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Risk factors for prolonged ventilation after cardiac surgery using APACHE II, SAPS II, and TISS: comparison of three different models

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Abstract *Objective*: To identify the risk for prolonged mechanical ventilation in cardiac surgical patients.
Design: Prospective study with retrospective combination of a second database.
Patients: Six hundred and eighty-seven patients after cardiac surgery over a period of 12 months.
Measurements: Demographic data were recorded preoperatively, and surgical procedures intraoperatively using a surgical database designed for quality control. Length of ICU and hospital stay, and hospital outcome were recorded. Severity of illness was assessed daily using APACHE II, SAPS II, and Organ Failure Score. Intensity of treatment and nursing care was monitored by means of the Therapeutic Intervention Scoring System (TISS). Univariate and multivariate analyses were performed using logistic regression. The predictive value of the identified variables was tested by the Wilcoxon test using the receiver operating characteristic curve.
Main results: Sixty-two patients (9.0 %) were ventilated for > 48 h and accounted for 42.8 % of the total costs in the ICU. The pre- and intraoperatively collected data produced a model with weak predictive capacity for prolonged ventilation [area under curve (AUC) 73.22 and 71.08, respectively]. The use of TISS and SAPS postoperatively resulted in an effective model of prediction (AUC 93.76). Adding the occurrence of reoperation, reintubation, emergency transfusion, intraaortic balloon pumping, and need for total parenteral nutrition to the model further improved its predictive capacity (AUC 94.74).
Conclusions: The present results strongly suggest that data collected postoperatively using established scoring systems as well as documented events of high clinical impact for risk assessment and quality control are reliable predictors of prolonged ventilation.

Key words Cardiac surgery · Mechanical ventilation · Risk stratification · Scoring systems

Introduction

The risk of prolonged mechanical ventilation after open heart surgery varies from 3 % to 23 % [1, 2, 3, 4]. While sedation and controlled mechanical ventilation for at least 12–24 h used to be the preferred management [5], early extubation has become the management of choice without significant increase in postoperative morbidity and mortality in low-risk patients [6, 7]. Amongst other beneficial effects of spontaneous breathing after cardiac surgery, raised cardiac output by improved diastolic filling [8], diminished hemodynamic disturbances, and reduced neurological deficit in elderly patients [9] may contribute to less morbidity and better outcome in this group of patients.

Changes in postoperative management of cardiac surgical patients owing to growing economic pressure have led to patients being looked after routinely in recovery areas rather than intensive care units (ICUs) [9, 10, 11]. Predictive models for mortality, morbidity, and intensive care length of stay have been developed for patients undergoing coronary artery bypass grafts (CABGs) for risk assessment and quality control in different institutions [12, 13, 14, 15, 16]. Preoperative lung function testing has not been able to predict postoperative morbidity and mortality after cardiac surgery [17]. Other preoperative risk factors for the stratification of morbidity and mortality in cardiac surgical patients, such as impaired left ventricular ejection fraction, congestive heart failure, angina pectoris, current smoking, or diabetes have also been tested [4, 12]. Recently, two different models were published identifying risk factors for prolonged mechanical ventilation, length of stay in the ICU, and mortality, in Canada [18] and in Scotland [19]. However, different pre-, intra-, and postoperative risk factors were identified by these two extensive studies, raising the question of the influence of the selection of variables on the resulting models. Therefore, we set out to investigate pre-, intra-, and postoperative risk factors for prolonged mechanical ventilation (> 48 h) in patients after cardiac surgery, including high-risk patients and emergency cases using established documentation and scoring systems.

Materials and methods

After approval by the Institutional Review Board, this study was designed as a prospective collection of demographic and clinical data of all patients admitted to the cardiothoracic intensive care unit at the University Hospital Charité, Berlin, Germany, between 1 January 1997 and 31 December 1997 after open heart surgery. The Institutional Review Board waived the need for informed consent since the study did not raise additional variables than those used in clinical practice and did not influence clinical treatment. Retrospectively, this database was combined with a surgical database designed for quality control [20], introducing pre- and intraoperatively collected data.

