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# Monitoring Patient Safety in the Recovery Room

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Monitoring Patient Safety in the Recovery Room

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## ABSTRACT

Respiratory depression is a serious complication after surgery. Early detection is a major patient safety concern for recovery room personnel as patients recover from anesthesia and experience pain. The opioids used for pain management may contribute to over-sedation effects and respiratory depression. Vital signs and pulse oximetry are standard postoperative monitoring procedures. End-tidal capnography and arterial blood gases may augment the standard-of-care procedures but may not be effective at detecting early respiratory depression. The purpose of this study was to generate baseline data trending patient safety variables and outcomes for postoperative patients using standard monitoring with standard-of-care plus transcutaneous capnography monitoring for CO<sub>2</sub> levels.

This study was guided by a retrospective, time series design with two study groups. A convenience sample of 800 patients from a large Midwestern hospital was assigned to postoperative recovery rooms equipped with standard monitoring (control group) or standard monitoring plus transcutaneous capnography (treatment group). The time series component refers to dependent measures collected at three points in time: admission to the recovery room and 30- and 60-minutes after admission. Dependent measures included respiratory rate, blood pressure, heart rate, oxygen saturation, pain score, Aldrete score, and opioid doses. Measures and time were treated as within subject factors.

Data were analyzed by: group (treatment vs control), dependent measures, and time using multivariate analysis of variance. Aldrete score and opioid doses were treated

as within-subject factors. Recovery time was assessed using an independent samples *t*-test. Trends in variables over time showed significant differences by groups.

The transcutaneous capnography treatment group showed a shorter length of stay in the recovery room and overall reduction in opioid administration compared to the control group. Pain scores worsened for the treatment group over time. The transcutaneous capnography may improve management of opioids and patients' level of consciousness but may have inadvertently heightened patients' awareness of pain. Transcutaneous monitoring of recovery room patients may be beneficial in avoiding respiratory depression and improving patient safety and it has long-term implications for health care costs.

## **CHAPTER 1: INTRODUCTION TO THE STUDY**

Postoperative opioid administration is common in the recovery room and is a recognized cause of respiratory depression (McCarter, Shaik, Scarfo, & Thompson, 2008). Life threatening respiratory depression is the most severe opioid adverse consequence (McCarter et al., 2008). Recovery room nurses are in charge of managing pain control for postoperative patients. A main goal of managing pain is to find a balance between pain control and the potential effects of over sedation.

Opioid administration is particularly challenging during the immediate postoperative period when patients are experiencing pain as well as the adverse effects from general anesthetics and intraoperative medications. If pain management is too aggressive it can result in a respiratory compromise that requires additional treatment to manage the patients' status and an increased length in hospital stay (McCarter et al., 2008).

The immediate postoperative period is the time of greatest risk for respiratory depression due to the mix of anesthetic drugs, muscle relaxants and narcotics affecting the respiratory rate of patients (Taylor, Kirton, Staff, & Kozol, 2005). There is an appreciation to optimize pain control after surgery to enhance patient comfort and expedite recovery. An understanding of the determinants of postoperative pain and knowledge of how pain and analgesic requirements relate to recovery time is needed by nursing staff (Pavlin, Chen, Penaloza, Polissar, & Buckley, 2002).

There is a small margin of safety on the impact of ventilation when administering sedatives after surgery (Sheahan & Mathews, 2014). Any unanticipated treatment can not

only lengthen the amount of time a patient may require in the recovery room to stabilize but may also increase the level of care needed within the hospital, such as admission to an observation unit or intensive care unit (Rose, 1996). Monitoring of oxygenation and ventilation through pulse oximetry and capnography (measurement of carbon dioxide), especially if a patient is ventilated or is in a drug-induced hypoventilation, can alert to impending respiratory compromise (Vimlate, Gilsanz, & Goldik, 2009).

Capnography is the standard of care in some institutions in monitoring of general anesthetic procedures. The use of capnography in the operating room environment has been credited with the overall drop in mortality associated with general anesthesia from 1 in 10,000 cases to virtually undetectable levels (Koniaris, Wilson, Durgas, & Simmons, 2003). Currently, the use of capnography in the recovery room is not the standard practice.

### **Problem Statement**

There are over 73 million surgeries performed annually in the United States (D'Arcy, 2010) that not only contribute to improved health but also increase the risk of morbidity and mortality. Pulmonary complications following the use of general anesthesia that accompanies major surgery are a recognized problem in the perioperative environment, with respiratory depression being the second most common cause of preventable postoperative deaths (Kasuya, Akca, Sessler, & Komatsu, 2009). Hypoventilation leading to hypoxia, hypercarbia, and respiratory acidosis is a central effect of general anesthesia and is also commonly associated with opioid usage (Kopka, Wallace, Reilly, & Binning, 2007).

Opioids are used extensively for pain management during the perianesthesia period and have the potential to contribute to respiratory depression (McCarter et al., 2008). Unfortunately, pain management can lead to overtreatment. In some instances, critical events such as respiratory depression and the need for reintubation may occur. The causes of respiratory depression from opioids are not limited to prescription and administration (Gordon & Pellino, 2005). Some patients, despite proper administration of appropriate orders, develop significant respiratory depression. Other medical issues may be associated with respiratory depression postoperatively such as a history of sleep apnea, chronic obstructive pulmonary disease, metabolic disturbances, and increased age (Gordon & Pellino, 2005).

Unfortunately, it can be challenging to know which patients will have respiratory complications because many factors are associated with respiratory depression, such as age, type of anesthesia, and use of opioids (Kasuya et al., 2009). A high level of carbon dioxide ( $\text{CO}_2$ ) is a sign of respiratory depression. Early identification of reduced ventilation can lead to the prevention of hypoxia, an unusually low concentration of oxygen in the blood. A result of reduced ventilation is a decreased  $\text{PaO}_2$  and an increase in  $\text{PaCO}_2$  which can cause hypercapnia, increased carbon dioxide (Drysdale, 2014). Research has found the use of capnometry as an early signal of respiratory failure is essential (Stein, Matz, Schneeweib, Eckmann, Roth-Isigkeit, Huppe, & Gehring, 2006).

