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RESEARCH ARTICLE

A CASE CONTROL STUDY ON PREDICTION MODELING OF DYSFUNCTIONAL VENTILATOR WEANING RESPONSE AMONG POSTOPERATIVE CABG PATIENTS

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ABSTRACT

Background: Although the majority of coronary artery bypass graft (CABG) surgery patients are extubated within 6 to 8 hours following surgery, 20% to 40% of patients remain intubated 12 hours after surgery due to dysfunctional ventilator weaning response (DVWR). DVWR associated with increased morbidity and mortality (30% to 43%) following CABG surgery. There is little known about the prediction of DVWR.
Objective: purposes of this research study were to describe the characteristics of Cardio Pulmonary Indicators (CPI) among patients with normal ventilator weaning response (NVWR) and dysfunctional ventilator weaning response (DVWR) after coronary artery bypass graft (CABG) surgery, to find the differences in characteristics of cardiopulmonary indicators between patients with NVWR and DVWR after CABG surgery, and to build a prediction model for DVWR with significant antecedence.
Methods: This study utilized a retrospective case control study with time series design. A purposive sampling technique was used to recruit 300 subjects from a retrospective audit of electronic medical records of patients who underwent CABG surgery between May 2003 and February 2006. Among the 300 subjects, 100 subjects constituted the case group and 200 constituted the control group. Data analysis included descriptive and inferential statistics using SAS programs.
Results: Findings revealed that several antecedence including COPD (OR 5.46), CHF (OR3.93), decrease in 10mm/Hg MAP (OR 1.91) , decrease in 5 points of RR (OR 2.97), decrease in 2 points mean of CO (OR 1.94), increase in 5mm/Hg of PAD (OR 3.64), and decrease of 10mm/Hg in PASP (OR3.05) were significantly associated with DVWR.
Conclusions: In this study, COPD, CHF, MAP, RR, CO, PAD, and PASP are found as significant predictors for DVWR after CABG surgery. The implication of these findings includes using these predictors in ventilator weaning protocols after CABG surgery may prevent DVWR.
Therefore, this study recommends that ventilator weaning criteria be developed considering the significant predictors for postoperative CBAG patients.

INTRODUCTION

Cardiopulmonary Predicators of Dysfunctional Ventilator Weaning Response after Coronary Artery Bypass Graft

Coronary artery bypass graft (CABG) surgery is one of the most common classes of surgical procedures performed worldwide. Branca *et al.* (2001) reported that in the United States, more than 500,000 CABG procedures are performed every year (Branca *et al*., 2001). Recovery and stabilization of cardiopulmonary function is the major task of postoperative intensive care following surgery. The most important component of the postoperative intensive care services after CABG surgery includes weaning from mechanical ventilation and hemodynamic stabilization. Advances in fast track weaning protocols have decreased the required duration of postoperative mechanical ventilation after CABG surgery from a few days to a few hours (Brucek *et al.*, 2003; Capdeville *et al*., 2001; Nichols *et al*., 2002; Sulzer *et al*., 2001). Findings from recent studies reveal that the time limits of normal ventilator weaning response (NVWR) after CABG surgery vary from one to ten hours (Branca *et al.*, 2001; Alexander and Cooper 1996; Bezanson *et al.*, 2004; Doering *et al*., 2000; Guller *et al*., 2004; Tokmakoglu *et al*., 2003; Modine *et al*., 2005; Bezanson *et al*., 2001; Habib *et al*., 1996; Legare *et al*., 2001; Nickerson *et al*., 1999; Plumer *et al*.,1998; Serrano *et al*., 2005; Spivack *et al*., 1996; Doering *et al*., 1998; Yende and Wunderink 2002; Ferguson *et al*., 2001; Insler *et al*., 2000; Anderson *et al*., 1999; Leon-Valles *et al*., 1996). Most patients are extubated within 6 to 8 hours after surgery. However, 20% to 40% of patients remain intubated 12 hours after surgery due to dysfunctional ventilator weaning response (Branca *et al*., 2001; Alexander and Cooper 1996; Bezanson *et al*., 2004; Doering *et al*., 2000; Guller *et al*., 2004; Tokmakoglu *et al*., 2003; Modine *et al*., 2005; Bezanson *et al*., 2001; Habib *et al*., 1996; Legare *et al*., 2001; Nickerson *et al*., 1999; Plumer *et al*.,1998; Serrano *et al*., 2005; Spivack *et al*., 1996; Doering *et al*., 1998; Yende and Wunderink 2002; Ferguson *et al*., 2001; Insler *et al*., 2000; Anderson *et al*., 1999; Leon-Valles *et al*., 1996). Dysfunctional ventilator weaning response is a major problem among postoperative CABG patients because it is associated with increased morbidity and mortality following CABG surgery (Brucek *et al*., 2003; Nickerson *et al*., 1999; Ferguson *et al*., 2001; Currey and Botti 2003; Nakai *et al*., 1995; Westaby *et al*., 1993). The mortality related to DVWR is reported as 30% to 43% (Yende and Wunderink 2002). It results from many complications of DVWR such as acute respiratory distress syndrome, 10% to 15% (Yende and Wunderink 2002); multiorgan dysfunction syndrome, 15% to 19% (Yende and Wunderink 2002); deep vein thrombosis, 10% to 12% (Kollef *et al*., 1995; Kollef *et al*., 1998; Kollef and Silver 1995) and ventilator-associated pneumonia, 30% to 50% (Vijay and McCusker 2003; Vijay and Gold 2003). Other health care problems resulting from DVWR are increased ICU length of stay and cost (Doering *et al*., 2000; Nickerson *et al*., 1999; Suematsu *et al*., 2000;

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Bardell *et al*., 2003). Early detection of DVWR is imperative to prevent postoperative complications and premature weaning after CABG surgery. Finding reliable predictive factors could help in the early detection of DVWR and might guide in planning early treatment for DVWR, and may aid in preventing complications and premature weaning after CABG surgery.

