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Readmission to the Intensive Care Unit in Times of Minimally Invasive Cardiac Surgery: Does Size Matter?

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ABSTRACT

Objectives: It is well known that patients who undergo readmission to an intensive care unit (ICU) after cardiac surgery face an increased risk of morbidity and mortality. The present study sought to evaluate whether less invasive procedures might be associated with a reduction of this economically as well as individually important problem. The role of the quantity of ICU and intermediate care (IMC) beds was investigated as well.

Methods: Altogether, we reviewed 5,333 patients who underwent cardiac surgery in our department between 2005 and 2010. The incidence of and reasons for readmission were determined with regard to individual subgroups, particularly comparing minimally invasive procedures with conventional strategies.

Results: A total of 5,132 patients were primarily discharged from the ICU. Out of this group, 293 patients were readmitted to the ICU at least once. After readmission, the average length of stay in the hospital was 21.9 ± 11.3 days compared to 12.8 ± 5.0 days in all other patients. Comparing the readmission rate in separate years, it was evident that this rate decreased with a growing ICU and IMC capacity. In patients who underwent less invasive cardiac surgery (ie, minimally invasive cardiac surgery, off-pump coronary artery bypass grafting), the readmission rates were significantly lower than in the entirety of patients studied.

Conclusion: Readmission to the ICU after cardiac surgery is associated with impaired outcome. Extended resources in terms of ICU and IMC capacity may positively influence this problem by decreasing the number of readmissions. Modern surgical strategies with less invasive procedures may be associated with a reduced incidence of readmission as well.

INTRODUCTION

Intensive care unit (ICU) resources are limited and the related costs are steadily increasing. Today, national costs are estimated to account for approximately 20% of the total in-patient costs in Germany [Hein 2006]. The increase in length of stay in the ICU after cardiac surgery over the last 15 years could be compensated for only by increasing ICU capacities [Shan 2009]. Otherwise, a decrease in the total number of annually performed operations would have to be accepted by the centers [Engoren 2002]. These economic considerations underline the need for discharge criteria, which may improve outcome and efficient utilization of ICU capacities. In 1988, a task force of the Society of Critical Care Medicine (SCCM) defined binding criteria for standard procedures, which undergo periodical review [SCCM 1988].

Factors affecting morbidity and mortality have been widely studied [Shan 2009]. It is well known that postoperative ICU readmission during the same hospital stay contributes to impaired outcome. In a former analysis, we confirmed this observation in our cardiosurgical center [Litmathe 2009]. A discharge from ICU that, retrospectively, had to be judged as too early led to an increased incidence of postoperative complications, probably caused by the relatively non-sufficient care on the general care wards. The majority of cardiosurgical patients are of advanced age, present increased comorbidity, and need complex surgery, which are determinants of a complicated postoperative course. In order to improve patient outcome and to avoid an explosion of costs, a standardized protocol for primary ICU discharge is needed, based on the judgment by experienced surgeons and ICU physicians. The availability of further resources such as an increased ICU capacity or the establishment of intermediate care (IMC) units to avoid premature discharges could beneficially affect this problem.

Continuing our former investigation [Litmathe 2009], we compared two time periods in which different amounts of ICU and IMC beds were available for a similar number of cardiosurgical patients. Furthermore, we focused on analyzing the impact of advanced and less invasive surgical procedures compared to conventional operations. In particular, we wanted to test the hypothesis that procedures like minimally invasive cardiac surgery (MIC), off-pump coronary artery bypass grafting (OPCAB), and surgery via partial sternotomy decrease the incidence of readmission to the ICU.

MATERIALS AND METHODS

We retrospectively reviewed 5,333 patients who had undergone coronary artery bypass grafting (CABG), valve surgery, or a combined procedure between 2005 and 2010. Patients who had been primarily discharged from the ICU

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Table 1. Capacity of ICU and IMC Ward and Cardiosurgical Procedures (Valve, CABG, or Combination): 2005-2010

Year	ICU beds, n	IMC beds, n	Operations, n
2005	11.4	6.2	882
2006	11.8	6.1	906
2007	12.1	6.8	875
2008	13.6	7.1	861
2009	14.7	7.0	869
2010	15.9	8.4	940

ICU indicates intensive care unit; IMC, intermediate care; CABG, coronary artery bypass grafting.

were distributed into two groups: patients with readmission to the ICU (group ICU) and patients with an uncomplicated postoperative course without another ICU stay (group control).

