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CLINICAL FACTORS ASSOCIATED WITH POSTOPERATIVE LENGTH OF TIME ON VENTILATOR AMONG CORONARY ARTERY GRAFT SURGERY PATIENTS

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Abstract:

Background: Very little is known about the optimum required length of time on ventilator after CABG surgery. Further there are inconsistencies in the practice of ventilator weaning criteria after CABG surgery. Identification of factors associated with ventilator weaning recovery may help to promote patient safety and quality care after CABG surgery.

Objectives: The purposes of this secondary analysis were to identify the factors associated with the length of time on ventilator and to determine the factors associated with the prolonged mechanical ventilator more than 8 hours.

Materials and Methods: Secondary analysis of a case control primary study data

Results: The results of this secondary analysis revealed the factors associated with the length of time on the ventilator including Age, Sex, COPD, and CHF. Among patients with a history of COPD, 29.1% remained > 8 hours on the ventilator compared to 67.7% among those without COPD (COPD: $p < 0.001$, Cramer's V = 0.25). Among patients with a history of CHF 75% remained on the ventilator > 8 hours compared to 31% among those without CHF ($p = 0.01$ and Cramer's V = 0.21).

Conclusion: These associations remained significant after adjusting for age, sex, number of grafts and body surface area. Based on the above findings, this analysis concludes that ventilator weaning outcomes should be closely monitored, while implementing weaning protocols for patients with diagnosis of COPD, and CHF co morbid conditions after CABG surgery.

Key Words: Ventilator Weaning, CABG surgery, Postoperative Ventilator Time, Clinical factors

INTRODUCTION

Clinical Indicators of Ventilator Weaning Outcomes among Postoperative Coronary Artery Graft Surgery patients

Postoperative ventilator weaning is the major task of critical carenurse following Coronary Artery bypass graft surgery (CABG). The critical care nurse plays an important role in the postoperative monitoring, hemodynamic stabilization, assessing the patient's readiness for weaning, and in preventing postoperative complications. Although, in the past, several researchers have reported that the majority of the ventilator weaning occurred at 4 to 8 hours after CABG surgery, very little is known about the optimum required length of time on ventilator after CABG surgery[3-17].

There are many clinical factors associated with the postoperative hours of ventilation. Finding the association between the clinical factors and the postoperative length of time on ventilator may help to prevent postoperative complications during weaning process. The clinical factors included in this secondary analysis include hemodynamic parameters, age, gender, and COPD, CHF, Renal Failure, number of grafts, Body Surface area as explanatory variables. The hemodynamic variables, which are Cardiopulmonary Indicators (CPI),included in this analysis are Heart Rate (HR), Mean Arterial Pressure (MAP), Central Venous Pressure (CVP), Cardiac Output (CO), Respiratory Rate (RR), Mixed Venous Oxygen Saturation (SVO_2), Oxygen Saturation (SPO_2), Pulmonary Artery Diastolic Pressure (PAD), and Pulmonary Artery Systolic Pressure (PASP). The outcome variable is postoperative length of time on ventilator. Postoperative length of time on ventilator is divided into two groups including those who required ventilation less than 8 hours and those who required ventilation more than 8 hours.

Ventilator Weaning

Ventilator weaning is an important aspect of critical care nursing for postoperative CABG surgery patients. Determination of optimum cardiopulmonary function is a prerequisite for the weaning process. Restoration and maintenance of normal cardiopulmonary function without injuring the heart and other organs represent the most important goal in the nursing care of postoperative CABG surgery patients [1]. Continuous postoperative monitoring of Cardiopulmonary Indicators (CPI) is used to prevent postoperative complications in the ICU.

Weaning is a gradual withdrawal or cessation of mechanical ventilation [2]. Weaning from mechanical ventilation is performed at the earliest possible time consistent with patient safety. Weaning is initiated when the patient is recovering from the acute stage of surgical problems and when the causes of respiratory failure are sufficiently reversed. Success in weaning the patient relies upon the individual's physiological clinical condition rather than a mechanical decision-making process. Recovery from cardiac anesthesia is an important element to consider before the initiation of the weaning process in patients after CABG surgery. Recent research findings reveal that fast track cardiac anesthesia was found effective in reducing required mechanical ventilation time after surgery, ICU length of stay, and hospital stay and cost [3-17]. Another researcher reported that fast track anesthesia enhanced early extubation after CABG surgery, prevented pulmonary complications, and expedited early rehabilitation [6].

