[27] observed a mean hospital stay of 6.8 days in fast-track coronary bypass patients. The observed difference is probably related to the different health care systems. With implementation of the German Diagnostic Related Groups, minimum and medium lengths of stay in hospital are defined and hospitals receive less reimbursement if patients are discharged before these predefined lengths of stay. Postoperative hospital lengths of stay are

therefore more difficult to interpret in the German health care system.

Most studies on fast-track cardiac anesthesia have focused on coronary bypass surgery. In contrast, we implemented fast-track therapy in a group of patients undergoing a wide variety of surgical operations, including such high risk operations as replacement of the ascending aorta, multiple valve surgery, and combined procedures. Our inclusion criteria for fast-track treatment are patients undergoing elective surgery who are hemodynamically stable with adequate body temperature and without excessive bleeding. This is in partial agreement with the prediction model previously described by Constantinides *et al.*[28] These investigators identified eight independent predictors for fast-track failure: impaired left ventricular function, acute coronary syndrome within 30 days of surgery, reoperative surgery, peripheral vascular disease, preoperative intraaortic balloon pump, raised serum creatinine, operative urgency, and complex surgery. In our opinion, preexisting impaired left ventricular function without intraoperative instability as well as redo and complex operations *per se* are not predictors for fast-track failure. If the inclusion criteria mentioned above are fulfilled, we administer short-acting drugs to all elective cardiac surgery patients intraoperatively, in case they can be transferred to the PACU at the end of the operation.

A total of 61 (14%) fast-track patients had to be transferred to the ICU in the current study, including 25 who were transferred simply because of a shortage of intermediate care resources at the end of the PACU's open hours. Despite the fact that these patients were transferred to the ICU, we feel they did not represent fast-track "failures," because they had significantly shorter stays in the ICU than their matched controls. It may be more beneficial to expand the opening hours of our PACU to ensure that the fast-track pathway is available to a larger group of patients.

Conclusions

A fast-track protocol with direct admission to an anesthesia-managed PACU can be applied to a wide variety of cardiac surgery patients with very good results. The Leipzig fast-track protocol is a safe and effective method to manage cardiac surgery patients.

