Original Article

Preoperative and intraoperative risk factors for prolonged mechanical ventilation among cardiac surgery patients

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Abstract

Background: The prolonged mechanical ventilation among cardiac surgery patients has been correlated with negative clinical outcome and increased healthcare resources utilization.
The aim of this study was to identify the risk preoperative and intraoperative factors for increased ventilation among cardiac operated patients.
Method and Material: An observational cohort study was carried out during a three-month period (from October 2010 to December 2010) among 48 consecutive patients who were admitted to the cardiac surgery intensive care unit of a general, tertiary hospital of Athens-Greece. A short questionnaire on basic socio-demographic characteristics and clinical patient data was attended. All patients had the same anesthetic and postoperative management. Statistical analysis was performed with SPSS version 16.0, using bivariate and multivariate linear regression. The p-value of ≤ 0.05 was considered as statistically significant.
Results: The mean patient age was 64.7 (±13.7) years old, while the mean duration of intubation was 939 (±545) minutes. 67% of the sample was male. Multivariate linear regression analysis revealed that the older age [β coefficient 13.5, 95% confidence interval (CI) 2.7-24.2, p=0.015] and the increased duration of surgery (β coefficient 1.5, 95% CI 0.01-3.1, p=0.05) were the main risk factors for prolonged mechanical patient ventilation.
Conclusions: The increased age and the prolonged duration of the surgery seem to be strongly associated with delayed tracheal extubation contributing to the early prediction of high risk patients for prolonged ventilation, a fact that could contribute to more effective allocation of the limited healthcare resources and better planning of the operative list

Keywords: Cardiac surgery, risk factors, ventilation

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Introduction

The number of patients undergoing cardiac surgery has increased substantially the last 20 years. It has been estimated that more than 30.000 and 10.000 operations are carried out each year in the United Kingdom[1] and Greece [2] respectively. In addition, the National Center for Health Statistics estimates that in 2007, in the United States of America, a total of 514.000 open heart operations (Coronary Artery Bypass Grafting - CABG and valve surgery) were performed [3].

The duration of the mechanical ventilation of cardiac surgery patients is among factors that affect the patient outcome, in terms of morbidity and mortality, as well as the cost of the procedure and the healthcare resource utilization in general. Several investigators has correlated the delayed patient extubation with higher mortality rates [4-6], more complications [6-8], increased length of stay in the intensive care unit (ICU-LOS) or the hospital (hospital LOS) [5,6] and higher healthcare cost [9]. Nevertheless, Hawkes et al. [10] conducted a systematic review aiming to assess the effect of the early extubation on patient outcomes and concluded that there was no evidence of lower mortality and morbidity rates on the early extubated patients compared with the conventially extubated patients. However, early extubation seems to reduce the ICU and Hospital – LOS.

The aim of our study was to identify the risk preoperative and intraoperative factors for increased mechanical ventilation among cardiac surgery patients. The early identification of high risk patients could contribute to more effective allocation of the limited healthcare resources and better planning of the operative list, a fact of great importance for centers with decreased ICU beds availability. In addition, might be helpful for the development of preemptive strategies.

Methodology

Study design and setting

An observational cohort study was carried out during a three-month period (form October 2010 to December 2010) among cardiac operated patients in a general, tertiary hospital of Athens, Greece. The inclusion criteria of our study were a priori defined as below: 1. patient age ≥ 18 years old, 2. the application of a cardiopulmonary bypass (CPB) during the surgery 3. the application of the same anesthetic procedures in all patients, 4. the same postoperative management of all patients. The exclusion criteria of this study were the following: 1. emergency procedure and 2. history of stroke, neurological or psychiatric disorder.

In total 114 patients were admitted to the 8-bed cardiac surgery ICU of the hospital, 48 of whom (42.1%) met the inclusion criteria and constituted our study sample.

Data Collection

A short questionnaire on basic socio-demographic characteristics (age, gender, weight, height) and clinical patient data (history of COPD, extracardiac arteriopathy, neurological dysfunction, previous cardiac surgery, active endocarditis, unstable angina, pulmonary hypertension, preoperative serum creatinine levels, preoperative EFLV, critical preoperative state, active endocarditis, recent [≤ 90 days] myocardial infarction, type of surgery, duration of surgery, duration of CPB, ischemic time, emergency operation, number of intraoperative RBC transfusions, duration of intubation) was attended. This questionnaire was formed by the researchers of this study.

For the evaluation of EuroSCORE we used data that had been included in the questionnaire of our study. EuroSCORE is a risk stratification model for predicting perioperative risk and mortality of patients undergoing cardiac surgery. It includes three wide categories of risk factors: the patient,

pp: 297-305
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the cardiac and the operation associated factors. The sum of the various risk factors results to a total score which represent the predicted probability of mortality and renged between 0 and 100% (logistic EuroSCORE) [11,12]. It is the most valid and reliable tool that has been used for predicting the perioperative risk in Europe, North America and Japan [13].