At first, the incidence of and reasons for readmission to the ICU were analyzed for two time periods in which there were significantly different ICU capacities at our department. With regard to this difference, we compared the time interval from 2005 to 2007 with the years 2008 to 2010. Table 1 shows the exact annual data of the individual number of ICU and IMC beds and the total amount of cardiosurgical procedures as described above. The number of operations did not change significantly, whereas the ICU as well as the IMC capacity increased from 2008 to 2010. The nurse-to-patient ratio was 1:2 in the ICU and 1:3 in the IMC, while a permanent presence of physicians was valid for both units.

In addition, we performed subgroup analyses for all minimally invasive procedures in comparison to the entirety of included patients. Structural changes in our department started in 2009 and caused an extension of our operative repertoire of minimally invasive procedures. Beginning in August 2009, we were conducting minimally invasive surgery via right-sided mini-thoracotomy for all single mitral and tricuspid valve procedures as well as for the treatment of atrial septal defects and atrial tumors (group MIC). For CABG, we were choosing an off-pump approach in the majority of patients (group OPCAB). Surgical access to the aortic valve and the ascending aorta was predominantly realized via partial sternotomy, either as "Z-sternotomy" [Nair 1998] or as upper "J-sternotomy" [Perrotta 2009] (groupZ/J).

Except these three procedures, all other operations were performed applying a standard approach with median sternotomy, extracorporeal circulation (ECC) and warm blood cardioplegia according to the technique of Calafiore or cold crystalloid cardioplegia (Bretschneider's solution).

For all groups of patients and for both time periods, we investigated the reasons for readmission and analyzed the postoperative course of the patients. By means of multivariate regression analysis, the risk factors for readmission to the ICU were determined.

Table 2. Perioperative Patient Characteristics for All Groups (Total, MIC, OPCAB, Z/J)

Variables	Total (n = 5333)	MIC (n = 129)	OPCAB (n = 441)	Z/J (n = 138)	p1*	p2*	p3*
Age, y	73.7 ± 5.4	62.6 ± 13.1	70.1 ± 9.3	68.2 ± 1.8	<0.05	n.s.	n.s.
Sex, male %	69.1	60.5	72.8	68.8	<0.05	n.s.	n.s.
COPD, %	10.1	8.5	9.1	7.2	n.s.	n.s.	<0.05
Cerebrovascular anamnesis, %	9.0	8.5	12.0	8.0	n.s.	<0.05	n.s.
Preop. EF <30%, %	7.4	6.2	5.0	8.7	n.s.	<0.05	n.s.
NYHA class (III/IV), %	13.5	10.9	11.6	13.0	n.s.	n.s.	n.s.
Preop. renal insufficiency, %	6.2	5.4	6.3	5.1	n.s.	n.s.	n.s.
Urgent/emergent status, %	62.0	7.0	58.5	29.0	<0.01	n.s.	<0.05
Redo operation, %	5.9	6.2	4.5	1.4	n.s.	n.s.	<0.05
CABG, %	70.7	0	100	0	<0.01	<0.05	<0.01
Valve/combined surgery/others, %	29.3	100	0	100	<0.01	<0.05	<0.01
Surgical reexploration, %	4.6	2.9	5.2	3.6	<0.05	n.s.	n.s.
LCOS (IABP/ECLS), %	4.7	2.3	4.1	2.2	<0.05	n.s.	< 0.05

*p1: total versus MIC group; p2: total versus OPCAB group; p3: total versus Z/J group.
MIC indicates minimally invasive cardiac surgery; OPCAB, off-pump coronary artery bypass grafting; Z/J, Z-/J-sternotomy; n.s., non-significant; COPD, chronic obstructive pulmonary disease; EF, ejection fraction; NYHA, New York Heart Association; CABG, coronary artery bypass grafting; LCOS, low cardiac output syndrome; IABP, intraaortic balloon pumping; ECLS, extracorporeal life support.