Many nomenclatures are used to denote DVWR, such as dysfunctional weaning, early extubation failure, DVWR, and prolonged mechanical ventilation (PMV). Many studies have defined this term operationally as the condition in which the patient is unable to be weaned from the ventilator and remains intubated and on mechanical ventilation >8 hours after surgery (Branca *et al*., 2001; Alexander and Cooper 1996; Bezanson *et al*., 2004; Doering *et al*., 2000; Guller *et al*., 2004; Tokmakoglu *et al*., 2003; Modine *et al*., 2005; Bezanson *et al*., 2001; Habib *et al*., 1996; Legare *et al*., 2001; Nickerson *et al*., 1999; Plumer *et al*.,1998; Serrano *et al*., 2005; Spivack *et al*., 1996; Doering *et al*., 1998; Yende and Wunderink 2002; Ferguson *et al*., 2001; Insler *et al*., 2000; Anderson *et al*., 1999; Leon-Valles *et al*., 1996). Based on the review of literature, this study operationally defines DVWR as the condition in which patients remain on the ventilator > 8 hours after surgery. In addition, the term normal ventilator weaning response (NVWR) is operationally defined as the condition in which the patient is extubated and placed on either a binasal cannula or aerosol facemask oxygen within 8 hours after surgery.

Cardiopulmonary Indicators in Prediction of Dysfunctional Ventilator Weaning Response

Clinically, hemodynamic stabilization is monitored through CPI. The selected CPI to predict DVWR in this research study include heart rate (HR), mean arterial blood pressure (MAP), central venous pressure (CVP), cardiac output (CO), respiratory rate (RR), mixed venous oxygen (SVO2), oxygen saturation pulmonary artery diastolic pressure (PAD), and pulmonary artery systolic pressure (PASP). In the weaning process, hemodynamic stability is a required criterion. Although hemodynamic stability is the prerequisite for initiating the weaning process, there is little known about its association with DVWR. Changes in CPI can be readily identified through hemodynamic trends. Cardiopulmonary indicators are sensitive clinical variables, which may be helpful to foresee DVWR. Therefore, this research study is conducted to determine the predictive values of CPI with regard to DVWR among postoperative CABG patients. There is reported evidence of an association between some CPI and weaning outcomes such as NVWR and DVWR (Kollef *et al*., 1998; Albage *et al*., 2001; Boldt and Hempelmann 1991; Cote *et al* 1991; Weiskopf *et al*., 1998; Wolfel *et al*.,1998). Frazier, *et al*. (2001) reported that hemodynamic instability during weaning from mechanical ventilation is one proposed cause of weaning failure (Frazier *et al*., 2001). Jubran, *et al*. (1998) reported a direct association between SPO2 level above 92% and NVWR (Jubran *et al*., 1998). Findings from some research reveal that the increase in MPASP and the change in CO during the weaning process are associated with weaning failure (Cason *et al*., 1994).

A progressive decrease in SVO2 during the weaning process is reportedly associated with weaning failure (Kirkeby-Garstad *et al*., 2000; Kirkeby-Garstad *et al*., 2005). Increased respiratory rate during the weaning process is also associated with weaning failure (Yende and Wunderink 2002; Vijay and Gold 2003). Doering, *et al*. (2001) reported that early hemodynamic instability and presence of arrhythmias are associated with weaning failure and postoperative mortality (Doering *et al*., 2001). Estenssoro, *et al*. (2005) reported that clinical conditions such as low cardiac output, increased heart rate, apprehension, deterioration of blood gas values, and slight respiratory accessory muscle use had the highest association with DVWR (Estenssoro *et al*., 2005). Ely, *et al*. (1996) reported that increases in RR, HR, and MAP are associated with DVWR (Ely EW *et al*.,1996; Ely EW *et al*., 2001). Alteration in cardiac index during weaning has been found to have association with weaning failure (Nickerson *et al*., 1999; Doering *et al*., 2001; Paulissian *et al*., 1991; Hudson *et al*., 2002).

Although many researchers have reported the association between CPI and weaning outcomes, there is no reported research using selected CPI for the prediction of DVWR. Using CPI to predict DVWR has many advantages, such as being sensitive indicators, reliable in detecting the complications beyond the associated comorbidity, helpful in early diagnosis, and feasible to implement in practice by the nurses in detecting DVWR and preventing premature trials. Cardiopulmonary indicators are sensitive indicators in identifying complications among cardiac surgery patients (Baraka *et al*., 2002; Reich *et al*., 2002; Lieberman *et al*., 1983; Hibbard *et al*., 1992). Some researchers have reported that the trends of hemodynamic variables for 4 hours following ICU admission after CABG surgery are sensitive indicators of prognosis (Poeze *et al*.,1999). In addition, CPI are reliable in detecting complications after heart surgery irrespective of comorbid factors associated with outcomes (David *et al*., 1998). Furthermore, some researchers have reported that cardiopulmonary indicators are helpful in rapid diagnosis of postoperative complications among heart surgery patients (Givertz *et al*., 1996; Gavazzi*et al*., 2003). Other research findings reveal that changes in CPI are reliable indicators of postoperative adverse events (Reich *et al*., 2002).