One of the researchers, the same each time, obtained the data based on both medical and nursing patient records.

Anesthetic procedures

All patients were given midazolam (0.05-0.06 mg/kg) and fentanyl (5-10 μg/kg) intravenously. In addition we gave an oxygen 100% mask until the induction of anesthesia. Anesthetic induction was achieved with a combination of thiopental (5mg/kg), propofol (1.5 mg/kg), etomidate (0.1-0.2 mg/kg) and atracurium (0.15 mg/kg) intravenously. During mechanical ventilation and anesthesia maintenance all patients were given oxygen, nitrous oxide, sevoflurane and propofol (2 mg/kg/h). Nitrous oxide was stopped before heparin was administered. In addition, we administrate additional dosing of narcotics (fentanyl 50-100 μg/kg/min) and muscle relaxants (atracurium). Apart from the loading dose of muscle relaxation, frequent preserving doses of myorelaxants (1/3 of the initial dose) were administered during the operation. Additionally sevoflurane was administered by the perfusionist along the whole cardiopulmonary bypass procedure. Eventually after extracorporeal withdrawal the anesthesiologist regain the management of sevoflurane from the perfusionist and perfuse it to the lungs.

Postoperative management

After the end of the operation, all patients were transferred to the cardiac surgery ICU and placed on a volume-cycled respirator for total ventilator support, under the administration of intravenous propofol sedation (25μg/kg/min). The patients were warmed with forced air until the surface temperature reach 36 ^{o}C. The patients were weaned off the respirator using a standard protocol, based on the following criteria [14]: 1. patient awake with stimulation, 2. chest tube drainage < 50ml/hour, 3. hemodynamic stability (cardiac index >2.2 L/min/m^2 on minimal inotropic support, systolic blood pressure at 100-140 mmHg, no arrhythmias), 3. core temperature > 35.5 ^{o}C, 4. evidence of reversal of neuromuscular blockage and 5. satisfactory oxygenation (PaO_2 >75mmHg with an $FiO_2 \leq 0.5$) and ventilation ($PaCO_2$ < 45mmHg). Then, patients were extubated when the following criteria met [14]: 1. patient awake without stimulation, 2. acceptable respiratory mechanics (negative inspiratory force > 25 cmH_2O, tidal volume > 5 ml/kg, vital capacity > 10-15 ml/kg, spontaneous respiratory rate < 24/min) and 3. acceptable arterial blood gases on T-piece (PaO_2 > 70 mmHg on $FiO_2 \leq 0.5$, $PaCO_2$ < 48 mmHg and pH = 7.32 – 7.45)

Statistical Analysis

The normality assumption for continuous variables was evaluated by both using the Kolmogorov – Smirnov criterion ($p>0.05$ for all variables) and normal probability plots. Quantitative variables are presented as means (±standard deviations - SD) whereas categorical variables are presented as absolute and relative frequencies. Quantitative variables were followed the normal distribution. Aiming to investigate the correlation between the duration of intubation and the demographic and clinical sample characteristic we used the t-test for independent samples, the Pearson's correlation coefficient (r) and the analysis of variance (ANOVA). Variables that were statistically different at p-value less than 0.25 ($p \leq 0.25$ was used only in that case) in bivariate analysis were entered into the backward stepwise multivariate linear regression analysis. All tests of statistical significance were two-tailed and p-values of less than 0.05 were considered as significant. Statistical analysis was performed using the Statistical Package for Social Sciences software (SPSS 16.0 for Windows, SPSS Inc., Chicago, IL, USA).

pp: 297-305
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Ethical approval

Permission to conduct this study was obtained by the ethical committee of the hospital. The study has been conducted in full accordance with ethical principles, including the World Medical Association Declaration of Helsinki and the International Committee of Medical Journal Editors. The methods of the study were restricted to observing and recording patient data and no part of the standard care was omitted. The investigators assured the anonymity and confidentiality of the collected data

Results

Sixty seven percent of the sample was male. The mean patient age was 64.7 (±13.7) years old, while the mean duration of intubation was 939 (±545) minutes. Most patients had either received a coronary bypass grafting (41.7%) or valve disease surgical repair (33.3%). **Table 1** provides the demographic and clinical sample characteristics.