Data collection

Pre- and intraoperative data were collected on site by the surgeon using a standardized document [20]. Preoperative data included admission criteria, history of chronic disease, organ failure or previous cardiac operation, previous left ventricular function including left ventricular end-diastolic pressure (LVEDP) and left ventricular ejection fraction (LVEF), as well as the amount of occluded coronary arteries. The operative procedure as well as the duration of the operation, cardiopulmonary bypass, and aortic cross-clamping time was determined intraoperatively. The occurrence of intraoperative complications, defined as life-threatening arrhythmia, repeated cardiopulmonary bypass (≥3 times), and hemorrhage (> 2 l), was documented. The pre- and intraoperative collected data were entered retrospectively by a trained research assistant into a computerized database.

Demographic data (age, sex), surgical procedures performed, length of stay in ICU, length of stay in the hospital, and outcome (i.e., survival or death) were recorded. Severity of illness was assessed daily using the Acute Physiology and Chronic Health Evaluation (APACHE II) score [21]. The Glasgow coma score [22] in the APACHE II score was standardized since most patients were still anesthetized and partially paralyzed for a period of time after ICU admission. The best verbal score of the Glasgow coma score was recorded as “normal” if communication was possible with the intubated patient or in the absence of clinically and/or computertomographically proven neurological failure. Furthermore, physiological data to determine the Simplified Acute Physiology Score (SAPS II) [23] and the Organ Failure Score (OFS) [24] were registered daily. The use of technological support and interventions, the intensity of treatment, and nursing care for patients after cardiac surgery were assessed using the Therapeutic Intervention Scoring System (TISS) [25]. The RIYADH-ICU Program (RIP) offers the opportunity to define the relationship between the observed and the predicted mortality rate according to the APACHE II admission score and the OFS as the standardized mortality ratio (SMR). The SMR can be used as an objective measurement of ICU performance since mortality is influenced by severity of illness [11, 26]. An SMR below 1 represents low ICU efficacy since the observed mortality is higher than the calculated risk of death (ROD). Postoperative data were collected daily on site by trained data collectors on the medical and nursing staff, verified by the physician in charge, and entered retrospectively by a trained research assistant into the RIP Version 5.0 [27]. Clinical care of patients after cardiac surgery was not affected by data collection.

Statistics

Univariate analysis

Univariate analysis of all pre-, intra-, and postoperatively collected data was performed to select factors significantly influencing duration of mechanical ventilation using chi-square or Fisher’s exact test for categorical variables. The Wilcoxon rank sum test was used for continuous variables. Median values were used for continuous variables and absolute and relative frequency for categorical variables.

The point-biserial coefficient of correlation r_{pbis} [28] was calculated to determine the impact of the duration of mechanical ventilation (continuous variable) upon hospital outcome (dichotomous variable).

Multiple logistic regression analysis

After identification of variables differing significantly between the two groups, logistic stepwise regression according to the likelihood-ratio [29] was used to select predictors for prolonged mechanical ventilation (> 48 h). The probability P of prolonged mechanical ventilation (> 48 h) was determined according to

$$P = 1/(1 + e^{-Z})$$

while Z was calculated by

$$Z = B_1 * X_1 + B_2 * X_2 + ... + B_n * X_n + \text{const}$$

Table 1 Analysis of the days on the ventilator and outcome. Values are shown as mean/median. Patients ventilated for less than 6 h were assessed as days ventilated = 0. (*SMR* standardized mortality ratio, *APACHE II* acute physiology and chronic health evaluation, *ROD* risk of death, *ICU* intensive care unit)