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 (Currey and Botti 2003). Continuous postoperative CPI monitoring to prevent postoperative complications in the ICU is a known practice. The critical care nurse plays an important role in the prevention of postoperative complications through CPI monitoring. The primary functions of the critical care nurse during the postoperative period are CPI monitoring, hemodynamic stabilization, and assessing weaning readiness of the patient. Thus, the critical care nurse plays an important role in predicting DVWR through CPI. Although the fast track weaning protocols driving early extubation have economic implications, it is imperative to consider that there are a considerable number of postoperative CABG patients at risk of developing DVWR.

Weaning from mechanical ventilation involves a significant amount of stress to physiological systems and increased risk of postoperative silent myocardial ischemia. Calzia, *et al*. (2001) reported evidence of increased plasma levels of epinephrine, nor epinephrine, cortisol, vasopressin, and prolactin during the weaning process, all of which are the indicators of stress (Calzia *et al*., 2001). Some researchers reported that the weaning process has a high risk for silent myocardial ischemia among the cardiac risk population during the non-cardiac surgery postoperative period (Abalos *et al*., 1992).Significance of the Study Prediction of DVWR is important because it may help to guide early identification of persons at risk for and in need of treatment to prevent DVWR. Prediction of DVWR also can help to prevent complications related to premature weaning trials after surgery on vulnerable patient populations.

A review of literature reveals that there is a need for studies focusing on finding the predictive factors for DVWR. Many researchers have cited the need for studies to improve the criteria to predict early extubation and DVWR (Ely *et al*., 1996; Meade *et al*., 2001; Schonhofer, 2000; Suematsu *et al*., 2001; Rady and Ryan 1999). Some researchers have examined the associated risk factors, readiness, feasibility, and effectiveness of early extubation (Branca *et al*., 2001; Alexander and Cooper 1996; Bezanson *et al*., 2004; Doering *et al*., 2000; Guller *et al*., 2004; Tokmakoglu *et al*., 2003; Modine *et al*., 2005; Bezanson *et al*., 2001; Habib *et al*., 1996; Legare *et al*., 2001; Nickerson *et al*., 1999; Plumer *et al*.,1998; Serrano *et al*., 2005; Spivack *et al*., 1996; Doering *et al*., 1998; Yende and Wunderink 2002; Ferguson *et al*., 2001; Insler *et al*., 2000; Anderson *et al*., 1999;

Leon-Valles *et al*., 1996). Other researchers have focused on identifying the associated factors and complications of early extubation failure (Brucek *et al*., 2003; Rady and Ryan 1999; Epstein and Ciubotaru 1998; Epstein and Ciubotaru 1996; Epstein, 1995 Epstein, 2004; Rothaar and Epstein 2003). Although many researchers have attempted to identify the predictive factors for early extubation failure and prolonged mechanical ventilation (PMV), which is the outcome of DVWR, no single proven predictor is reported to be valid to predict DVWR (Suematsu *et al*., 2000; Meade *et al*., 2001; Afessa *et al*.,1999; Rothenburger *et al*., 2001).

Although DVWR among postoperative CABG surgery patients is a critical problem associated with many postoperative complications such as PMV, increased ICU mortality, increased ICU length of stay, and increased ICU cost, very little has been done to predict the DVWR in this patient population. Previous researchers have used traditional respiratory parameters such as tidal volume, respiratory rate, and spontaneous minute ventilation to predict the weaning outcomes (Serrano *et al*., 2005; Yende and Wunderink 2002). The findings of many research studies reveal that traditional respiratory parameters have poor predictive value in the weaning outcomes (Serrano *et al*., 2005; Yende and Wunderink 2002). Some researchers have reported that hemodynamic variables can be used to predict the weaning outcomes (Keinanen *et al*., 1992; Poelaert *et al*., 2004; Kruger *et al*., 1996). However, the prediction of DVWR using CPI is unexplored. In past decades, research studies have focused on examining various weaning protocols and found that a fast track weaning protocol can be effectively and safely implemented among postoperative CABG patients (Doering *et al*., 2000; Nickerson *et al*., 1999; Suematsu *et al*., 2000; Bardell *et al*., 2003). Despite implementing fast track weaning protocols, there is a gap in the practice of weaning postoperative cardiac surgery patients, which is evidenced by the findings from many studies (Currey and Botti 2003; Epstein, 2002). Some researchers have reported that 40% of ICU time is devoted in the weaning process, and 50% of self-extubated patients do not require re-intubation (Bezanson *et al*., 2001; Bezanson *et al*., 2002). Many research findings reveal that traditional respiratory parameters such as tidal volume, respiratory rate, and spontaneous minute ventilation have poor predictive value for DVWR and PMV.

In the weaning process, hemodynamic stability is a required criterion. Although the hemodynamic stability is the prerequisite for the initiation of the weaning process, little is known about its association with DVWR. Cardiopulmonary indicators (CPI) are the clinical hemodynamic variables monitored through invasive and non-invasive monitoring techniques in the ICU. The selected CPI to examine the predictive value in this study were heart rate (HR), mean arterial pressure (MAP), central venous pressure (CVP), cardiac output (CO), respiratory rate (RR), mixed venous oxygen saturation (SVO2), oxygen saturation (SPO2), pulmonary artery diastolic pressure (PAD), and pulmonary artery systolic pressure (PASP). Changes in CPI precede the dysfunctional ventilator weaning response. They can be readily identified through hemodynamic trends by the bedside clinician. In addition, CPI is a sensitive and reliable clinical variable, which may be helpful to foresee the DVWR. Therefore, this research study was conducted to determine the values of CPI in predicting DVWR among postoperative CABG patients.