Standard monitoring for recovery room patients includes vital signs and pulse oximetry, but does not routinely include the measurement of capnography. If there are respiratory concerns, physicians may order end-tidal capnography which is the most common method for continuous estimation of  $\text{CO}_2$  expired gases. This capnography

method assesses ventilation via a nasal-oral cannula the patient wears (Bendjelid, Schutz, Stotz, Gerard, Suter, & Romand, 2005; Tobias & Meyer, 1997).

Measurements of arterial blood gases (PaCO<sub>2</sub>) are occasionally obtained for patients with an invasive arterial line. Arterial blood gas analysis (ABG) is considered the gold standard for the measurement of arterial CO<sub>2</sub>. It is the most accurate method available as it uses a sample of blood to test (Drysdale, 2014). Blood samples are withdrawn from either a single arterial stick or an arterial line (Huttman, Windisch, & Storre, 2014). Blood tests require a wait time for results to be reported and can be painful for the patient. Drawing the ABG can be time consuming and requires specially-trained staff (Beyan, Cirak, Varol, & Ucar, 2015). It is not a continuous reading but offers a reflection of the blood levels at the time of being drawn (Drysdale, 2014). The correlation between ABGs and transcutaneous capnography was found to be excellent in providing adequate trending (Coates, Chaize, Goodman, & Rozenfeld, 2014).

Pulse oximetry is commonly used to monitor postoperative patients for hypoxemia but does not provide early detection of hypoventilation, apnea or airway obstruction (Waugh, Epps, & Khodneva, 2010). Oximetry cannot detect hypercarbia which displays the adequacy of ventilation (Drysdale, 2014). Capnometry is a useful monitoring parameter for early recognition of respiratory depression during post-anesthesia care. Although postoperative patients are usually monitored by pulse oximetry, many research articles support using capnography as a reliable warning for respiratory depression compared to pulse oximetry. McCarter et al. (2008) reported that pulse oximetry identified only 33% of patients with respiratory issues, where monitoring with capnography identified 100% of patients.

In the perioperative environment, it is advantageous to identifying patients who may suffer from respiratory depression, and have a subsequent need for naloxone to be administered to reverse the effects of the opioids. Trends in CO<sub>2</sub> may have an impact on dose administration of opioids, potential reduction in reversals with naloxone, and a decline in the number of intubations postoperatively.

Performing a retrospective quasi-experimental study in the recovery room environment may offer insight into providing safer postoperative management of surgery patients. A comparison of data trends in patients was made of those who received standard monitoring postoperatively (respiratory rate, oxygen saturations, etc.) to the patients who had the additional assessment through trends of transcutaneous CO<sub>2</sub> monitoring. Assessing these data comparisons may provide cues for respiratory depression.

Identification of factors that may predict critical events within the postoperative patient is imperative to the initiation of safer healthcare practices. Respiratory depression is one of these life-threatening events. The complications patients can incur from respiratory compromise can be catastrophic to their health and safety. Preventative strategies to avoid respiratory problems include early identification of the patients at high risk, avoidance of long-lasting anesthetic drugs which depress the level of consciousness, safe pain management and close monitoring (Rose, 1996).

An opportunity exists to review the current assessment components obtained in postoperative patients, incorporate the additional monitoring of transcutaneous CO<sub>2</sub> monitoring, and trend the patient's data and outcomes. Analysis of the data trends may offer insight into the development of safety and quality improvement protocols. The

ability to recognize which patients may have an untoward event through early recognition of symptoms would be valuable in individualizing the care provided.

### **Purpose of Research**

The purpose of this retrospective quasi-experimental research design study was to generate baseline data to trend postoperative patient safety variables and outcomes.

Transcutaneous CO<sub>2</sub> levels were assessed for the effects of transcutaneous capnography monitoring on detection of carbon dioxide levels in recovery room patients compared with standard of care.

This study had two objectives. One objective was to compare patients on transcutaneous capnography with patients who received standard postsurgical monitoring to determine if there was a difference in postoperative safety variable trends and outcomes. The second objective of the study was to compare postoperative complications of patients monitored with transcutaneous capnography with patients receiving standard monitoring.

Transcutaneous capnography monitoring offers continuous information, making it possible for the nurse to detect and follow trends (Torok, Leuppi, Baty, Tamm, & Chhajed, 2008). The early identification of hypoxemic patients can lead to early intervention, not by re-intubation and initiation of mechanical ventilation, but by the timeliness of less invasive interventions such as increased incentive spirometer use and turn-cough-breathe techniques. One potential benefit of utilizing transcutaneous capnography with its continuous trends is that it may give nurses increased confidence in successfully monitoring for respiratory distress while increasing or decreasing opioid usage when needed. Although not a focus of this research the potential increased self-



confidence and effectiveness in management could lead to improved patient outcomes, increased job satisfaction of staff and decreased turnover of nurses.

For this proposal, complications are defined as any additional respiratory intervention required within the recovery room such as naloxone administration, increased in the length of recovery stay, reintubation or transfer to higher level of care. The transcutaneous method provides a constant, real-time measurement and is not affected by ventilation/perfusion abnormalities, as may be the case with the end-tidal method (Kirk, Batuyong, & Bohn, 2006). Abnormal levels of capnography can signal staff to reassess patients, prepare to provide potential airway support, and even avoid administering extra amounts of sedative until concerns are resolved (Green & Pershad, 2010).