Table 1. Demographic and clinical sample characteristics

	N (%)
Gender	
Male	32 (67)
Female	16 (33)
Age (years)*	64.7 (± 13.7)
BMI (kg/m2)*	19.1 (± 2.3)
COPD	
Yes	10 (20.8)
No	38 (79.2)
Preoperative serum Creatinine (mg/dl)*	1.1 (± 0.6)
EFLV (%)*	52.3 (± 11.7)
Type of surgery	
Coronary artery bypass grafting (Type I)	20 (41.7)
Valve surgery (Type II)	16 (33.3)
Type I + Type II	4 (8.3)
Aorta aneurysm repair or combination with valve surgery	6 (12.5)
Atrial Septal Defect	2 (4.2)
Number of RBC transfusions intraoperatively (unit)*	0.46 (± 0.71)
Duration of surgery (min)*	267.4 (± 93.4)
Duration of CPB (min)*	133.1 (± 65.6)
Ischemic time (min)*	82.8 (± 47.9)
EuroSCORE (%)*	8.3 (± 9.6)
Duration of mechanical ventilation (min)*	939 (± 545)

*

Mean (± standard deviation)

BMI: Body Mass Iindex, COPD: Chronic Obstructive Pulmonary Disease, EFLV: Ejection Fraction of Left Ventricle, RBC: Red Blood Cells, CPB: Cardio Pulmonary Bypass, EuroSCORE: European system for Cardiac Risk Evaluation

pp: 297-305
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The correlation between the duration of tracheal intubation and the main risk factors, including preoperative and intraoperative variables is depicted in **Table 2**. Age (r=0.36, p=0.001), gender (p=0.15), EFLV (r= - 0.20, p=14), duration of surgery (r=0.27, p=0.06) and CPB (r=0.32, p=0.03), ischemic time (r=0.24, p=0.09), number of intraoperative RBC tranfussions (r=0.26, p=0.08) were associated with the duration of patient intubation at the level of 25% (a=0.25) in bivariate analysis. In particular, the older age, the male subjects, the decreased EFLV and the increased duration of surgery, CPB, ischemia and number of intraoperative transfusions with RBC units were correlated with prolonged duration of tracheal intubation among cardiac surgery patients. We did not observe any significant correlation between the duration of intubation and variables such as BMI, history of COPD, preoperative serum creatinine levels, type of surgery and EuroSCORE.

Table 3 summarizes the main findings of the multivariate analysis. We found a positive correlation between the increased age and the prolonged duration of tracheal intubation (β coefficient 13.5, 95%CI 2.7-24.2, p=0.015). In particular, the increased patient age by 1 year is correlated with increased duration of patient intubation by 1.5 minutes. In addition with the above patients with increased duration of surgery had greater probability of delayed tracheal extubation in the cardiac surgery ICU (β coefficient 1.5, 95%CI 0.01-3.1, p=0.05). In particular, the increased duration of the cardiac operation by 1 minute has as a consequence delayed patient extubation by 1.5 minutes.

Table 2. Bivariate analysis between duration of mechanical ventilation and independent variables

	Duration of mechanical ventilation (min) Mean (± SD)	p-value
Gender		0.15*
Male	1020 (± 600)	
Female	776 (± 380)	
Age (years)	0.36**	0.01
BMI (kg/m2)	-0.09**	0.54
COPD		0.27*
Yes	1212 (± 909)	
No	867 (± 389)	
Preoperative serum Creatinine (mg/dl)	-0.01**	0.93
EFLV (%)	-0.20**	0.14
Type of surgery		0.5***
CABG (Type I)	978 (± 590)	
Valve surgery (Type II)	1005 (± 578)	
Type I + Type II	975 (± 261)	
Aorta aneurysm repair or combination with valve surgery	830 (± 459)	
Atrial Septal Defect	270 (± 42,4)	
Number of RBC transfusions intraoperatively (unit)	0.26**	0.08
Duration of surgery (min)	0.27**	0.06
Duration of CPB (min)	0.32**	0.03
Ischemic time (min)	0.24**	0.09
EuroSCORE (%)	0.15**	0.31

* t test

** Pearson's correlation coefficient (r)

*** analysis of variance (ANOVA)

BMI: Body Mass Iindex, COPD: Chronic Obstructive Pulmonary Disease, EFLV: Ejection Fraction of Left Ventricle, RBC: Red Blood Cells, CPB: Cardio Pulmonary Bypass, EuroSCORE: European system for Cardiac Risk Evaluation

Table 3. Linear regression analysis of the association of the main perioperative factors and prolonged duration of mechanical ventilation

	B Coefficient	S.E	95% CI	p-value
Age (years)	13.5	5.4	2,7 - 24,2	0.015
Duration of surgery (min)	1.5	0.8	0,01 - 3,1	0.05

Discussion

The main findings of our study were the statistically significant association of one preoperative (age) and one intraoperative (duration of the surgery) factor with the prolonged mechanical ventilation of the cardiac surgery patients. In particular the older age and the increased duration of the surgery were the independent predictors of the delayed tracheal extubation.