Traditional criteria for the weaning process include optimum achievements of vital capacity, inspiratory force, respiratory rate, tidal volume, minute ventilation, and arterial blood gases [18-21]. One researcher reported that traditional weaning criteria are not useful in predicting weaning ability, but RR and tidal volume may be used as valuable predictors [3]. Another finding from a comparative study in evaluation of the value of standard and recent indices in predicting successful extubation following prolonged mechanical ventilation revealed that maximal inspiratory pressure may be used as a valuable predictor of weaning out comes [22]. Success in the prediction of weaning outcomes depends upon the assessment of the trend of the criteria rather than single measurements [23]. The weaning process has an effect on cardiopulmonary status. Weaning from mechanical ventilation may cause cardiac output changes as well as redistribution of blood flow to the respiratory muscles. A clinical prospective study revealed that there was splanchnic blood flow reduction after extubation [24]. Abnormal cardiopulmonary changes during the weaning process may be an indicator for Dysfunctional ventilator weaning response (DWVR). Findings from a study on cardiopulmonary effects of pressure support ventilation revealed a significant increase in RR and tidal volume in patients who are difficult to wean due to respiratory muscle fatigue [26].

Dysfunctional ventilator weaning response (DWVR) is a complication of prolonged mechanical ventilation which is time-sensitive event. There is no standard time limit found in the literature for DVWR. Several researchers reported that the majority of the Normal Ventilator Weaning Response (NVWR) occurred at 4 to 8 hours after CABG surgery [51, 53]. Findings from some recent studies reveal that the rate of weaning failure is higher among early weaning trials, which may indicate an association between premature weaning trials and weaning failures [2, 33, 34].

Among the comorbid conditions of cardiac surgery patients, Chronic Pulmonary Obstructive Disease (COPD) is a common pulmonary condition associated with prolonged mechanical ventilation after CABG surgery [1, 27-30]. In contrast, findings from a series of investigations of the changes in respiratory and circulatory functions in COPD patients during sequential invasive-noninvasive mechanical ventilation therapy revealed that the respiratory and circulatory functions of COPD patients remained stable during the weaning process [31, 32].

In health care practices, there is emphasis on the reduction of ICU length of stay and cost after CABG surgery. Fast track weaning protocols are found to provide cost effective care after CABG surgery. Fast track weaning protocols enhance early extubation, resulting in shorter hospital stay and decreased costs in CABG surgery. The new goal of critical care after CABG surgery is to extubate patients within 4 to 6 hours upon arrival in the ICU [35, 36].

Practice of fast track weaning protocol has reduced the required duration of mechanical ventilation after surgery and reduced ICU and hospital length of stay [34, 37-44]. Findings from one research study revealed that a fast track weaning protocol reduced the percentage of patients requiring more than one course of mechanical ventilation during the hospitalization from 33% to 26% ($p = .039$), a total cost savings of $3,440,787 and a decrease in mortality from 32% to 28% ($p = .062$) [45]. Identification of factors associated with the postoperative length of ventilator time may help to promote patient safety and quality care.

Effects of comorbidity in alteration of cardiopulmonary indicators in weaning process

Ventilator weaning process is determined by the Cardiopulmonary Indicators (CPI) stabilization. Alterations or unstable CPI may delay the weaning process resulting in prolonged mechanical ventilation after CABG surgery. Comorbidities such as COPD, CHF, and renal disease are associated with alterations of the Cardiopulmonary Indicator

(CPI), which delays the weaning process. Many researchers have reported the alterations in CPI among COPD patients. The predominant risk factors that have an association with altered cardiopulmonary function are preoperative comorbid conditions such as chronic obstructive pulmonary disease (COPD), congestive heart failure (CHF), and renal disease.