Variable	Days on ventilator		
	< 2 days	2–4 days	> 4 days
Number of patients	625	40	22
Died	3	4	3
Hospital mortality %	0.48	10.00[b]	13.60[d,e]
SMR	0.07	0.67	0.59
APACHE II score	10.0/9.3	16.1/16.6[b]	19.8/19.8[d,e]
APACHE II ROD	6.5/4.7	15.0/11.9[b]	23.2/19.9[d,e]
APACHE II score: survivors	10.0/9.3	15.3/16.2[b]	20.2/20.0[d,f]
APACHE II score: non-survivors	9.3/9.0	22.3/23.5[a]	17.7/13.0
APACHE II ROD: survivors	6.5/4.7	13.2/10.9[b]	23.7/20.5[c,f]
APACHE II ROD: non-survivors	4.0/3.0	31.3/31.8[a]	20.1/8.2
Days ventilated: survivors	0/0	3/2[b]	13/9[d,f]
Days ventilated: non-survivors	0/0	3/3[a]	13/13[c,e]
ICU Length of stay: survivors	2/1	5/5[b]	18/13[d,f]
ICU Length of stay: non-survivors	5/5	3/3	17/15[e]

[a] $P < 0.05$ (Mann-Whitney U-test) < 2 days versus 2–4 days
[b] $P < 0.01$ < 2 days versus 2–4 days
[c] $P < 0.05$ (Mann-Whitney U-test) < 2 days versus > 4 days
[d] $P < 0.01$ < 2 days versus > 4 days
[e] $P < 0.05$ (Mann-Whitney U-test) 2–4 days versus > 4 days
[f] $P < 0.01$ 2–4 days versus > 4 days

where $X_1, X_2, ..., X_n$ represented different values of the tested variables and B_i the coefficient of regression. If the calculated probability P was > 0.5, the patient was passed into the group of prolonged mechanical ventilation (> 48 h).

ROC Curve

Each point of the receiver operating characteristic (ROC) curve represented a 4-square field of the correctly predicted and false positively predicted patients using randomly selected cut-off points. The area under the curve (AUC) was calculated using the trapezoidal rule and correlates to the quality of prediction [30]. An arbitrary distribution of the predicted variables in both groups would produce a diagonal in the presented diagram resulting in an AUC of 50 %. In that case, the independent and the dependent variable would not correlate, representing no predictive power of this variable. An AUC of 100 % would equate to a predictive power of 100 %, which is impossible to achieve in practice.

Results

A total of 955 patients was entered into the RIYADH-ICU Program [27]. The remaining of the overall 1275 patients after cardiac surgery were treated at the neonatal or medical ICU. Physiological data were excluded in patients who were treated for less than 8 h in the ICU, in children under 13 years of age [21], in patients who were not admitted directly after cardiac surgery, and if hospital outcome was not followed up. After combination of the remaining 795 complete postoperative data sets with the pre- and intraoperatively collected data, a total of 687 patients was analyzed. Of the 492 male and 195 female patients, 72.0 % were treated after coronary artery bypass grafts, 19.1 % after cardiac valve operations, 4.4 % after combined cardiac valve repair and CABG, and the remaining 4.5 % after correction of congenital heart disease, cardiomyoplasty, or partial left ventricular reduction (Batista's operation). Sixty-two patients (9.0 %) were ventilated for > 48 h.

ICU Performance

Hospital mortality of patients ventilated for > 48 h was higher (11.3 %) than the whole study population (1.5 %). In 1997, the SMR in the whole study population according to APACHE II was only 0.19. The SMR according to SAPS II was even lower (0.10) because calculated ROD was higher using SAPS II (14.5 %) in comparison to APACHE II (7.5 %). Mean ROD on ICU admission was significantly higher in non-survivors than survivors (APACHE II 17.0 vs 10.6, $P = 0.079$; ROD 19.7 vs 7.3, $P < 0.05$). ICU performance decreased in patients ventilated for > 48 h (Table 1).