### **Research Questions**

In this retrospective quasi-experimental study, routine demographics such as age, sex, height, weight, body mass index (BMI), and the American Society of Anesthesiologists (ASA) Physical status classification system scores were attained. The following data points were also obtained for trends: pulse oximeter (SaO<sub>2</sub>), mean levels of noninvasive arterial blood pressure measurements, respiratory rate, heart rate, level of consciousness (LOC), pain scores, Aldrete scores and capnography (end-tidal and transcutaneous). Opioids by dose amount and time administered were captured. The research questions investigated are below.

Research Question 1: Are there postoperative differences in trends of safety variables for patients who were monitored with transcutaneous capnography compared to those who received standard monitoring?

Research Question 2: How do patient complication trends relate to the capnography trends and other safety variable trends in recovery room patients?

### **Significance**

Surgery is an area of high impact and high potential harm to patients. Aside from its inherent risks such as surgical site infections and deep vein thrombosis, the perioperative environment is complex, involving multiple teams of caregivers and transitions of care. The first 24 hours after surgery represents a high-risk period for a respiratory event caused by narcotic use. Standards could be developed to increase safety on the first postoperative day through identification of patients who are high-risk for respiratory depression (Taylor et al., 2005).

Many sedation-related respiratory issues begin first with irregularities in ventilation that can be seen in capnography trends. Oxygen saturation is often the last sign of the respiratory issue, particularly when supplemental oxygen has been administered (Green & Pershad, 2010). Capnography levels are not affected by supplemental oxygen which many post-surgical patients have administered as needed (Drysdale, 2014).

The addition of capnography in the operating room environment is credited with an overall drop in mortality associated with general anesthesia from 1 in 10,000 cases to virtually undetectable levels (Fecho, Joyner, & Pfeiffer, 2008). Unfortunately, the use of capnography in the recovery room is not standard practice. The standard for a postsurgical recovery room patient is the assessment of vital signs and pulse oximetry (SaO<sub>2</sub>). Respiratory rates may be influenced by various factors such as patient age,

weight, impaired gas exchange and sedation levels (Fu, Downs, Schweiger, Miguel, & Smith, 2004), and the diagnostic value of pulse oximetry is limited (Kopka et al., 2007). Assessing oxygen saturation using pulse oximetry is an important late indicator of ventilatory status. Whereas carbon dioxide (CO<sub>2</sub>) is a better measure of determining ventilatory standing and provides an earlier notice of impending respiratory depression (Kopka et al., 2007).

Early identification of hypoxemic patients with respiratory compromise could a) lead to early interventions by clinicians, b) reduce the need for re-intubation, and c) reduce direct costs from additional procedures and extended hospitalizations (Young, 2006). There have been no large scale studies assessing the use of transcutaneous CO<sub>2</sub> monitoring in the immediate postoperative period of the recovery room. Exploring if the transcutaneous CO<sub>2</sub> monitoring device is useful in detecting which patients incur a complication and where this complication occurs during their recovery could be extremely valuable for preventive or early intervention efforts.

### **Limitations**

As with any research study, there were limitations. The limitations were:

- 1) This study was a retrospective quasi-experimental design with random assignment to treatment. Patients were not randomized as in a controlled trial. Patients were randomly assigned through standard room assignment. As surgeries complete in the operating room, the operating room personnel calls out for a recovery room assignment. Depending on open and available rooms, a random room assignment was given. Some rooms had transcutaneous monitoring equipment in them; others did not.

- 2) During analysis of the data, consideration will be given to whether there was an association between variables. None of these judgments can provide indisputable evidence of cause and effect, but rather prompt for further consideration to whether there were any other more likely cause and effect.
- 3) Trends in variables over time were taken from the electronic documentation. Nursing and anesthesiology have an opportunity to capture documentation in a thorough and timely manner. Electronic data is confirmed for accuracy when the nurse highlights the content and signs off on the information. If nursing staff does not agree with the information, it is left unconfirmed.
- 4) All missing data were inputted.

### **Assumptions**

- 1) It was assumed that the patients participating in the study would be representative of the recovery room population. The random selection of the participants should represent the entire populace.
- 2) The four hundred patients who were randomly assigned to rooms with the transcutaneous monitoring were compared to 400 patients who were randomly assigned to rooms without transcutaneous monitoring within the same time frame.

### **Summary**

This chapter provided an introduction to the research project, including an overview of the topic postoperative respiratory depression. The purpose of the study and significance of the issue regarding potential respiratory complications post operatively

and the management of the patients in the recovery room was reviewed. The research questions and aims were discussed as well as key definitions.

## **CHAPTER 2:**

### **CONCEPTUAL FRAMEWORK AND LITERATURE REVIEW**

This chapter is divided into two sections. First, the conceptual framework of General Systems Theory is discussed in depth as providing a guide for this study. Second, in the literature review the concept of patient safety in the perioperative environment and the significance of early recognition of rising carbon dioxide levels in recovery room patients are discussed. The historical use of transcutaneous capnography monitoring is reviewed as well as reasons the monitor is not currently used in the recovery room despite positive research findings.

#### **Research Questions**

Research Question 1: Are there postoperative differences in trends of safety variables for patients who were monitored with transcutaneous capnography compared to those who received standard monitoring?

Research Question 2: How do patient complication trends relate to the capnography trends and other safety variable trends in recovery room patients?