A common cause for the alteration in CPI due to COPD is autonomic neuropathy. Autonomic neuropathy is a common complication associated with COPD. Autonomic neuropathy results in hemodynamic alterations in patients with COPD; it alters the baseline hemodynamic parameters among these patients such as pulmonary artery pressures, respiratory rate, and oxygen saturation [46]. Breathing pattern alteration in a COPD patient is a common finding; it alters hemodynamic status. Particularly in mechanically ventilated patients with COPD, the pattern of lung inflation and expiratory time alteration have a significant impact on respiratory system mechanics, gas exchange, and hemodynamics [47]. Another phenomenon involving alteration in CPI among COPD patients is salt and water accumulation due to the vasodilator properties of hypercapnia. The consequent low arterial blood pressure may be the stimulus for the neurohormonal activation and retention of salt and water [48]. Findings from a clinical study revealed that significant increase in renal plasma flow, increased CVP, pulmonary artery pressures, and decreased cardiac output is associated with COPD. Another researcher reported that patients with COPD markedly increase their pulmonary artery wedge pressure on mild exercise even though they have no overt left heart disease [49].

The effect of CHF on CPI is due to the cardiopulmonary dynamics. Left ventricular failure is associated with increased pulmonary pressures and decreased cardiac output. In addition, cardiac surgery depresses the myocardial pump function [50]. Right heart failure is associated with increased right atrial pressure and impeding venous return and venous congestion alters hemodynamics [51, 52]. A compensatory mechanism of CHF also includes increased sympathetic nervous system activity due to increased angiotensin converting enzymes which results in increased heart rate [53].

The effect of renal diseases in altering CPI is reported to be associated with the adoptive mechanism. The adoptive mechanism in renal disease includes volume overload and pressure overload thatare responsible for adoptive alterations of the heart and vessels. The persistence of the adaptive mechanism leads to a detrimental process, mainly cardiac dilation, and failure and alteration in hemodynamics **[54]**. Renal disease patients exhibit various hemodynamic alterations such as hypertension, left ventricular hypertrophy, and altered cardiac output **[55]**. Renal failure also predisposes to alterations in left ventricle structure, aortic structure, and performance. Many pathogenesis related to left ventricular hypertrophy, such as high cardiac output, arerelated to renal anemia, hypertension, volume overload, and an arteriovenous fistula **[56]**. Renal anemia predisposes to alterations in CPI because it induces functional and organic alterations of cardiac-circulatory function. One clinical researcher reported that patients with severe anemia showed a tendency to an impaired cardiac index below Hb< 5-6 g/dl with no alterations in pulmonary artery pressure **[57]**. Changes in the structure of the aorta include endovascular deposition of microparticles from platelet aggregation resulting in stiffness and stenosis, which also predispose to concentric left ventricular hypertrophy, which is associated with diastolic dysfunction and alterations in CPI **[58]**.

Hemodynamic alterations among renal disease patients from chronic renal ischemia are a common pathophysiology. Another clinical study revealed evidence of chronic renal arterial ischemia producing many of the hemodynamic alterations and end-organ injury seen in patients with renal artery stenosis, including persistent hypertension, renal insufficiency, and cardiac disturbance syndromes **[59]**. Another author proposed the uric acid hypotheses as an explanation for the alterations in CPI among renal disease patients. The researcher demonstrated hyperuricemia as a cause for the alteration in blood pressure and renal damage in an experimental animal study **[60]**.

Although alterations in CPI is a factor associated with the prolonged mechanical ventilation after CABG surgery, there is very little is known about the predisposing factors for length of ventilator time after CABG surgery. Knowing the factors associated with the length of time on ventilator after CABG surgery may help to plan, provide, and evaluate quality care provided for these high risk patients.

Purpose

The purposes of this secondary data analysis include:

1. To identify the factors associated with the length of time on ventilator
2. To determine the factors associated with the prolonged mechanical ventilator more than 8 hours.