As aforementioned, the increased patient age was significantly correlated with prolonged intubation. In line with our results, Rajakura et al., [9] Cislaghi et al., [5] and Legare et al [15], investigating large series of cardiac surgery patients (7553, 5123 and 1829 patients respectively) concluded that the older age old is among the independent preoperative predictors of prolonged patient ventilation. In addition, Prapas et al., [16] conducted a study in a cardiac surgery center in Greece among 1359 of pump CABG patients and found that prolonged mechanical ventilation was strongly associated with advanced age. Finally, the correlation between the increased age and the delayed patient extubation was revealed by several other studies [6,17-19]. We could easily find o logical interpretation of this correlation based on the fact that elder patients are characterized as high risk surgical patients with prolong ICU and Hospital LOS [20-23] and increased mortality and morbidity rates [6,24]. Indeed the including of age as a risk factor in various risk stratification models, such as EuroSCORE and Parsonett Score, could, also, confirm our previous assertion.

At this point, we should mention that the significant correlation between older age and delayed patient extubation is a point of great interest, based on a steady increase in the age of either the cardiac surgical population over time [20,25] or of the general Greek population (23% of more than 60 years old) in conjunction with the restricted beds availability in Greece [26]. This combination reveals the necessity for rational healthcare resource allocation and utilization and also highlights the significance of the early prediction of high risk patients for prolonged mechanical ventilation, a clinical outcome which has been correlated with higher morbidity, mortality, increased length of hospital stay and therefore greater use of the restricted resources of the healthcare system.

Another important finding of this study was the association of the increased duration of surgery with the delayed patient extubation. In line with our results, Sato et al. [27] in a study of 484 CABG patients found that patients with a successful early extubation (within 6 hours of their ICU admission) had statistically significant shorter mean operation time (275±62 min) than those with delayed extubation time (325±83 min). In addition, Suemutsu et al., [19] concluded that the increased duration of the surgery was among the predictive risk factors for delayed extubation among 167 CABG patients. The long operation time often denote technical difficulties in executing the planned operation due to unfavorable anatomy or intraoperative complications [20], a parameter which could interpret the association between the increased duration of surgery and the delayed patient extubation.

Although the duration of the operation constituted a risk factor for prolonged ventilation in our study, we did not correlate the duration of CPB with this outcome. Contrary to the findings of our study, several studies have correlated the duration of the CPB with the prolonged

mechanical ventilation [4-6,28]. This result could be justified by the pulmonary complications and the increased morbidity rates that associated with the application of the extracorporeal circulation which inhibits the function of the lungs [29,30]. In addition, it is known that the use of CPB has been associated with a systematic inflammatory response that produces an increase in endothelial permeability and accumulation of extravascular lung water, decreases lung surfactant contributing to atelectasis and therefore has been incriminated as the major cause of postoperative pulmonary dysfunction [31,32].

Limitations

Our study allows us to reach significant conclusions regarding the preoperative and intraoperative factors that might affect the duration of the mechanical ventilation of cardiac surgery patients. In addition, is, among the few Greek studies, aiming to examine and indicate the risk factors for prolonged ventilation in this particular population. However, this study has some limitations. Firstly, the small sample size in conjunction with the fact that the study was conducted in one cardiac surgery ICU of one hospital limit the generalization of the findings to cardiac surgery patients treated in a wide range of ICUs and affect the external validity of our study. Secondly, our study did not identify postoperative variables that could be risk factors for prolonged patient ventilation aiming to examine only postoperative and intraoperative variables that could contribute to the prediction of high risk patients and the more effective allocation of healthcare resources. Nevertheless, the requirement for prolonged ventilation is greatly influenced by postoperative variables, such as the use of multiple blood products [19], the excessive mediastinal bleeding and the reoperation for bleeding [9,15,28]. Finally, another important limitation is the different cut off points for the definition of the prolonged mechanical ventilation, which limits the ability to compare the literature findings. Further research is needed to identify factors that might affect the duration of the mechanical ventilation among cardiac surgery patients.

Conclusions

The duration of the mechanical patient ventilation after cardiac surgery is a significant parameter, which influence the healthcare outcome, in terms of morbidity, mortality, resources' utilization and healthcare cost. The increased age and the prolonged duration of the surgery seem to be strongly associated with delayed tracheal extubation contributing to the early prediction of high risk patients for prolonged ventilation. Early identification could encourage the relevant authorities to efficiently allocate the limited resources available and plan the operative list, a fact of great significance for centers with restricted beds capacity. Finally, it would assist clinicians in planning measures to limit the influence of parameters associated with prolonged ventilation.

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pp: 297-305
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