Table 3. Perioperative Course, Morbidity and Mortality in ICU and Control Groups

	Group ICU (n = 293)	Control (n = 4839)	*P*
Mechanical ventilation (primary stay), h	33.4 ± 11.3	11.5 ± 4.4	<.05
Primary stay in ICU, d	4.1 ± 2.5	2.7 ± 1.0	<.05
Hospital stay (total), d	21.9 ± 11.3	12.8 ± 5.0	<.05
Mortality in hospital, %	14.0	1.4	<.01
Postop. morbidity/ MACCE, %	25.3	6.6	<.01

ICU indicates intensive care unit; MACCE, major adverse cardiac and cerebrovascular events.

Statistical Analysis

Continuous variables are reported as mean values ± standard deviations. Statistical analysis was performed using analysis of variance, paired and unpaired Student's t test, or χ^2 tests as appropriate. Multivariate analysis was carried out to determine independent predictors of mortality. Statistical significance was assumed for *P* values lower than .05.

RESULTS

In the total of 5,333 patients, we found a mean age of 73.7 ± 5.4 years. The incidence of a clinical status of at least NYHA III was similar when comparing the entirety of patients in the study with the three subgroups. There were fewer patients with emergent or urgent procedures in the groups with MIC surgery or partial sternotomy. Table 2 depicts perioperative patient characteristics in all groups.

5,132 of the 5,333 patients (96.2%) were primarily discharged from the ICU. Out of this group, 293 patients were readmitted to the ICU at least once (5.7%, group ICU). The control group consisted of 4,839 patients.

There was a significantly higher incidence of readmission to the ICU in patients with valve procedures alone or in combination with CABG when compared to isolated CABG (8.8 versus 4.9%; *P* < .05). Table 3 illustrates the patients' courses until readmission in both groups as well as subsequent morbidity and mortality.

Among the patients who were not readmitted, 1.4% died in the hospital, compared to 14.0% in group ICU (*P* < .05). After readmission, the mean length of stay in the hospital was 21.9 ± 11.3 days compared to 12.8 ± 5.0 days in all other patients (*P* < .05).

Comparing the readmission rate in separate years, it is clear that this rate decreased with a growing capacity in the ICU and IMC wards. On the other hand, the quantity of operations was constant over time. In Table 4, these data are shown in detail. Interestingly, the duration of primary ICU and IMC stay for all patients was significantly longer in the years 2008-2010 versus 2005-2007.

The number of patients undergoing minimally invasive procedures and data on their primary discharge from the ICU between August 2009 and December 2010, as well as their perioperative and postoperative courses in comparison to the total patient number are analyzed in detail in Table 5.

In comparing OPCAB procedures and on-pump CABG in 2009 and 2010 with regard to readmission rate, perioperative course, morbidity and mortality, we could not find significant differences. The readmission rate was 4.4% in on-pump patients (compared to 4.0%) and the mortality rate was 2.0% compared to 1.9%.

The primary reasons for readmission were respiratory failure, cardiovascular instability, renal failure, pericardial

Table 4. Capacity of ICU, Surgical Procedures, Primary ICU Stay, and Readmission Rate

Year	ICU beds, n	IMC beds, n	Operations, n	Primary ICU Stay, d	Readmission, %
2005	11.4	6.2	882	2.5	6.2
2006	11.8	6.1	906	2.3	6.3
2007	12.1	6.8	875	2.7	5.7
2008	13.6	7.1	861	2.9	5.4
2009	14.7	7.0	869	2.9	5.4
2010	15.9	8.4	940	3.0	5.2
Readmission rates, %					
2005-2010	5.7				
2005-2007*	6.07				
2008-2010*	5.33				

*Comparing 2005-2007 with 2008-2010: *P* < .05
ICU indicates intensive care unit.