Purposes of the Study

The purposes of this research study were the following

1. Describe the characteristics of CPI among patients with normal ventilator weaning response (NVWR) and dysfunctional ventilator weaning response (DVWR) after CABG surgery.
2. Find the differences in characteristics of cardiopulmonary indicators between patients with normal ventilator weaning response (NVWR) and dysfunctional ventilator weaning response (DVWR) after CABG surgery.
3. Build a prediction model for dysfunctional ventilator weaning response (DVWR) with significant antecedence.

Research Questions

This research study was guided by the following research questions in patients after coronary artery bypass graft surgery:

1. What are the characteristics of cardiopulmonary indicators in patients with dysfunctional ventilator weaning response (DVWR) and normal ventilator weaning response (NVWR)?
2. What are the differences in the characteristics of cardiopulmonary indicators in patients with dysfunctional ventilator weaning response (DVWR) and normal ventilator weaning response (NVWR)?
3. What is the best predictive model for dysfunctional ventilator weaning response (DVWR)?

METHOD

Research Design

This research study utilized a retrospective case control study with time series design. A hallmark of the case control study is that it begins with people with the disease (cases) and compares them to people without the disease (controls). The cases (DVWR) in this study are defined as patients who remained on a mechanical ventilator > 8 hours after CABG surgery (Branca *et al*., 2001; Alexander and Cooper 1996; Bezanson *et al*., 2004; Doering *et al*., 2000; Guller *et al*., 2004; Tokmakoglu *et al*., 2003; Modine *et al*., 2005; Bezanson *et al*., 2001; Habib *et al*., 1996; Legare *et al*., 2001; Nickerson *et al*., 1999; Plumer *et al*.,1998; Serrano *et al*., 2005; Spivack *et al*., 1996; Doering *et al*., 1998; Yende and Wunderink 2002; Ferguson *et al*., 2001; Insler *et al*., 2000; Anderson *et al*., 1999; Leon-Valles *et al*., 1996). The controls (NVWR) in this study were defined as patients who were extubated within 8 hours after CABG surgery (Branca *et al*., 2001; Alexander and Cooper 1996; Bezanson *et al*., 2004; Doering *et al*., 2000; Guller *et al*., 2004; Tokmakoglu *et al*., 2003; Modine *et al*., 2005; Bezanson *et al*., 2001; Habib *et al*., 1996; Legare *et al*., 2001; Nickerson *et al*., 1999; Plumer *et al*.,1998; Serrano *et al*., 2005; Spivack *et al*., 1996; Doering *et al*., 1998; Yende and Wunderink 2002; Ferguson *et al*., 2001; Insler *et al*., 2000; Anderson *et al*., 1999; Leon-Valles *et al*., 1996).

The differences between cases and controls were established in this study by the comparison of CPI measurements between cases and controls on an hourly basis during the postoperative period. The selected CPI data collected hourly in a time series design for 12 hours postoperatively in both cases and controls were compared to demonstrate the significant differences. This study design was selected to find the predictive value of CPI for DVWR after CABG surgery. The independent variable of this study was CPI. The selected CPI to predict DVWR in this research study included heart rate (HR), mean arterial blood pressure (MAP), central venous pressure (CVP), cardiac output (CO), respiratory rate (RR), mixed venous oxygen (SVO2), oxygen saturation pulmonary artery diastolic pressure (PAD), and pulmonary artery systolic pressure (PASP). The dependent variable of the study was DVWR, which is operationally defined as the condition in which the patient failed to wean from mechanical ventilation 8 hours after surgery (Serrano 2005; Yende and Wunderink 2002; Gimenez *et al*., 1997; Gimenez *et al*., 2003).

Setting

The study was conducted at a suburban, 500-bed private for profit Mid-South hospital, with a 40-bed adult ICU. The hospital performs approximately 1 to 3 CABG surgeries daily. In addition, this hospital has a fast track weaning protocol that is implemented after all CABG surgeries. Furthermore, the hospital has an electronic patient file system with electronic documentation and storage of hemodynamic data and patient data for later retrieval.

Selection of Sample

The 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 researcher collected CPI for 12 consecutive hours during postoperative periods, and utilized all 12 hours CPI in descriptive statistics for description of the study sample. Further, the researcher utilized only the first 8 hours data for inferential statistics in accordance with the definition of DVWR.