Impact of duration of mechanical ventilation upon outcome and costs

The point-biserial coefficient of correlation r_{pbis} [28] calculated to determine the impact of the duration of mechanical ventilation upon hospital outcome demonstrated a highly significant correlation ($r_{pbis} = 0.1829$, $P < 0.0001$). The mortality rate in the whole study population was low (1.5 %), but increased sevenfold in patients ventilated 2–4 days and ninefold in those ventilat-

Table 2 Estimated cost of treatment (DM). Variables are shown as mean. Total costs of all patients (including short-time ventilated patients < 6 h) summed up to 5,771,232.00 DM. (*TISS* therapeutic intervention scoring system)

Variable	Days on ventilator		
	< 2 days	2–4 days	> 4 days
Number of patients	625	40	22
Total cost (DM)	3,301,128.00	791,208.00	1,678,896.00
Cost per survivor (DM)	5,213.00	20,220.00[b]	74,721.00[d,f]
Cost per non-survivor (DM)	19,512.00	15,822.00	86,400.00[c]
Effective cost per survivor (DM)	5,307.00	21,978.00[b]	88,336.00[d,f]
Average cost per patient (DM)	5,282.00	19,780.00[b]	76,313.00[d,f]
% of overall cost (DM)	57.2	13.7[b]	29.1[d,f]
Total TISS	45,849	10,989[b]	23,318
Average daily TISS	48.3	57.5[a]	60.5[d]

[a] $P < 0.05$ (Mann-Whitney U-test) < 2 days versus 2–4 days
[b] $P < 0.01$ < 2 days versus 2–4 days
[c] $P < 0.05$ (Mann-Whitney U-test) < 2 days versus > 4 days
[d] $P < 0.01$ < 2 days versus > 4 days
[e] $P < 0.05$ (Mann-Whitney U-test) 2–4 days versus > 4 days
[f] $P < 0.01$ 2–4 days versus > 4 days

Table 3 Univariate analysis of preoperative risk factors significantly influencing duration of mechanical ventilation. Median values (range) were used for continuous variables and absolute and relative frequency for categorical variables. (*APACHE* acute physiology and chronic health evaluation, *CABG* coronary artery bypass grafting, *LVEF* left ventricular ejection fraction, *LVEDP* left ventricular end-diastolic pressure, *NYHA* New York Heart Association; *SAPS* simplified acute physiology score, *TISS* therapeutic intervention scoring system)

Preoperative categorical variable	< 48 h ventilated $n = 625$ Occurrence (%)	> 48 h ventilated $n = 62$ Occurrence (%)	*P*
Age > 65 years	235 (37.5)	33 (53.2)	< 0.05
Female gender	173 (27.7)	22 (35.5)	n.s.
Emergency operation	11 (1.8)	1 (1.6)	n.s.
Admission criteria			
Coronary artery disease	497 (76.6)	48 (77.4)	n.s.
Valvular disease	137 (21.9)	22 (35.5)	< 0.05
Others	23 (3.7)	0	n.s.
History of			
Myocardial infarction	315 (50.4)	32 (51.6)	n.s.
Cardiogenic shock	112 (17.9)	17 (27.0)	n.s.
Hyperlipoproteinemia	342 (54.7)	27 (43.5)	n.s.
Arterial hypertension	346 (55.4)	26 (41.9)	< 0.05
Diabetes mellitus	136 (21.8)	25 (40.3)	< 0.01
Platelet aggregation inhibitors	280 (44.8)	32 (51.6)	n.s.
Continuous anticoagulation	72 (11.5)	8 (12.9)	n.s.
Previous cardiac surgery	63 (10.1)	12 (19.4)	= 0.05
Chronic peripheral vascular disease	84 (13.4)	15 (24.2)	< 0.05
APACHE II: chronic disease	106 (17.0)	(37.1)	< 0.001
Preoperative status			
NYHA class IV	93 (14.9)	15 (24.2)	n.s.
LVEDP > 15 mmHg	162 (25.9)	21 (30.9)	n.s.
LVEF < 40 %	450 (72.0)	43 (69.4)	n.s.
Three- or more vessel disease	101 (16.2)	21 (30.9)	< 0.001
Atrial fibrillation	42 (6.7)	8 (12.9)	n.s.

ed for > 4 days (Table 1). The 62 (9.2 %) patients requiring ventilatory support for > 2 days accounted for 42.8 % of the total costs. Effective cost per survivor was five times higher in patients ventilated 2–4 days and 18 times higher in patients ventilated for > 4 days due to a significantly increased length of stay in the ICU ($P < 0.05$, see Table 2).