#### **Conceptual Framework**

##### **General Systems Theory**

The General System Theory (GST), first proposed in 1936 by Ludwig von Bertalanffy, emphasizes that systems interact with their environment and that there is an association between the parts which connect the whole (Weinberg, 1975). The primary concern is given to the interactions of all of the components within the system. The system is defined as complex interacting elements (Von Bertalanffy, 1968). Investigating single parts of processes cannot always provide a complete explanation of the process

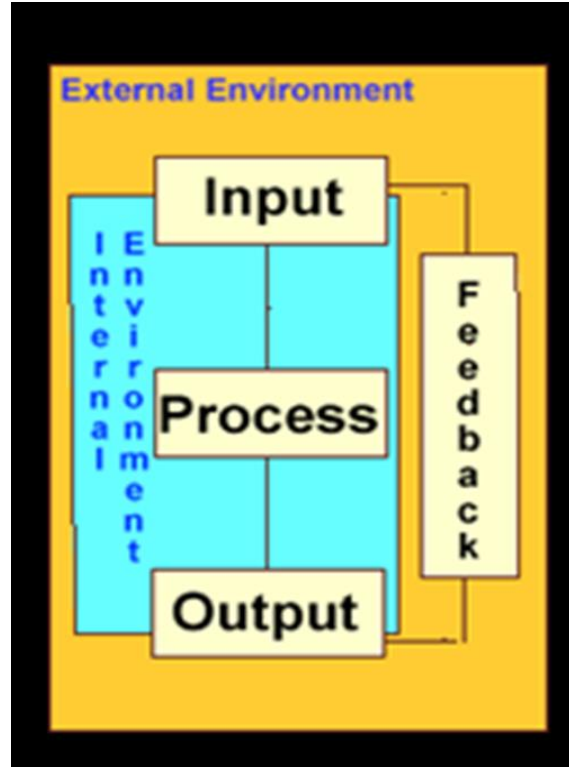
(Von Bertalanffy, 1972). The GST deals with the efficiency and effectiveness of systems and their ability to produce a meaningful, useful output to surrounding supra systems (Gray, Duhl, & Rizzo, 1969). A rudimentary concept in systems thinking is that of hierarchical relationships between systems. A system is composed of subsystems of lesser order and is also part of a larger system (Kast & Rosenzweig, 1972).

Systems are made up of an arrangement of subsystems, all of which are characterized by individual patterns of interactions; both within their sub-systems and with other parts of the system (Paton, Sengupta, & Hassan, 2005). The GST emphasizes that systems are organized and that they are composed of interdependent components in some relationship (Kast & Rosenzweig, 1972). Every system is made of at least two interconnected elements. In a dynamic relationship with its environment, the system receives various inputs, transforms these contributions in some way, and exports outputs (Kast & Rosenzweig, 1972).

The concept of “General System” is broad and embraces dynamic interaction between many variables. There is a defining characteristic of maintaining in a continuous exchange of components. General Systems Theory offers several concepts that help to explain the behavior of a hospital as it applies to both material and mental phenomena (Von Bertalanffy, 1968).

A hospital is a system with inputs, processes, and outputs. It is by itself a component of a larger system, the health care system (Weinberg, 1975). The diagram of GST, as seen in Figure 1, can be used to understand health care structures, processes, outcomes and their interactions within a health care system as feedback loops are incorporated to assess the effects of interventions (Weinberg, 1975).

Figure 1. General Systems Theory Framework



### Concepts of General System Theory

The important concepts of general systems theory are well-defined and used by multiple organizations. The purpose of this section is to provide a brief review of those characteristics which seem to have widespread acceptance. Also, an explanation of how this theory applies to the patient, their hospital stay, potential safety implications and the importance of having a feedback loop.

*Inputs* include raw material, energy, and resources needed to produce the output. *Input* comes from the environment and converts into energy. On a small scale, the input may be the nurses' or physicians giving their energy, care and time devoted to thinking, planning, diagnosis, and decision-making. The multidisciplinary team within the hospital demonstrates daily their plan of patient care, discuss resources needed and deliver concrete decisions for the patient's care. On a larger scale, examples of input could



include the hospital environment itself. Each hospital is a part of a larger system of hospital institutions collaborating in providing congruent processes to better the health care delivered. Patients are impacted by the hospital setting in a variety of manners. Critical care nurses are trained to rapidly recover a patient from anesthesia postoperatively. Nurses with experience can not only recover the patient but anticipate potential problems which may arise and intervene prior to their development.

The *elements* or *components* are the parts that make up the system. Elements are a broad category and may include people, equipment, and supplies (Weinberg, 1975). Individuals in a hospital environment are inclusive of patients, families and all personnel. Equipment and supplies used on a daily basis is an enormous amount. The General Systems Theory takes into account every components impact on the outcome. Monitoring patients after surgery can include many specialty equipment and supplies unique to the recovering patients. Guidelines have been established as to what minimal requirements in monitoring are required. The measurement of capnography has not been defined as a minimal requirement by the recovery room association.

*Internal factors* may include the skill of the personnel caring for patients. As the patients and conditions treated within hospitals changes, so will the skills needed by staff. Although all subsystems within a hospital are significant, improving the clinical performance of staff is central to the hospital's role. The challenge is to evaluate the quality of care provided and to change clinical practice to make it better (McKee & Healy, 2002). Although patients can usually have input into who their surgeon will be, they do not have the ability to select the team that supports the surgeon. The skill level of

residents, interns, and even nurses, can potentially be an internal factor affecting the outcome of their stay.

*External factors* can be associated with the patient or the hospital. Examples of external sources which may place influence on the patient are the population served, patterns in diseases, and public expectations. The hospitals and hospital systems can have many structural and cultural external factors impacting function. Hospitals configurations can reflect the practice of health care and can range from rooms with too few sockets for increasing electronic monitors or too few operating rooms to accommodate the rise in surgeries (McKee & Healy., 2002). Also, hospitals are inhabited by a large group of multidiscipline personnel who require consideration in how they develop working relationships. In the hospital setting, recovery room patients are monitored with specialized equipment and multidisciplinary teams. The fast pace, multicultural arena can be overwhelming to the patient experience.