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 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). Selection of cases and controls: Cases and controls were selected with operational definitions from the EPF medical records of patients who had undergone CABG surgery. Cases were defined as patients who remained on mechanical ventilator more than 8 hours after CABG surgery (Branca *et al*., 2001; Alexander and Cooper 1996; Bezanson *et al*., 2004; Doering *et al*., 2000; Guller *et al*., 2004; Tokmakoglu *et al*., 2003; Modine *et al*., 2005; Bezanson *et al*., 2001; Habib *et al*., 1996; Legare *et al*., 2001; Nickerson *et al*., 1999; Plumer *et al*.,1998; Serrano *et al*., 2005; Spivack *et al*., 1996; Doering *et al*., 1998; Yende and Wunderink 2002; Ferguson *et al*., 2001; Insler *et al*., 2000; Anderson *et al*., 1999; Leon-Valles *et al*., 1996). Controls were defined as patients who were extubated within 8 hours after the CABG surgery (Branca *et al*., 2001; Alexander and Cooper 1996; Bezanson *et al*., 2004; Doering *et al*., 2000; Guller *et al*., 2004; Tokmakoglu *et al*., 2003; Modine *et al*., 2005; Bezanson *et al*., 2001; Habib *et al*., 1996; Legare *et al*., 2001; Nickerson *et al*., 1999; Plumer *et al*.,1998; Serrano *et al*., 2005; Spivack *et al*., 1996; Doering *et al*., 1998; Yende and Wunderink 2002; Ferguson *et al*., 2001; Insler *et al*., 2000; Anderson *et al*., 1999; Leon-Valles *et al*., 1996). Cases and controls were selected from the same hospital. Sample size and sampling technique: The sample size requirement for fitting a multiple regression analysis was 5 to 10 observations for each potential predicting variable. Accordingly, the sample size of the cases was 100. In case control studies, the proportion of the study population that consists of cases is determined by the ratio of controls per case, typically ranging from 1 to 4 controls per case. This study utilized the 1: 2 ratios of cases and controls. Thus, this study consisted of 100 cases and 200 controls.

Instrument and Measurements

This case control study utilized the medical records of those patients who had CABG surgery in a Mid-South hospital from 2003 to 2006. Data were abstracted from the EPF medical records system to an Excel spreadsheet on the researcher's personal computer. The EPF system is an electronic recording and storage of the vital parameters measured by various sensors, which are transmitted to a medical service provider via mobile communication. The data was stored in a database through the automatic electronic charting interface from the Spacelab PC I 90303B bedside cardiac monitor to the patient's personal computer, which stored it in an electronic patient file (EPF). The file contained all medical documentation. Authorized clinics and physicians can access this file to support diagnosis and therapy. The CPI measurements involved hemodynamic monitoring devices such as a Spacelabs cardiac monitor, Edwards Life sciences cardiac output SVO2 monitor, 7.5 FR pulmonary artery catheters, Servo I mechanical ventilator, and Massimo TM pulse ox sensor. The reliability and quality control tests were performed for the Spacelabs cardiac monitor, Servo I ventilator and Edwards Life sciences cardiac output monitor by the biomedical department of the hospital. The reliability of the SVO2 monitor was evaluated and maintained periodically through performance check procedures by the biomedical department of the hospital. Sensitivity of Spacelabs cardiac monitors were estimated as 92%. The positive predictive value of Spacelabs cardiac monitors were estimated as 97%. The estimated reliability of the oxymetry values for the Massimo SET oxymetry was 95%.

Sources of Data

The types of data obtained from the EPF system were demographic, clinical, and CPI measurements. The demographic data includes age and sex, which were retrieved from the history and physical pages of the EPF. The clinical data included COPD, CHF, renal disease and redo surgery, which were retrieved from the history and physical pages of the EPF. Extubation time was derived from the respiratory flow sheet and nursing assessment pages of the EPF. The CPI data were HR, MAP, CVP, CO, RR, SVO2, SPO2, PAD and PASP, which were recorded from the nursing assessment and vital signs confirmation page of the EPF.

Procedure

The researcher obtained approval for the research study from the University of Tennessee Health Science Center (UTHSC) IRB and the Mid-South hospital IRB. After IRB approval, the researcher obtained a security pin from the hospital administration to access the 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).

Data Analysis

Statistical analysis was performed using a SAS statistical analysis software program. Descriptive statistics were performed on all variables, including demographic and comorbid data. All the statistical significance tests were performed as two-tailed tests. A p-value of < 0.05 was considered significant. Descriptive statistics were derived from a univariate procedure. To compare the means and find the differences in the means between the groups, t-statistics were performed for continuous data, and Chi-square tests were used to compare the difference in proportions of categorical data. A multiple group comparison was performed by repeated measure ANOVA PROC MIXED. To estimate the correlation coefficience for a linear regression model, GLM procedure and REG procedures were performed. To build the prediction model, multiple logistic regressions through LOGISTIC procedure were used.

RESULTS

The study sample consisted of subjects who ranged in age from 33 years to 91 years. The mean age of the subjects in the case group was 64.28 ± 11.45 years. The mean age of the subjects in the control group was 61.8 ± 11.05 years. The majority of the study sample consisted of 204 male subjects (68.23%); the number of female patients was 95 (31.77%). The case group consisted of 58 (58.59%) males, and the control group consisted of 146 (73%) males. Comorbid conditions that were included in this study were COPD, CHF, and renal disease. The total number of subjects who had comorbid conditions was 55 (18.39%). The subjects who had COPD constituted the majority at 31 (10.37%); the number of CHF subjects was 16 (5.35%), and the number of renal failures was 8 (2.68%). Number of grafts: The number of grafts ranged from 1 to 6. The number of subjects who had one graft in cases was 6 (6.06%), and in controls 7 (3.52%). The number of subjects who had two grafts in cases was 13 (13.13%), and in controls

38 (38.38%). The number of subjects who had three grafts in cases was 38 (38.38%), and in controls 75 (37.69%). The number of subjects who had four grafts in cases was 30 (30.30%) and in controls 53 (26.63%). The number of subjects who had five grafts in cases was 10 (10.10%), and in controls 20 (10.05%). The number of subjects who had 6 grafts in cases was 2 (2.02%) and in controls 6 (3.02%). In this study, the majority of the subjects had three grafts (38% in cases and controls). The total number of hours in ventilation: The range of the total ventilator hours in cases was 8.30 to 349 hours and in controls 1.35 to 8 hours. The average hours in ventilation in the control group was 4.51 ± 1.58 hours. Body surface area: Body surface area (BSA) was estimated from the CO and CI values, as this data was not available. Although BSA was calibrated in the SVO2 monitor, it was not recorded in the nursing notes. Mean BSA in the case group was 1.96, with a standard deviation of 0.249. Mean BSA in the control group was 2.028, with a standard deviation of 0.245.