References

1. Cheng DC, Wall C, Djaiani G, Peragallo RA, Carroll J, Li C, Naylor D: Randomized assessment of resource use in fast-track cardiac surgery 1- year after hospital discharge. ANESTHESIOLOGY 2003; 98:651–7
2. Cheng DC: Fast track cardiac surgery pathways: Early extubation, process of care and cost containment. ANESTHESIOLOGY 1998; 88:1429–33
3. Lison S, Schill M, Conzen P: Fast-track cardiac anesthesia: Efficacy and safety of remifentanil *versus* sufentanil. J Cardiothorac Vasc Anesth 2007; 21:35–40
4. Quasha AL, Loeber W, Feeley TW, Ullyot DJ, Roizen MF: Postoperative respiratory care: A controlled trial of early and late extubation following coronary artery bypass grafting. ANESTHESIOLOGY 1980; 52:135–41
5. Ramsay JG, DeLima LGR, Wynands JE, O' Connor JP, Ralley FE, Robbins GR: Pure opioid *versus* opioid—volatile anesthesia for coronary artery bypass graft surgery: A prospective, randomized, double-blind study. Anesth Analg 1994; 78:867–75
6. Mora CT, Dudek C, Torjman MC, White PF: The effects of anesthetic technique on the hemodynamic response and recovery profile in coronary artery revascularization patients. Anesth Analg 1995; 81:900–10
7. Cheng DC, Karski J, Peniston C, Raveendran G, Asokumar B, Carroll J, David T, Sandler A: Early tracheal extubation after coronary artery bypass graft surgery reduces costs and improves resource use: A prospective, randomized, controlled trial. ANESTHESIOLOGY 1996; 85:1300–10
8. Myles PS, Weeks AM, Buckland MR, Bujor MA, McRae R, Langley M, Moloney JT, Hunt JO, Davis BB: Hemodynamic effects, myocardial ischemia, and timing of extubation with propofol-based anesthesia for cardiac surgery. Anesth Analg 1997; 84:12–9
9. Myles PS, Hunt JO, Holdgaard HO, McRae R, Buckland MR, Moloney J, Hall J, Bujor MA, Esmore DS, Davis BB, Morgan DJ: Clonidine and cardiac surgery: Hemodynamic and metabolic effects, myocardial ischemia and recovery. Anaesth Intensive Care 1999; 27:137–47
10. Berry P, Thomas S, Mahon S, Jackson M, Fox MA, Fabri B, Weir WI, Russel GN: Myocardial ischemia after coronary artery bypass grafting: Early *versus* late extubation. Br J Anaesth 1998; 80:20–5
11. Montes FR, Sanchez SI, Giraldo JC, Rincón JD, Rincón IE, Vanegas MV, Charris H: The lack of benefit of tracheal extubation in the operating room after coronary artery bypass surgery. Anesth Analg 2000; 91:776–80
12. Hemmerling TM, Lê N, Olivier JF, Choinière JL, Basile F, Prieto I: Immediate extubation after aortic valve surgery using high thoracic epidural analgesia or opioid-based analgesia. J Cardiothorac Vasc Anesth 2005; 19:176–81
13. Ivanov J, Borger MA, Rao V, David TE: The Toronto Risk Score for adverse events after cardiac surgery. Can J Cardiol 2006; 22:221–7
14. Toumpoulisa IK, Anagnostopoulos CE, Swistel D, DeRose JJ: Does EuroSCORE predict length of stay and specific postoperative complications after cardiac surgery? Eur J Cardiothorac Surg 2005; 27:128–33
15. Rosenbaum PR, Rubin DB: Constructing a control group using multivariate matched sampling methods that incorporate the propensity score. Am Stat 1985; 39:33–8
16. Cochran WG, Rubin DB: Controlling bias in observational studies: A review. Sankya, Series A 1973; 35:417–46
17. D'Agostino RB: Propensity score methods for bias reduction in the comparison of a treatment to a non-randomized control group. Stat Med 1998; 17: 2265–81
18. Ihaka R, Gentleman R: R a language for data analysis and graphics. J Comp Graph Stat 1996; 5:299–314
19. Austin PC: A critical appraisal of propensity-score matching in the medical literature between 1996 and 2003. Stat Med 2008; 27:2037–49
20. Austin PC: Propensity-score matching in the cardiovascular surgery literature from 2004 to 2006: A systematic review and suggestions for improvement. J Thorac Cardiovasc Surg 2007; 134:1128–35
21. Cheng DC, Newman MF, Duke P, Wong DT, Finegan B, Howie M, Fitch J, Bowdle A, Hogue C, Hillel Z, Pierce E, Bukenya D: The efficacy and resource utilization of remifentanil and fentanyl in fast-track coronary artery bypass graft surgery: A prospective randomized, double-blinded controlled, multi-center trial. Anesth Analg 2001; 92:1094–102
22. Horswell JL, Herbert MA, Prince SL, Mack MJ: Routine extubation after off-pump coronary artery bypass surgery: 514 consecutive patients. J Cardiothorac Vasc Anesth 2005; 19:282–87
23. London MJ, Shroyer ALW, Grover FL: Fast tracking into the new millennium: An evolving paradigm. ANESTHESIOLOGY 1999; 91:911–5
24. Myles PS, Daly DJ, Djaiani G, Lee A, Cheng DC: A systematic review of the safety and effectiveness of fast-track cardiac anesthesia. ANESTHESIOLOGY 2003; 99:982–7
25. McIntosh C, Dexter F, Epstein RH: The impact of service-specific staffing, case scheduling, turnovers, and first-case starts on anesthesia group and operating room productivity: A tutorial using data from an Australian hospital. Anesth Analg 2006; 103:1499–516
26. Chong JL, Grebenik C, Sinclair M, Fisher A, Pillai R, Westaby S: The effect of cardiac surgical recovery area on the timing of extubation. J Cardiothorac Vasc Anesth 1993; 7:137–41
27. Cheng DC, Karski J, Peniston C, Asokumar B, Raveendran G, Carroll J, Nierenberg H, Roger S, Mickle D, Tong J, Zelovitsky J, David T, Sandler A: Morbidity outcome in early *versus* conventional tracheal extubation following coronary artery bypass graft (CABG) surgery: A prospective randomized controlled trial. J Thorac Cardiovasc Surg 1996; 102:755–64
28. Constantinides VA, Tekkis PP, Fazil A, Kaur K, Leonard R, Platt M, Casula R, Stanbridge R, Darzi A, Athanasiou T: Fast-track failure after cardiac surgery: Development of a prediction model. Crit Care Med 2006; 34:2875–82