The *Output* is the outcome or the product result. Examples are potentially having improved health and decision outcomes. The development of any strategy aimed at a patient or organizational improvement requires an assessment of the present situation. After critical variables and factors that affect health and well-being about the organization are identified, data can be gathered and analyzed (Paton et al., 2005). It's important to be extremely attentive and examine the systems at the level of the person, the group, the organization, the society, and the larger system (Duncan, 1972). The output for patients postoperatively would ideally be to have no complications from their procedure. Several complications routinely occur after surgery and are managed in the recovery room. Pain, nausea and fluid resuscitation are common issues requiring

proactive interventions to allow for the best outcomes. The output is monitored by the “feedback loop” which senses a response and the subsequent action of the system (Von Bertalanffy, 1968). Reassessment of interventions occurs based on the feedback.

*Feedback* is information about some aspect of data or energy processing that can be used to evaluate, monitor the system and to guide it to more operative performance (Weinberg, 1975). The concept of feedback is important to understanding how a system maintains a steady state. Information concerning outputs or processes of the system is fed back as an input into the system. Feedback can be positive or negative (Kast & Rosenzweig, 1972). Analyzing feedback allows for ongoing or alternate treatment depending on whether the outcome is positive or negative. The internal factors associated with the skill of personnel caring for the patient is the nurse’s ability to, not just recognize, but anticipate potential postoperative issues. The experience and expertise of the staff can impact this early recognition. Many variables can impact the patient outcome after surgery. Monitoring capnography trends can provide an additional measurement of assessment. If a patient’s respiratory status is noted to be compromised through the feedback of trending, staff could intervene early by lowering opioid doses if applicable to prevent further sedation.

Monitoring of postoperative patient safety variables for changes and intervening when appropriate in the feedback loop is similar to the GST ongoing model. Immediate and ongoing trends of capnography provide real-time opportunity for information regarding the patient’s respiratory status. Identifying and understanding the components of which safety variables in the recovery room have a significant impact can potentially offer an opportunity to improve patient outcomes with early interventions.

## Review of Literature

### Overview of Patient Safety

Healthcare professionals have known about potential safety issues which impact patients in our healthcare system, but these concerns only recently moved to the focus of national healthcare agendas. It took several initiatives in the last decade to bring healthcare issues to the forefront. The Institute of Medicine's (IOM's) landmark, 1999 report *To Err is Human: Building a Safer Health System* caused headlines across the world and created much of the momentum for the patient safety movement of today (Clancy, Farquhar, & Sharp, 2005). The Institute of Medicine estimated in the report that as many as 44,000 to 98,000 people die in the U.S. hospitals yearly due to lapses in patient safety (Brief report, 1999). The magnitude of healthcare safety concerns was identified as one way organizations might change to improve the care they provide. Each institute can vary in the development of programs their establishment may initiate to address their specific issues (Frankel, Gandhi, & Bates, 2003).

The National Healthcare Quality Report (NHQR) has tracked a growing number of patient safety measures. In 2011, the NHQR identified measurements to keep patients from being hurt or becoming more ill. Postoperative respiratory failure is one of the measures noted by this organization as requiring attention. Respiratory failure was recognized as being not uncommon after surgery and that reintubation or prolonged mechanical ventilation may be required. The NHQR identified over sedation as a potential contributing source, and closer attention to risk factors may reduce rates (Agency for Healthcare Research and Quality [AHRQ], 2014). Identifying and treating

potential complications when recognized may prevent progression of issues in the patients' medical management.

In 2001, the development of nationwide pain assessment and management standards employed by The Joint Commission had a key influence in healthcare. The standards require hospitals to be familiar with the right of patients to have an accurate pain assessment and management of their symptoms. The call to improve pain management also led to some over treatment and increases in the incidence of reported critical events. The Institute for Safe Medication Practices (ISMP) noticed being more attentive to the management of pain caused a rise in events of over-sedation and respiratory depression. Between January 1995 and June 2006, there were 369 sentinel events in the Joint Commission database from medication errors and 20% involved opioids. This category is the largest number of sentinel events. Almost all (e.g., 98%) of these events resulted in death (Gordon, Rees, McCausland, Pellino, Sanford-Ring, Smith-Helmenstine, & Danis, 2008).

Aligning with TJC, AHRQ has been funding research on patient safety and ensuring to support the application to daily patient care. The defining mission statement of the AHRQ is "to improve the quality, safety, efficiency, and effectiveness of health care for all Americans" (AHRQ version 3, 2006). Patient safety goals established by AHRQ promote specific improvements using Patient Safety Indicators (PSIs) as a guide for identifying the incidence of adverse events following surgeries, procedures, and childbirth. The U.S. Congress has supported AHRQ patient safety efforts by appropriating \$165 million for their research in the PSI. Also, Congress appropriated

\$139 million for AHRQ's new health information technology initiative to improve safety (Clancy et al., 2005).

### **Perioperative Patient Safety**

Perioperative services is a very complex environment. Patients are provided care in the preoperative screening division, same day surgery, preoperative holding areas, operating rooms and post anesthesia care units. The care provided is given by many teams, is fast paced, involves new technologies and ultimately causes the need for several handoffs (Eckstrand, Habib, Williamson, Horvath, Gattis, Cozart, & Ferranti, 2009). This combined environmental characteristic creates a risk for potential harm.

The American Society of Perianesthesia Nurses (ASPAN) is a nursing organization which endorses a safe environment for perianesthesia practice. ASPAN guidelines focus on the immediate postoperative course of the patient and emphasize potential concerns which may impact immediate recovery. The guidelines provide direction in the management of patient care as they emerge from anesthesia and are updated every two years.

Common safety concerns include hemodynamic, respiratory, renal, and neurological complications (Barash, Cullen, & Stoelting, 2006). Patients must be observed continuously for changes in their status which may indicate potential unsafe situations. There are many postoperative perioperative safety variables monitored. Through close monitoring, the clinician hopes to identify issues quickly to intervene earlier reducing the likelihood of critical events (American Society of Anesthesiologist Task Force on Sedation and Analgesia by Non-Anesthesiologist, 2002). Respiratory monitoring is a serious aspect in assuring quality care and clinical observation alone has

been proven to be undependable in evaluating respiratory status (Sheahan & Mathews, 2014). Complementary detection methods are always considered desirable.