Post-operative ventilator settings and medications: The ventilator setting was common for all the patients during the weaning process. The setting was SIMV mode ventilation with FIO2 40%, pressure support of 10 cm of H2O, PEEP of 5 cm of H2O. The use of sedation was common for all patients in the study sample. The choice of sedation was precedex continuous infusion and morphine whenever necessary. The postoperative use of dobutamine to titrate for cardiac index of 2 liters was common for all the subjects. The vasodilator nipride was used as the PRN drug of choice to treat hypertension in all the subjects. The cardiac monitors, monitoring techniques, and weaning protocol were common for both case and control groups.

Cardiopulmonary Indicators

After coronary artery bypass surgery, the first research question of this research study was: What are the characteristics of cardiopulmonary indicators in patients with dysfunctional ventilator weaning response and normal ventilator weaning response? Cardiopulmonary indicators values were analyzed by a univariate procedure. From this procedure the mean and standard deviation for each individual variable was generated. The hourly means of the CPI were plotted in line graphs for both cases and controls to depict and describe the trend of the variables.

Heart rate: The average heart rate during the first 8 postoperative hours for cases was 94.67 per minute and for controls was 93.64 per minute. The mean HR ranged from 93.01 to 96.73 in cases and from 90.84 to 95.01 in controls. The mean heart rate trend showed that the heart rate was higher in cases during the first 3 hours. An upward trend was noted in both cases and controls during the first 3 hours. In addition, a downward trend occurred in mean heart rate during fifth, sixth, seventh and eighth hours among cases, while there was a plateau in controls. Mean arterial pressure: The average MAP during the first 8 postoperative hours for cases were 78.28 mm/Hg and for controls 79.59 mm/Hg. The trend of mean MAP showed that there was a downward trend in MAP from first hour to sixth hour in both case and control groups, MAP stabilized at seventh and eighth hour. Overall, MAP in the control group was higher than in the case group.

Central venous pressure: The average CVP during the first 8 postoperative hours for cases was 10.75cm/H2O and for controls 10.32 cm/ H2O. The trend of CVP showed that CVP in cases was lower in first hour than CVP in controls. However, CVP in cases showed an upward trend from second hour. The overall trend showed that CVP in cases was higher than in controls from second to eighth hour.

Respiratory rate: Average RR during the first 8 postoperative hours for cases was 14.47 per minute and for controls 16.96 per minute. The trend of RR showed that there was an upward trend from the first hour to the eighth hour in both cases and controls. The overall respiratory rate was higher in controls than cases.

Oxygen saturation: The average SPO2 during the first 8 postoperative hours for cases was 98.29% and 98% for controls. The trend showed that the SPO2 of the cases was higher than controls for the first 3 hours, but there was a downward trend in cases from fourth hour. The trend of SPO2 in controls showed stability for first 3 hours and a downward trend at fourth hour, followed by a stable SPO2 for the next 4 hours. Overall, the SPO2 showed a downward trend at the fourth hour in both cases and controls. Although the SPO2 of cases was higher than controls, the SPO2 of controls showed a more stable trend than the cases.

Pulmonary artery pressures: PAD of controls decreased during the third, fourth, fifth, and sixth hours, followed by a plateau at the seventh and eighth hours. Average PASP during first 8 postoperative hours for cases were 29.2 mm/Hg and for controls 28 mm/Hg. Hourly mean and standard deviation of PASP revealed that PASP in patients with DVWR (cases) was higher than in patients with NVWR (control) for the first 3 hours. There was a gradual increase in PASP in patients with NVWR from the fourth hour, and it remained higher than in the cases from the fourth to the eighth hours.

Mixed venous oxygen saturation: The average SVO2 during first 8 postoperative hours for cases was 69% and for controls 68%. The mean of SVO2 ranged from 68% to 69.63% in cases and from 67.81% to 69.00% in controls. The mean SVO2 in cases was higher than in controls. There was a downward trend in the first 3 hours in cases, followed by an upward trend during the fourth, fifth, and sixth hours and a decline in the seventh hour, followed by an upward trend in the eighth hour. In controls, there was a downward trend during the first 2 hours and an upward trend during the third and fourth hour, followed by a downward trend during the fifth and sixth hours and a plateau during the seventh and eighth hours.