Preoperative data

Median age in the prolonged ventilated patients was 66.2 years in comparison to 62.3 years in the successfully extubated patient group. Thirty-three patients (53.2 %) ventilated for > 48 h were over 65 years old in comparison to 235 (37.6 %) patients over 65 years old who were successfully extubated. Univariate analysis (Table 3) demonstrated that age, prevalence of chronic disease according to APACHE II, history of diabetes mellitus,

Table 4 Univariate analysis of intraoperative risk factors significantly influencing duration of mechanical ventilation: continuous variables

Variable	< 48 h ventilated (*n* = 625)	> 48 h ventilated (*n* = 62)	*P*
Operation time (min)	181 (80–500)	213 (115–480)	< 0.0001
Cardiopulmonary bypass time (min)	75 (0–360)	100 (0–212)	< 0.0001
Aortic cross-clamping time (min)	45 (0–175)	58 (0–158)	< 0.0001

Table 5 Univariate analysis of intraoperative risk factors significantly influencing duration of mechanical ventilation: categorical variables

Variable	Occurrence (%)	Occurrence (%)	*P*
Complications	37 (5.9)	18 (29.0)	< 0.0001
Surgical procedure			
CABG	458 (73.3)	37 (59.1)	< 0.05
Valve repair	114 (18.2)	17 (27.4)	n.s.
Combined CABG + valve repair	24 (3.8)	6 (9.7)	< 0.05
Others	29 (4.6)	2 (3.2)	n.s.

Table 6 Univariate analysis of postoperative risk factors significantly influencing duration of mechanical ventilation: continuous variables

Variable	< 48 h ventilated (*n* = 625)	> 48 h ventilated (*n* = 62)	*P*
APACHE II score	10 (0–30)	20 (3–35)	< 0.0001
SAPS II	27 (6–70)	48 (23–82)	< 0.0001
TISS points	50 (27–76)	64 (43–99)	< 0.0001

chronic peripheral vascular disease, previous cardiac surgery, and coronary artery disease including three or more vessels significantly influenced the duration of mechanical ventilation. The incidence of a history of syncopes, embolic events, chronic pulmonary disease, chronic neurological deficit, or chronic renal insufficiency was infrequent and did not differ significantly between both groups.

Intraoperative data

The period of the operation, cardiopulmonary bypass, and aortic cross-clamping was significantly higher in patients ventilated for > 48 h (Tables 4, 5). The percentage of CABG patients was significantly lower in the prolonged ventilated patient group (59.1 %) in comparison to the successfully extubated group (73.3 %). Combined CABG and valvular surgery has a higher risk for prolonged ventilation (9.7 % vs 3.8 % in the successfully extubated patients).

Postoperative data

The scores of patients ventilated for > 48 h were twice those of the successfully extubated patients (APACHE II: 20 vs 10, SAPS II: 48 vs 27; TISS: 64 vs 50). Of the patients ventilated for > 48 h, 77.8 % had an APACHE II score > 15 on admission to the ICU in comparison to 18.1 % of the successfully extubated patients. The prolonged ventilated patients were furthermore characterized by a SAPS II > 30 (95.2 % vs 39.5 % in the extubated group) and by > 60 TISS points (59.6 % vs 7.2 % in the extubated group). Using these cut-off points in the univariate analysis demonstrated a highly significant influence of these scoring systems on the occurrence of prolonged mechanical ventilation. Use of the OFS and all other postoperatively collected data demonstrated a significant result except for the occurrence of respiratory failure (Tables 6, 7).