The American Society of Anesthesiologists (ASA) stresses that observing oxygenation by pulse oximetry is not a replacement for assessing ventilation capabilities through measuring capnography. Normal oxygen saturation can be maintained even with a low respiratory rate. The pulse oximetry may not detect patient deterioration especially if they are on supplemental oxygen immediately following surgery (ASA Task Force on Sedation and Analgesia by Non-Anesthesiologist, 2002). The ASA developed practice guidelines for post-anesthetic care and summarized their recommendations for assessing and monitoring. The ASA use a classification of physical status for comparison of statistical information on patients (Wolters, Wolf, Stutzer, & Schroder, 1996). The ASA physical status classification is used to strengthen the assessment of perioperative risk factors and, hopefully, better predict postoperative outcomes.

Monitoring respiratory status postoperatively include lung sounds, work of breathing, SpO<sub>2</sub>, respiratory rate, and breathing pattern. Effective patient respiratory effort can be assessed by visualization of chest expansion, the rate and depth of their breathing, monitoring the use of accessory muscles, and the number and quality of breath sounds (Coates et al., 2014). These are subjective findings and can be misleading. Potential renal complications are assessed through the measuring of intake and hourly urine output. Neurological status is measured by the patient's mental status, level of consciousness (LOC), and whether they are delayed in waking up (Vimlati et al., 2009).

**Perioperative Safety Variables**

The recovery room uses a scoring system known as the Modified Aldrete for assessing the patient's progress in recovery and assists in establishing stability for discharge see Table 2. This assessment specifically evaluates the level of return to the patient's baseline before surgery for activity, respiration, circulation, consciousness, and O<sub>2</sub> saturation. The system is designed to assess the patient's transition from the discontinuation of anesthesia until a return of protective reflexes and motor function (Ead, 2006). Scoring is performed upon arrival to the recovery room and every thirty minutes until the patient is fully recovered with a score minimum of 8 to 10 needed for discharge. Aldrete uses a rating scale of zero to two to score each of the five categories: activity, respiration, circulation, consciousness, and oxygen saturation. A score of two in each category is considered best in all areas.

ASPAN guidelines have established discharge criteria to utilize in the evaluation of patients. Discharge criteria include assessment and stabilization of the Aldrete components, as well as the stabilization of the patient reports of pain and nausea. The ASPAN Pain and Comfort Clinical Guidelines (released 2003) were developed to provide direction for assessment, interventions, and expected outcomes for the preoperative and postoperative phases of treatment. Patient discomfort should be managed and reduced to a score of less than five on a scale of 1 to 10 before discharge. Symptoms of nausea should be treated for resolution as much as possible.



Table 1

*Modified Aldrete Recovery Score*

Variable	Description	Score
Activity	Able to move four extremities on command	2
	Able to move two extremities on command	1
	Able to move no extremities on command	0
Breathing	Able to breathe deeply and cough deeply	2
	Dyspnea	1
	Apnea	0
Circulation	Systemic blood pressure =20%of the preanesthetic level	2
	Systemic blood pressure is 20%-49% of the preanesthetic level	1
	Systemic blood pressure is =50% of the preanesthetic level	0
Consciousness	Fully awake	2
	Arousable	1
	Not responding	0
Oxygen Saturation (pulse oximetry)	>92% while breathing room air	2
	Needs supplemental oxygen to maintain saturation >90%	1
	<90% even with supplemental oxygen	0

The depth of sedation can vary after a patient's procedure and requires an ongoing assessment and documentation (Sheahan & Mathews, 2014). Although several sedation assessment methods are used in clinical practice, the Ramsay Sedation scale (RASS) is primarily used in recovery to assess the depth of sedation (Table 2).

Table 2

*Richmond Agitation-Sedation Scale Score*

Score	Descriptor	Characteristics
+4	Combative	Combative, violent, immediate danger to staff
+3	Very Agitated	Pulls or removes tube(s), or catheter(s); aggressive
+2	Agitated	Frequent nonpurposeful movement, fights ventilator
+1	Restless	Anxious, apprehensive but movements not aggressive or vigorous
0	Alerts and Calm	

-1	Drowsy	Not fully alert, sustained awakening to voice (eye opening and contact >10 seconds)
-2	Light Sedation	Briefly awakens to voice (eye opening and contact <10 seconds)
-3	Moderate Sedation	Movement/eyes open to voice but no contact
-4	Deep Sedation	No response to voice; has movement/eye opening to physical stimulation
-5	Unarousable	No response to voice or physical stimulation

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For this proposal, the safety variables observed for trends were respiratory status, neurological changes, circulatory status, pain levels, and hemodynamic status. These variables were monitored through respiratory rate, mean blood pressure, heart rate, oxygen saturation, capnography levels, pain scores, Aldrete scores and RASS scores. The ideal direction variables should take postoperatively is a respiratory rate maintaining between twelve and twenty, a mean blood pressure < 80, a heart rate <80, an oxygen saturation increasing > 92%, a pain score decreasing < 5, an Aldrete score increasing to 9-10, and a RASS score increasing to 0. Opioid doses, both individual and total, were also collected in data trends.

### **Increased Monitoring of Safety Variables through Capnography**

Capnography is a graphic display of carbon dioxide (CO<sub>2</sub>) concentration during the respiratory cycle. Capnometry is a monitor display in number value of CO<sub>2</sub> concentrations during the breathing. This direct technique displays a continuous level of CO<sub>2</sub> eliminated by the lungs, and also reflects the amount of CO<sub>2</sub> produced by tissues and transported to the lungs (Todorova, 2008). Capnography is accurate and non-invasive. The number of arterial blood samplings can be drastically reduced when patients are monitored with capnography. Although John Scott Haldane is credited with developing the first practical means of measuring carbon dioxide in a mixture of gasses in 1905, the

fundamentals of capnography were established by Karl Friedrich Luft in 1937 when he discovered that carbon dioxide could absorb infrared radiation (Westhorpe & Ball, 2010). Clinical capnography was introduced into the United States in 1978 and has been in routine use in operating rooms since 1988. The use of capnography has expanded over the years to be used in a variety of acute care settings.