Table 5. Readmission Rate, Perioperative Course, Morbidity and Mortality Totals

Variable	Total (n = 5132)	MIC (n = 126)	OPCAB (n = 426)	Z/J (n = 133)	*P*
Readmission rate, %	5.7	4.8	4.0	3.8	<.05
Mechanical ventilation (primary stay), h	12.8 ± 4.2	6.2 ± 6.0	5.8 ± 3.8	7.8 ± 6.5	<.05
Primary stay in ICU, d	2.8 ± 0.8	1.7 ± 1.5	1.6 ± 1.1	2.1 ± 1.6	<.05
Hospital stay (total), d	13.3 ± 3.3	14.0 ± 7.3	12.6 ± 4.4	14.2 ± 6.2	n.s.
Mortality in hospital, %	2.1	1.6	1.9	1.5	<.05
Postop. morbidity/MACCE, %	7.7	4.8	4.9	4.5	<.05
Primary discharge from ICU*					
Total	5132/5333				
Group MIC	126/129				
Group OPCAB	426/441				
Group Z/J	133/138				

*Group total vs. MIC+OPCAB+Z/J

MIC indicates minimally invasive cardiac surgery; OPCAB, off-pump coronary artery bypass grafting; Z/J, Z-/J-sternotomy; ICU, intensive care unit; MACCE, major adverse cardiac and cerebrovascular events.

tamponade or bleeding, gastrointestinal complications and sepsis. However, there were some remarkable differences concerning the complications that caused an additional ICU stay in the separate groups as shown in Table 6.

Multivariate logistic regression analysis revealed the following parameters as the best preoperative predictors for readmission to the ICU: renal failure, a NYHA-class ≥ III and an emergent procedure.

Intra- and postoperatively, a combined surgical procedure, mechanical ventilation >24 hours, reexploration for bleeding, and the intraoperative need for mechanical assistance were identified as the most suitably predictive parameters.

Table 6. Causes of Readmission in Total and in Groups MIC, OPCAB, Z/J

Cause	Total (n = 293), %	MIC (n = 6), %	OPCAB (n = 17), %	Z/J (n = 5), %
Cardiac	27	33.3	29.4	20.0
Pulmonary	54.6	33.3	52.9	0
Renal	6.5	0	5.9	0
Bleeding	5.1	33.3	11.8	20.0
Wound infection	2.7	0	0	20.0
Sepsis	1.4	0	0	0
Gastrointestinal	2.0	0	0	20.0
Neurologic	1.0	0	0	20.0

MIC indicates minimally invasive cardiac surgery; OPCAB, off-pump coronary artery bypass grafting; Z/J, Z-/J sternotomy.

DISCUSSION

In continuation of a former study in our department [Litmathe 2009], we were now particularly aiming to investigate the influence of ICU as well as IMC capacity on the incidence of readmission to the ICU after cardiac surgery. In times of decreasing procedural invasiveness, the influence of minimally invasive strategies compared to conventional cardiac surgery should also be analyzed. We analyzed a large group of cardiosurgical patients who were able to be primarily discharged from the ICU. Out of these patients, 5.7% needed at least a second treatment in the ICU, which parallels the incidence in previous reports [Snow 1985; Elliot 2006; Rosenberg 2001].

In our patients, a readmission to the ICU was more common after valve or combined procedures as compared to isolated CABG. This observation was expected due to the complexity of these procedures. In contrast to another investigation [Bardell 2003], the clinical impact of a secondary ICU stay was very severe in our cohort. Postoperative major complications occurred with significantly more frequency in patients after readmission, and the length of hospital stay increased. Moreover, this group exhibited a ten-fold higher mortality rate.

In most centers, the decision for a discharge follows a standard protocol, but the final view is made clinically. High readmission rates are frequently associated with premature primary discharges. Metnitz et al showed that the last day of the first ICU stay is most responsible for the further course of the patient [Metnitz 2003]. They found that readmitted patients needed significantly more organ support for respiratory, cardiovascular, and renal systems. These patients were mechanically ventilated more than twice as often as other patients and also received supplementary ventilator support more frequently. Additionally, the authors clearly pointed out that the time between extubation and ICU discharge was significantly shorter in readmitted patients than in patients during their primary ICU stay. About 25% of readmitted patients were extubated again at the day of primary readmission. These data of the last day of the first ICU stay show that readmitted patients still needed an increased level of observation and sometimes intervention. Our results regarding the association of the ICU stay duration with the readmission rate confirm the previous reports in the literature. In general, a premature discharge from the ICU may increase patient morbidity and mortality. Daly and colleagues stated that about one third of all ICU patients are at increased risk of death and that delaying the discharge by 48 hours might reduce the risk of death significantly [Daly 2001]. In addition to this observation, Priestap et al showed that a discharge at night is associated with much higher risk than discharge during daily routine [Priestap 2006].