Multiple logistic regression analysis

Multiple logistic regression analysis of the preoperative data resulted in a model of five significant parameters (Table 8) correctly predicting 99.84 % of patients being ventilated for less than 48 h, but only one (1.61 %) patient ventilated for > 48 h was predicted correctly (AUC 73.22). The analysis of the intraoperative data (Table 8) correctly identified 99.4 % of the patients being successfully extubated, whereas only 4.8 % of the prolonged ventilated patients could be isolated (AUC 71.08). The use of the seven significant parameters of the postoperative data produced a model correctly predicting 99.2 % of the patients being ventilated for < 48 h and 64.5 % of the patients ventilated for > 48 h (AUC 97.74). The model correctly identified 96.1 % of all patients. The AUC was higher (97.74 %)

Table 7 Univariate analysis of postoperative risk factors significantly influencing duration of mechanical ventilation: categorical variables

Variable	Occurrence (%)	Occurrence (%)	*P*
Total parenteral nutrition	46 (7.4)	26 (41.9)	< 0.0001
Organ failure			
Renal (acute)	7 (1.1)	12 (19.4)	< 0.0001
Neurological	31 (5.0)	11 (17.7)	< 0.001
Cardiovascular	56 (9.0)	24 (38.7)	< 0.0001
Respiratory	121 (19.4)	14 (22.6)	n.s.
Gastrointestinal	5 (0.8)	11 (17.7)	< 0.0001
Iatrogenic complication	15 (2.4)	21 (33.9)	< 0.0001
Emergency transfusion	16 (2.6)	17 (27.4)	< 0.0001
Continuous antiarrhythmic therapy	36 (5.8)	17 (27.4)	< 0.0001
Cardioversion due to tachycardia	8 (1.3)	12 (19.4)	< 0.0001
Re-intubation	8 (1.3)	7 (11.3)	< 0.001
More than five units packed red blood cells	8 (1.3)	11 (17.7)	< 0.0001
Intraaortic balloon pumping	6 (1.0)	18 (29.0)	< 0.0001
Re-operation	6 (1.0)	21 (33.9)	< 0.0001
> 1 Inotropic agent	116 (18.6)	33 (53.2)	< 0.0001
Dialysis	8 (1.3)	4 (6.5)	< 0.05
Pacemaker	83 (13.3)	21 (33.9)	< 0.001

Table 8 Multiple logistic regression analysis of risk factors for prolonged mechanical ventilation. Multivariate analysis of all data acquired in the pre-, intra- or postoperative setting significantly influencing the probability of prolonged mechanical ventilation > 48 h after open heart surgery. Logistic stepwise regression according to the likelihood-ratio [28] was used to select predictors for prolonged mechanical ventilation (> 48 h). If the calculated probability *P* was > 0.5, the patient was passed into the group of prolonged mechanical ventilation (> 48 h). (*APACHE* acute physiology and chronic health evaluation, *SAPS* simplified acute physiology score, *TISS* therapeutic intervention scoring system, *CI* confidence interval)

Variable	Odds ratio	95% CI	*P*
Preoperative variable			
Three- or more vessel disease	3.11	2.55–3.67	0.0002
Chronic disease APACHE II	2.90	2.32–3.48	0.0003
Valve disease	2.51	1.92–3.10	0.0021
Diabetes mellitus	2.18	1.58–2.78	0.0061
Age < 65 years	1.74	1.20–2.28	0.045
Intraoperative variable			
Operation time per minute	1.01	1.00–1.02	0.0013
Intraoperative complication	4.30	3.60–5.00	< 0.0001
Postoperative variable			
SAPS per point	1.11	1.08–1.15	< 0.0001
TISS per point	1.09	1.03–1.15	0.0034
Intraaortic balloon pumping	9.22	7.68–10.76	0.0046
Total parenteral nutrition	8.59	7.67–9.51	< 0.0001
Re-operation	7.12	5.74–8.50	0.0052
Re-intubation	6.85	5.08–8.62	0.0329
Emergency transfusion	6.84	5.44–8.24	0.0072