Safety indications for use of capnography monitoring include utilization to confirm and continuously monitor endotracheal tube placement. Subtle changes in trends can alert for impending problems. In settings where patients are breathing spontaneously through their airways, capnography use has been mainly advocated for early detection of respiratory depression and apnea (Fanelli, Baciarello, Squicciarini, Malagutti, Zasa & Casati, 2008). Besides monitoring lung ventilation, capnography delivers data about circulation and metabolism, can help in the analysis of low cardiac output conditions, and in identify pulmonary embolisms (Whitaker, 2011).

The use of capnography during clinical events such as cardiac or respiratory arrest can be helpful. Capnography provides continuous, real-time information concerning the efficiency of resuscitative efforts (Jaffe, 2002). Capnography trends, side-stream, end-tidal, or transcutaneous, has become the standard of care in many hospitals for monitoring patients who receive general anesthesia during their surgery and has been used to successfully detect a patient's declining respiratory status (Koniaris et al., 2003).

### **Transcutaneous Capnography as Related to Patient Safety**

Previously, the use of capnography meant the patient had to be intubated and in the intensive care unit. With the development in monitoring, side-stream capnography proved to be reliable for use on intubated and non-intubated patients (McCarter et al.,

2008). Side-stream devices take a continuous sample of gas from the breathing circuit through a six to eight-foot long small bore tube. The sample is delivered through a water trap. After drying in the tube, the sample cell is analyzed. There can be a delay for several seconds, and also a distorted rise time, due to the use of a remote location (Jaffe, 2002). The response time delay can be considered substantial as clinicians need the earliest warning as possible to any potential respiratory concern.

Less utilized, the measurement of carbon dioxide using transcutaneous capnography on skin surfaces was first defined in 1960 by Severinghaus with an unheated electrode. A linear relationship between skin surface  $PCO_2$  and blood level  $PCO_2$  was noted (Eberhard, 2007). A few years later, a heated sensor was utilized by Eberhard (2007) and proved to be a scientific breakthrough, allowing continuous measurement of  $CO_2$  for prolonged time periods. When placed on the skin, the heated sensor dilates the capillaries underneath. The dilatation increases the gas diffusion through the skin allowing 20 times greater diffusion of both carbon dioxide and oxygen to the sensor (Eberhard, 2007). At the sensor, there is a gas permeable membrane (Beyan et al., 2015). The signal is converted by the monitor and displayed as a  $CO_2$  value (Lim & Kelly, 2010).

Even though the heated electrode transcutaneous method was patented in 1971, the first commercially available transcutaneous sensors were not introduced until 1980. The term *cutaneous* was used to describe the technique of analyzing the concentration of gas diffusing through the cutaneous tissue at the skin surface. The word *cutaneous* is still used. Most publications have utilized the word *transcutaneous* making it the most commonly used of the two (Eberhard, 2007).

Transcutaneous carbon dioxide (TrCO<sub>2</sub>) measurement has become a unique way of monitoring respiratory function noninvasively. Based on the use of a temperature-controlled Stow-Severinghaus pH-sensitive glass electrode, this device has shown good correlation to PaCO<sub>2</sub> values in a wide variety of patients (Fanelli et al., 2008).

Transcutaneous monitoring is noninvasive and relies on high-resolution CO<sub>2</sub> measurement which is applied through the heated sensors placed locally on the skin (Beyan et al., 2015). Transcutaneous monitoring of CO<sub>2</sub> at the skin eliminates the influence of ventilation/perfusion abnormalities present in diseased lungs (Berkenbosch, Lam, Burd, & Tobias, 2001; Oshibuchi, Cho, Hara, Tomiyasu, Makita, & Sumikawa, 2003; Xue, Wu, Jin, Yu, & Zheng, 2010).

### **Current Research**

Over the years, multiple studies with small sample sizes comparing the two methods of noninvasive CO<sub>2</sub> monitoring have been performed by a variety of researchers as seen in Table 3.

Table 3

#### *Summary of Transcutaneous Capnography Research*

Author	Sample Size & Purpose	Results
Barker, Tremper, & Gamel (1986)	N=55 Correlation of accuracy	Comparison of transcutaneous PCO <sub>2</sub> and pulse oximetry in the operating room found both are useful noninvasive monitoring devices which measure different variables
Reid, Marineau, Miller, Hull, Baines,	N=22 Randomized, prospective trial	Comparison of transcutaneous, end-tidal and arterial measurements of carbon dioxide during general anesthesia established transcutaneous measurements

& Sullivan (1992)		to be more precise than end-tidal in comparing to actual arterial blood level CO <sub>2</sub>
Tobias et al. (1997)	N=25 Prospective comparison of two noninvasive measures of capnography monitoring	Transcutaneous monitoring found to be more accurate in estimation of carbon dioxide levels compared to end-tidal capnography results in toddlers & infants during respiratory failure
Tobias, Wilson, & Meyer (1999)	N=33 Prospective study investigating the efficacy and accuracy of transcutaneous monitoring	Transcutaneous monitoring found to be an accurate assessment of arterial carbon dioxide in infants and children after cardiothoracic surgery
Berkenbosch et al.(2001)	N=25 Prospective comparison of two noninvasive measures of capnography monitoring	Transcutaneous monitoring found to provide more accurate assessment of carbon dioxide compared to end-tidal capnography in older children during mechanical ventilation
Griffin, Terry, Burton, Ray, Keller Landrum & Tobias (2003)	N=30 Prospective comparison of two noninvasive measures of capnography monitoring	Transcutaneous monitoring found to provide more accurate assessment of carbon dioxide compared to end-tidal carbon dioxide measurements during general anesthesia in severely obese adults
Oshibuchi et al. (2003)	N=26 Usefulness and accuracy of transcutaneous	Transcutaneous monitoring found to provide more accurate assessment of carbon dioxide compared to end-tidal CO <sub>2</sub> measurements in patients undergoing thoracic anesthesia