In the majority of Western countries, the demand for increasing ICU and IMC capacities is relevant. However, independent of the actual capacity, there are always complaints about a lack of ICU beds [Wild 2005]. In fact, there is still a low level of evidence for the ultimately appropriate necessities. Wild et al reported that in countries with a high density of ICU services, an improved utilization of the existing resources might be more beneficial than a further increase in capacities. They demanded a more appropriate and flexible use of ICU beds by applying scoring systems, participation in quality assurance programs and, most importantly, improving the personnel resources to enhance efficiency. In our department, increasing ICU capacity in combination with a constant number of cardiosurgical procedures enabled us to extend the duration of the primary ICU stay, which was associated with a decreased readmission rate. However, a further extension of our cardiosurgical procedures can be achieved only by improved use of the actual ICU capacity as described above.

The rate of cardiosurgical patients with the necessity for readmission due to various reasons was 5.7%. Compared to the literature [Snow 1985; Elliot 2006; Rosenberg 2001], this incidence is quite low for cardiosurgical patients with complex multimorbidity. In order to further improve the ICU readmission rate, IMC organization is a crucial aspect. Not only the existence of but also the enlargement of the IMC units seems to be an inevitable condition. In our patients, the decreasing need for a second ICU stay was not only associated with a growing ICU capacity but also with a larger amount of IMC beds. Jaber et al showed the impact of the availability of non-invasive ventilation to avoid readmission to the ICU [Jaber 2011]. These non-invasive procedures like nasal continuous positive airway pressure (NCPAP) or nasal intermittent positive pressure ventilation (NIPPV) can be safely performed in an IMC unit. Nevertheless, the authors also pronounce the necessity for not prolonging this treatment and delaying a finally unavoidable readmission to the ICU, as this would further impair patient outcome.

In our patients, we found several classical risk factors that were associated with the incidence of readmission to the ICU. According to Bardell et al, preoperative renal failure and primary ventilation >24 hours are significant predictors of readmission [Bardell 2003]. Furthermore, we could identify cardiovascular and respiratory complications as the most important factors that necessitated a second ICU stay. This observation corresponds to the results of previous studies [Priestap 2006, Cooper 1999].

In times of increasing rates of minimally invasive procedures, in general as well as in cardiac surgery, the impact of this reduction in surgical trauma on the need for ICU treatment is discussed controversially. Celkan et al analyzed a group of patients undergoing OPCAB with a so-called fast-track recovery protocol [Celkan 2005]. It significantly reduced the rate of readmissions compared to other groups. These results are compatible with the observations of Bucerius et al, who found a lower prevalence of prolonged ICU stay in patients undergoing CABG procedures in beating heart groups when compared to conventional on-pump revascularization [Bucerius 2004]. Our results confirm these statements, as we found a significantly reduced rate of readmission to the ICU in all groups of patients with minimally invasive procedures as compared to the total group of patients.

In summary, it is well known that readmission to the ICU after cardiac surgery is associated with an impaired outcome. Growing resources with regard to ICU and IMC capacity may positively influence this problem by decreasing the number of readmissions. However, the use of existing resources has to be optimized. Recent surgical strategies with less invasive procedures are also associated with a reduced incidence of readmission based on fewer respiratory problems.

Limitations of the Study

Our study is designed as a retrospective analysis, resulting in the well-known disadvantages of such an investigation. One major problem is caused by the lack of a standardized ICU discharge protocol. However, even in the case of clear criteria that must be fulfilled before ICU discharge, the final decision is often based on subjectively estimating the clinical status of the patient. Another problem with this analysis is based on the missing risk score (ie, EuroSCORE). A retrospective calculation of such a score was not possible in quite a number of patients, particularly in the first years of this analysis, due to several missing parameters that would have been necessary for score determination.

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