in comparison to APACHE II (AUC 87.55%) and SAPS II (AUC 89.61%). Comparing ROC curves of the pre-, intra-, and postoperatively collected data (Fig. 1) demonstrated the differing predictive capacity of the three resulting models. The combined use of the SAPS II score and total amount of TISS points improved the power of prediction (AUC 93.76). The resulting model correctly identified 98.88% of the patients being ventilated for < 48 h and 48.39% of the patients ventilated for > 48 h. Comparing ROC curves produced by the use of different postoperative scoring systems demonstrated that the predictive capacity was becoming more similar (Fig. 2).

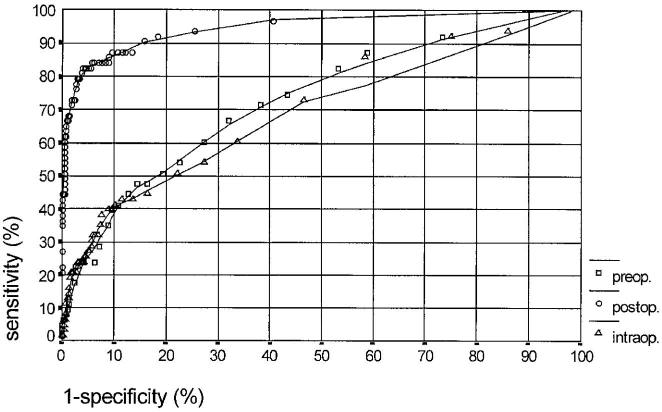

Fig. 1 Receiver operating characteristic (ROC) curve predicting prolonged mechanical ventilation > 48 h using pre-, intra-, and postoperatively collected data. (*intraop* intraoperatively collected data identified by multiple logistic regression, *preop* preoperatively collected data identified by multiple logistic regression, *postop* postoperatively collected data identified by multiple logistic regression)

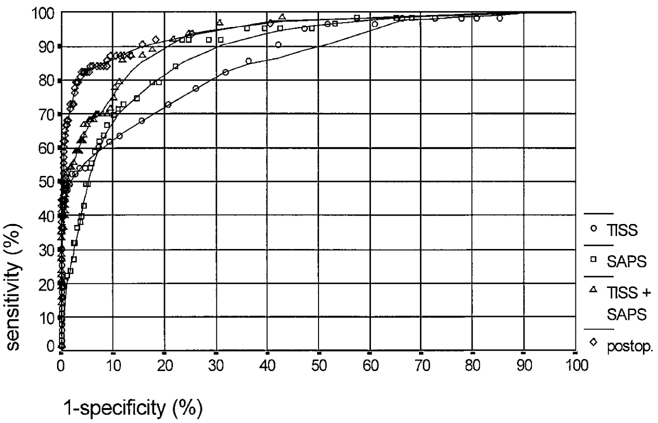

Fig. 2 Receiver operating characteristic (ROC) curve predicting prolonged mechanical ventilation > 48 h using APACHE II, SAPS II, TISS, and five other variables identified by multiple logistic regression analysis. (*postop* postoperatively collected data identified by multiple logistic regression, *SAPS* simplified acute physiology score, *TISS* therapeutic intervention scoring system)

Discussion

The most important finding of the presented study was that the use of pre- and intraoperative data could not predict the risk for prolonged mechanical ventilation. Postoperatively collected data using established scoring systems resulted in a more sensitive predictive model. These results differ from previously published data [18, 19], raising the question about the influence of the selection of variables on the resulting model.