Differences in the Characteristics of Cardiopulmonary Indicators

- The second research question of this research study was: In patients after coronary artery bypass surgery, what are the differences in the characteristics of cardiopulmonary indicators in patients with dysfunctional ventilator weaning response and normal ventilator weaning response?
- To answer the above research question, the researcher found the differences in the characteristics of CPI between DVWR (cases) and NVWR (controls) by performing an unpaired t-test. The differences in the mean heart rate were established by performing an unpaired t-test comparing the hourly mean of heart rate in cases and controls. The result revealed that there were no significant differences in the hourly mean heart rate between cases and controls except at the first hour ($p = 0.05$).
- Differences in the mean MAP were established by performing an unpaired t-test comparing the hourly mean of MAP in case and control groups. The results revealed no significant differences in the hourly mean MAP between cases and controls except at the fifth hour ($p = 0.01$).
- The differences in the mean CVP were established by performing an unpaired t-test comparing the hourly mean of the CVP in cases and controls. The result revealed that there were no significant differences between cases and controls in the hourly mean CVP of first, second, fourth, fifth, and sixth hours. However, there was a significant difference between cases and controls in the mean CVP at the third hour ($p = 0.05$), the seventh hour ($p = 0.004$), and the eighth hour ($p = 0.01$).
- The differences in the mean RR were established by performing an unpaired t-test comparing the hourly mean of RR in cases and controls. The result revealed no significant difference in the mean RR between cases and controls at the first hour. However, there was a significant difference between cases and controls in mean RR at all the times. Differences in the mean SPO2 were established by performing an unpaired t-test comparing the hourly means of SPO2 in cases and

controls. The result revealed no significant difference in the hourly mean of SPO2 between cases and controls except in the fourth, fifth, and sixth hour. The differences in the mean CO were established by performing an unpaired t-test comparing the hourly mean of CO in cases and controls. The result revealed that there was significant difference in the hourly mean of CO between cases and controls. The differences in the mean CI were established by performing an unpaired t-test comparing the hourly mean of CI in cases and controls. The result revealed significant difference in the hourly mean of CI between cases and controls in the first, fifth, sixth, and eighth hour.

- The differences in the mean PAD were established by performing an unpaired t-test comparing the hourly mean of PAD in cases and controls. The result revealed that there was significant difference in the hourly mean of PAD between cases and controls in all the hours except the first and eighth hour. The differences in the mean PASP were established by performing an unpaired t-test comparing the hourly mean of PASP in cases and controls. The result revealed no significant difference between cases and controls in the hourly mean of PASP.
- The differences in the mean SVO2 were established by performing an unpaired t-test comparing the hourly means of SVO2 in cases and controls. The result revealed no significant difference between cases and controls in the hourly mean of SvO2.
- In summary, all the cardiopulmonary indicators showed significant differences between cases and controls except pulmonary artery systolic pressure. The earliest differences were noted as early as first hour in heart rate, cardiac output, cardiac index, and pulmonary artery diastolic pressure. The CPI that showed consistent differences included CVP, RR, CO, CI, and PAD.

Prediction Model

The third research question of this research study was: What is the best predictive model for DVWR after CABG surgery? To build the prediction model, a multiple logistic regression analysis was performed using a logistic procedure with stepwise selection method. The first consideration in this procedure was multicollinearity. Multicollinearity can be a problem in logistic regression models because of strong correlations between independent variables, which can inflate the variances of the parameter estimates. Therefore, it is imperative to control this problem. In order to identify the multicollinearity of the CPI, a diagnostic procedure was performed by a linear regression analysis through REG procedure with option VIF TOL in SAS. Through this procedure, tolerance and inflation factors were examined for each explanatory variable. First, the Pearson correlation coefficient matrix of the CPI was generated through the REG procedure. The Pearson correlation coefficient matrix showing CPI that had significant effect on DVWR. The correlation matrix revealed that there were significant correlations between CO, PAD, PASP, and MAP. MAP had significant correlations with CO and PASP. RR was significantly correlated with CO and PASP. CO had significant correlation with MAP and RR. PAD was significantly correlated with PASP. Although p-value showed significance in correlations between the above variables, all r-values were less than 0.5. So, next R-square method was used to detect the multicollinearity. The R-square of the model was = 0.2454, which indicated that the model was not over parameterized by the collinearity. By rule of thumb, R-square $\leq$ 0.25 indicated that the model was free from multicollinearity (187). Further, multicollinearity was tested through the VIF and tolerance procedure. Analysis of maximum likelihood estimates of CPI results indicated the significant predictors as MAP ($p = 0.004$), RR ($p < 0.0001$), and PAD ($p = 0.0004$). It implies that MAP, RR, and PAD are statistically significant predictors of DVWR.

Accordingly, the prediction equation for DVWR can be derived using CPI as shown below:

Probability of DVWR = P (X)/ 1- P(X) = e x
Where the x = - 1.72 – 0.06(MAP) – 0.19 (RR) + 0.23 (PAD).

Implications

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, prevention, and treatment of DVWR. The knowledge acquired through this study includes antecedence such as COPD, CHF, mean MAP, mean RR, mean CO, mean PAD, and mean PASP that were found significant in the prediction of DVWR after CABG surgery. This specific knowledge can be used to benefit the fields of critical care medicine, critical care nursing, and critical care administration in the aspects of theory, practice, education, research, quality improvement, and cost-effective care in postoperative critical care after CABG surgery. Theory and practice: The findings of this research study have an implication for critical care medicine in the aspects of prevention, treatment, and health promotion. They may contribute to the prevention of ICU mortality and morbidity following CABG surgery. The finding of the significant predictors of DVWR after CABG surgery has added new knowledge to critical care medicine, critical care nursing, and respiratory medicine. Introduction of this new knowledge in the discipline's practice may enable the prevention of DVWR after CABG surgery. The description of the trends of the significant predictors has added new knowledge to the respective disciplines, which may in turn help in planning postoperative care for patients in the ICU who had CABG surgery. This knowledge may also aid in preventing premature weaning trials and in providing early treatment, which in turn can prevent mortality and morbidity associated with CABG surgery. This study benefits critical care nursing, as it adds new knowledge to the discipline. The knowledge of significant antecedence for DVWR would contribute to the critical care nursing practice in the aspects of prevention of complications and providing quality care through hemodynamic monitoring and assessment skills. Postoperative ventilator weaning is the major task of critical care nursing following CABG surgery. The critical care nurse plays an important role in the postoperative monitoring of CPI, hemodynamic stabilization, assessing the patient's readiness for weaning, and in preventing postoperative complications. The trends of the CPI and prediction model derived from this research study could provide a reliable tool to guide the practice of monitoring, assessment, and ventilator weaning practice after CABG surgery.