Methods

This secondary data analysis utilized a data set from a primary retrospective case control study including 299 patients, who were admitted to the ICU after undergoing coronary artery bypass surgery. The primary study population included all patients who underwent CABG surgery with inclusion criteria guided purposive sampling technique. Three hundred electronic medical records (EPF) of patients who underwent CABG surgery between May 2003 and February 2006 and who met the inclusion and exclusion criteria were selected by retrospective sequential sampling. Among the 300 subjects, 100 subjects constituted the case group and 200 subjects constituted the control group. The source of research data was the EPF system that contains the electronic medical records (MR) of all adult patients who underwent CABG surgery within the study period. The primary data collection method included a retrospective chart audit of medical records of the CABG patients through the EPF system. A list of CABG patients from January 1, 2003 to February 28, 2006 was prepared from the ICU CABG surgery logbook. The medical records of patients who met the inclusion criteria were accessed through the Electronic Patient File (EPF). The inclusion criteria were age> 18 years and patients who had undergone CABG surgery. The exclusion criteria were patients who had any one of the following treatments: intra-aortic balloon pump, pacemaker, epinephrine, nor epinephrine, dopamine, and continuous renal replacement therapy (CRRT).

Statistical analysis

All statistical procedures were performed using SPSS statistical software version 21. An alpha value of 0.05 was set to be significant. Bivariate analyses were performed to determine unadjusted associations between the independent variables and time length on ventilator. Mean time length on ventilator was compared between the dichotomous categories of each of the following determinants: Sex, history of COPD, history of HF, and history of RF, using non-parametric Mann-Whitney test. Spearman correlation was used to test the correlation between age and hours on ventilator.

In multivariable analyses, three models were examined using linear regression: 1st, the associations of anthropometric and clinical history variables with the outcome (time length on the ventilator) were examined. The independent variables included: age, gender, body surface area, Hx of HF, Hx of COPD, Hx of RF and number of grafts.

Second, the associations of clinical indicators, measured at the beginning of assisted ventilation, on the time length on ventilator were tested. CI, CO, HR, MAP, CVP, SPO, SVO, RR, PAD, and PASP1 included in the model as explanatory variables. The third model combined the two models described above. In all the regression models "hours on ventilator" was entered as a log-transformed form because it was not normally distributed. In all models stepwise elimination method was used to identify the significant variables

Next, we categorized "hours on ventilator" as > 8 hr and ≤ 8 hr. we used logistic regression to test the effect of the variables identified from the previous models on the constructed binary variable.

Results

Among patients with a history of COPD, 29.1% remained > 8 hours on the ventilator compared to 67.7% among those without COPD (COPD: $p< 0.001$, Cramer's V = 0.25). Among patients with a history of CHF 75% remained on the ventilator > 8 hours compared to 31% among those without CHF ($p = 0.01$ and Cramer's V = 0.21). These associations remained significant after adjusting for age, sex, number of grafts and body surface area. There was no association between RF and time on ventilator. In bivariate analyses: gender, Hx of COPD and Hx of HF were significantly associated with time length on the ventilator. Table 1 shows the general description on the study population.

Table 1. General description of the study population

	Men n=204 (68.2%)	Women n=95 (31.8%)
Mean age (SD)	62.2 (11.2)	63.6 (11.4)
COPD (yes)	17 (8.3%)	14 (14.9%)
CHF (yes)	8 (3.8%)	8 (8.4%)
RF (yes)	5 (2.5%)	3 (3.2%)
# of grafts (median)	3	3

COPD=chronic obstructive pulmonary disease; CHF=congestive heart failure; RH = renal failure

Table 2.Multivariate analysis Factors associated with time length on ventilator

Variable	*B*	Standardized *B*	*P*
Age (years)	0.01	0.13	.017

Sex (m=1, f=0)	-0.30	-0.16	.003
COPD (yes/no)	0.77	0.27	.000
HF (yes/no)	0.75	0.19	.001

Variables entered in the model: age, sex, chronic obstructive pulmonary disease (COPD), congestive heart failure (CHF), renal failure, number of grafts, body surface area. Independent variable: Log hours-on-ventilator

For the second model, respiratory rate (p=0.052) and cardiac output (p=0.013) were inversely associated with time length on ventilator. In the combined model, none of the clinical indicators was associated with time length on the ventilator and the model essentially gave the same results of the first model.