In the present study, female gender was not a risk factor of delayed extubation in contrast to the literature. Butterworth et al. [31] demonstrated in the Clinical Benchmarking Database a strong association between female gender and increased duration of intubation and length of stay. The percentage of female patients in the present database (29 %) was comparable to the studies by Butterworth et al. [31] (29 %) and Wong et al. [18] (24 %), but lower than in Thompson et al.'s [19] study population (45 %). The predictive models using the preoperative available data as well as the intraoperative collected data were unable to identify correctly patients at risk for mechanical ventilation > 48 h. Concentrating on data available directly from the immediate postoperative period, we could identify the following major risk factors for prolonged mechanical ventilation:

1. Increased severity of illness assessed using the SAPS II and a higher intensity of treatment by the use of TISS.
2. Insertion of intraaortic balloon pumping or need for parenteral nutrition.
3. The necessity of emergency operation or postoperative complications resulting in the need for emergency transfusion, re-operation and/or re-intubation.

Previous heart surgery, surgical priority, age, peripheral vascular disease, and high serum creatinine had been identified as the most powerful preoperative predictors for postoperative complications such as prolonged ventilation [32]. Tu et al. [13] has developed a six-variable risk index (age, sex, left ventricular function, type of surgery, urgency, and repeat operation) to predict in-hospital mortality and length of stay in the ICU as well as in the hospital. The variables age, female gender, preoperatively impaired left ventricular function, emergency surgery, and rethoracotomy had been identified as risk factors in other major cardiac surgical outcome studies [12, 14, 15, 16, 33]. Recently, Wong et al. [18] developed a new cardiac risk score for delayed extubation, prolonged ICU length of stay, and mortality. Multiple logistic regression identified age, female gender, postoperative use of inotropes, and intraaortic balloon pumping, as well as excessive bleeding and atrial arrhythmia, as risk factors for delayed extubation. Prolonged length of ICU stay was accompanied additionally by myocardial infarction at least 1 week before surgery, and renal insufficiency. Mortality was influenced only by impaired left ventricular function, female gender, and emergency surgery. Following case note review of 139 consecutive cardiac surgical patients ventilated for > 7 days by Thompson et al. [19], urban residence, chronic obstructive airway disease, prolonged operation, and bypass time were isolated as significant predictors of prolonged ventilation. Urban residence, inotrope days, sepsis, perioperative cerebrovascular accident, and coagulopathy requiring fresh frozen plasma transfusion were predictive of increased ICU mortality on multivariate analysis. The consequences of using three different risk scores in daily practice are at least questionable and may lead to an unselected combination of all three scores. In the present study, a significant correlation between prolonged ventilation > 48 h and mortality was proven; therefore we did not statistically analyze risk factors of mortality. Furthermore, overall mortality was remarkably low (1.5 %), but comparable with the data collected by Wong et al. [18] (2.6 %) and Butterworth et al. [31] (male 1.7 %, female 3.6 %). Thompson et al.'s [19] mortality rate of the long-term ventilated patients retrospectively selected by case note review was higher according to their study design.

The reported results may have been biased by the relatively high drop-out rate due to the retrospective combination of the two databases. However, following case note review as carried out by others [19] may produce even stronger bias since the statistical model was not designed to be tested on patients without delayed extubation. Wong et al. [18] did not mention any drop-out rate but included only CABG patients. Therefore, the reliability of their model on patients with valve repair or complex cardiac surgery remains unclear.

The present data strongly suggest the reliability of postoperatively collected data by the use of established scoring systems and additionally documented events of high clinical impact. The use of APACHE II, SAPS II, and TISS in these patients, however, has always been reported to be limited. Patients after coronary artery bypass grafting were excluded from Knaus' validation of the methodology due to the unique situation of high initial APACHE II scores and low mortality rates [21]. In addition, during the first 24 h, TISS largely represents interventions that were instituted in the operating room but have an impact on intensive care nursing workload and unit resources [34]. Otherwise, APACHE II, SAPS II, and TISS are still commonly used, easy to perform, and deliver reliable results in cardiac surgical patients [26, 35]. The selection of data to be documented for risk stratification of prolonged intubation and mortality varies extensively between different studies [18, 19, 31]. This may influence the resulting predictive models. The use of established postoperative scoring systems after cardiac surgery may produce reliable predictive models for risk assessment and quality control in different institutions.

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