This research study may contribute to critical care nursing education through the addition of new knowledge to nursing theory. The specific findings, such as trends of CPI and significant antecedence of DVWR, may contribute to the development of the nursing process for caring for patients after CABG surgery. The findings of this research study may contribute to the quality of care in critical care nursing and medicine through the implications for patient safety after CABG surgery. The identification of reliable predictors for DVWR, the trends of CPI for DVWR, and the prediction model may help to identify a possible DVWR before it occurs, thereby it may help in preventing premature ventilator weaning trials that subject vulnerable patients to the risk of developing hypoxia, myocardial ischemia, and the complications that follow.

In addition, this research study has implications for the quality improvement through the development of weaning protocols and policy after CABG surgery. Research: This research study contributes to critical care research. The new knowledge derived from this study opens new avenues for future research, such as the development of a preoperative risk assessment tool using the significant antecedence. The knowledge of COPD and CHF has significant predictive value for DVWR after CABG surgery and can 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.

Further, studying the perspectives of development of a preoperative teaching tool and interventions focused on high-risk individuals may be useful. Next, incorporation of significant antecedence in weaning protocols and development of patient specific and risk specific weaning protocols may open the avenue for quality improvement of evidencebased projects. Testing the effectiveness of the weaning protocols, performance assessment and comorbidity-specific weaning practice may be planned as an evaluation research. In addition, this study may be conducted with a larger sample involving multiple sites before generalizing the results and to test the reliability and validity of the findings. Furthermore, the research design, methods, and analysis adopted and tested in this study could aid in guiding future research addressing similar problems in other populations, settings, and disciplines. The findings of this research study may also contribute to cost-effective care in critical care after CABG surgery. Including ICU length of stay as a variable may help to study the cost involved in treating high-risk population. The significant antecedence may help predict and prevent DVWR after CABG surgery, which in turn can result in reduced ICU length of stay after CABG surgery. Thereby, it can reduce the postoperative ICU cost.

Based on this study's findings, the following further research questions arise:

1. This study found that there was a significant effect of time on RR, which leads to the question regarding whether there are differences in the effect of time on RR between cases and controls.
2. This study found that there was a significant effect of the number of grafts on RR and SPO2. This leads to the question regarding whether there are differences in the effect of number of grafts on RR and SPO2.
3. This study found that there were differences in the effects of time on PAD, which leads to the question about what are the differences in the effect of time on PAD.
4. This study found significant differences in the means of certain CPI including RR, CO, CI, PAD, and SPO2, that lead to the question about what are the differences in trends of above mentioned CPI.
5. This study found that COPD has a significant predictive value for DVWR, which

Leads to questions such as:

- What are the preoperative pulmonary indicators (volumes and compliances) that exist with patients with COPD?
- What are the preoperative treatments that can maximize the lung functions to enhance normal weaning?
- What are the other attributes that coexist with this disease condition that affect the weaning outcome?
- What is the clinical model that can guide in the postoperative management of patients with COPD?

Limitations

Although utilizing a retrospective study design was suitable and appropriate for the research problem, this design has both strengths and limitations. The readily available data is strength for the study, as it prevents a data collection bias and helps to reveal existing relationships as they are dictated by the available data. However, this design does not exhibit the examination of cause and effect relationships between the study variables. Another limitation of this research study was that the researcher had no control over the completeness of the available data. Completeness and accuracy of the available data are two critical elements to consider in this design. Data extraction is another step where there is possibility of data error. A systemic chart extraction format and counter verification with another peer in the discipline controlled the accuracy of the data extraction. The generalizability of the study's findings is limited because it is a single site study. This study finding is limited to adult postoperative CABG patients and is not applicable to pediatric population or any other postoperative adult patients.

Conclusion

This retrospective case control study set out to find the values of CPI in the prediction of DVWR after CABG surgery. The study was guided by three research questions, which included describing the characteristics of CPI among patients with NVWR and DVWR after CABG surgery, finding the differences in characteristics of cardiopulmonary indicators between patients with NVWR and DVWR after CABG surgery, and building a prediction model for DVWR with significant antecedence. A retrospective case control study was utilized with a time series design using a sample consisting of 300 subjects who underwent CABG surgery. The results of this study revealed significant antecedence to predict DVWR after CABG surgery, which include COPD, CHF, MAP, RR, CO, PAD, and PASP. Therefore, this study concludes with a recommendation that the above-mentioned significant antecedence may be used to predict DVWR after CABG surgery in critical care. Further prospective studies are needed to establish the cause and effect relationship of these predictors to DVWR after CABG surgery.

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