In the binary analysis, women and patients with history of COPD or HF were more likely to stay longer on the ventilator (i.e., more than 8 hours) after bypass operation. Table 3 shows the results of the logistic regression analysis.

Table 3. Factors associated with staying on the ventilator for more than 8 hours

Variable	*B*	OR	%95 CI
Sex (m=1, f=0)	-0.64	0.53	0.31, 0.91
COPD (yes/no)	1.59	4.91	2.16, 11.15
CHF (yes/no)	1.71	5.51	1.64, 18.56

Variables entered in the model: age, sex, chronic obstructive pulmonary disease (COPD), congestive heart failure (CHF), renal failure, number of grafts, body surface area. When initial clinical variables were entered in the model, sex became insignificant while both PASP and CVP were borderline significant (p=0.052 and p=0.058, respectively).

The interaction term (sex*COPD) was highly significant in predicting > 8 hours ventilator. When the association of COPD with > 8 hours stay on the ventilator was separately assessed in men and women, it was found that COPD was strongly associated with > 8 hours stay on the ventilator in women (OR = 15.5, 95% CI = 4.2, 56.7), while no such association was found in men (OR = 1.3, 95% CI = 0.4, 4.2). The interaction between age and COPD was not significant.

Discussion and Implications

The results of this secondary analysis revealed the factors associated with the length of time on the ventilator including Age, Sex, COPD, and CHF. In addition, analysis revealed the significant factors associated with ventilation more than 8 hours after CABG surgery including Sex, COPD, and CHF. Preoperative diagnosis of COPD and CHF were found to be significant predictors of length of time on ventilator after CABG surgery in all the analysis.

This study's results have implications for the theory, practice, education, and research involving postoperative care after CABG surgery from the perspectives of early detection of the factors associated with the delayed weaning outcomes. Patients with diagnosis of COPD and CHF have spent more than 8 hours after the surgery. This specific knowledge may be used to benefit the practice, education, research, quality improvement, and cost-effective care in postoperative critical care after CABG surgery patients with COPD and CHF.

The findings of this secondary analysis have an implication for critical care medicine in the aspects of prevention, treatment, and health promotion. Patients with the preoperative diagnosis of COPD and CHF may require additional screening and support for the post-operative ventilator weaning process, which may prevent premature weaning trials and in providing early treatment, which in turn can prevent mortality and morbidity associated with CABG surgery.

The new knowledge derived from this secondary analysis opens the new avenues for future research, such as the development of a preoperative risk assessment tool using the significant factors. The knowledge of significant predictive value of COPD and CHF for ventilator weaning outcomes after CABG surgery may be used to study the comparative preoperative risk factors. In addition, interventional studies can be conducted with preoperative teaching and treatments among above risky populations.

Based on this analysis finding, the following further research questions arise:

This analysis found that COPD and CHF have a significant predictive value for ventilator weaning outcome, which leads to questions such as:

- What are the preoperative pulmonary indicators (volumes and compliances) that exist with patients with COPD and CHF?
- What are the preoperative treatments that can maximize the lung functions to enhance normal weaning among patients with COPD and CHF?

- What are the other attributes that coexist with this disease condition that affect the weaning outcome for patients with COPD and CHF?
- What is the clinical model that can guide in the postoperative management of patients with COPD and CHF?

Conclusion

The secondary analysis was guided by two research purposes, which included: (1) to identify the factors associated with the length of time on ventilator after CABG surgery, and (2) to determine the factors associated with the prolonged mechanical ventilator more than 8 hours. The results of this analysis revealed significant factors that are associated with length of time on the ventilator after CABG surgery, which include age, sex, COPD, and CHF. Gender, COPD, and CHF were associated with the prolonged ventilation more than 8 hours after CABG surgery. Among the findings, preoperative diagnosis of COPD and CHF is directly associated with the ventilator length of time after CABG surgery. Based on the above findings, this analysis concludes that ventilator weaning outcomes should be closely monitored, while implementing weaning process and protocols for patients with diagnosis of COPD, and CHF co morbid conditions after CABG surgery.

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