	monitoring	
Chhajed, Rajasekaran, Kaegi, Chhajed, Pflimlin, Leuppi, & Tamm (2006)	N=114 Quantify degree of change in pulse oximetry and transcutaneous capnography during bronch	Both oximetry and cutaneous capnography found to be useful noninvasive monitors measuring different variables during flexible bronchoscopy
Kirk et al.(2006)	N=609 Usefulness and accuracy of transcutaneous monitoring during sleep	Transcutaneous carbon dioxide monitoring of pediatric patients during polysomnography found to provide accurate and interpretable results in children
Kopka et al.(2007)	N=28 Prospective, observational pilot study and comparison study of epidural or patient controlled infusion analgesia	Transcutaneous capnography found to be an easy, sensitive indicator of respiratory depression and can have a role in safe administration of opioid analgesia though early recognition of increasing carbon dioxide levels
Storre, Steurer, Kabitz, Dreher, & Windisch (2007)	N=10 Usefulness and accuracy of transcutaneous monitoring	Transcutaneous found to be easy, sensitive indicator of respiratory depression by recognition of increasing carbon dioxide levels
Fanelli et al. (2008)	N=13 Accuracy of device in estimating carbon dioxide in recovery room patients	Transcutaneous monitoring found to provide accurate assessment of carbon dioxide for monitoring spontaneously breathing, nonintubated patients in the early postoperative period
Torok et al. (2008)	N=20 Feasibility of	Combined oximetry and capnography found to be feasible alternative approaches to

	combined oximetry and transcutaneous capnography to reduce the need of arterial blood gas sampling	reduce the number of arterial blood gas samplings performed when assessing patients for long term oxygen therapy
De Oliveira, Ahamad, Fitzgerald, & McCarthy (2010)	N=40 Comparison between transcutaneous and nasal end-tidal carbon dioxide measurement for detection of hypoventilation during deep sedation in patients undergoing ambulatory gynecological hysteroscopy	For patients under deep sedation, non-invasive carbon dioxide monitoring was more sensitive and accurate for detecting hypercarbia than standard end-tidal carbon dioxide measurements.
Dreher, Ekkernkamp, Storre, & Kabitz (2010)	N=15 Compared transcutaneous capnography, oxygen saturation, drug dosages and time to recovery	Transcutaneous monitoring found to provide an accurate assessment of carbon dioxide in patients undergoing sedation during flexible bronchoscopy who had pre-existing respiratory failure
Chakravarthy, Narayan, Govindarajan, Jawali, & Rajeev (2010)	N=32 Usefulness and accuracy of transcutaneous monitoring was compared to arterial blood levels	Transcutaneous accurately found to be accurate and comparable to arterial blood levels of carbon dioxide in patients weaning from mechanical ventilation after off-pump coronary artery bypass graft procedures
Waugh et al. (2010)	Meta-analysis of 5	A meta-analysis with pooled findings found capnography significantly increased



	selected studies	detection of adverse respiratory events during procedural sedation
Xue et al. (2010)	N=16 Accuracy of transcutaneous monitoring	Transcutaneous monitoring found to provide accurate assessment of carbon dioxide in patients undergoing prolonged laparoscopic surgery
Coates et al. (2014)	N=29 Convenience sample measuring performance of capnometry in non-intubated infants in pediatric ICU. Simultaneous ABG drawn if arterial line present.	Correlation of side stream CO <sub>2</sub> with ABG was excellent and provided adequate trending Transcutaneous correlated better than side stream to ABG CO <sub>2</sub>
Beyan et al. (2015)	N=30 Comparison of partial pressure of carbon dioxide in arterial blood and transcutaneous carbon dioxide monitorization in patients	Transcutaneous monitoring proven useful in patients with obstructive sleep apnea and sleep related hypoventilation

The recent research in Table 3 primarily supported that both transcutaneous and end-tidal capnography were found to provide an accurate assessment of carbon dioxide in patients. Overall, even the studies utilizing the transcutaneous monitoring alone showed this method to be a precise and easy way to trend carbon dioxide. Although both approaches offer the ability to trend, additional studies have also demonstrated that the transcutaneous method may be an easy, accurate measurement for early recognition of respiratory depression (Bendjelid et al., 2005; Berkenbosch et al., 2001; Chakravarthy,

Narayan, Govindarajan, Jawali, & Rajeev, 2010; Fanelli et al., 2008; Griffin et al., 2003; Oshibuchi et al., 2003; Reid, Marineau, Miller, Hull, Baines, & Sullivan, 1992; Tobias & Meyer, 1997).

Transcutaneous CO<sub>2</sub> monitoring has been established through multiple studies as a technology that provides an earlier warning sign of impending respiratory depression than both standard monitoring and end-tidal capnography (Bendjelid et al., 2005; Berkenbosch et al., 2001; Chakravarthy et al., 2010; Fanelli et al., 2008; Griffin et al., 2003; Oshibuchi et al., 2003; Reid et al., 1992; Tobias & Meyer, 1997). A transcutaneous CO<sub>2</sub> monitoring device may provide immediate and continuous readings as opposed to the intermittent measure of arterial blood gas PaCO<sub>2</sub>, which is considered the gold standard for assessing CO<sub>2</sub> levels. Further, transcutaneous CO<sub>2</sub> isn't compromised by irregularities in gas exchange (Oshibuchi et al., 2003).

Even though it cannot replace the accuracy of ABG, continuous CO<sub>2</sub> measurement provides an ongoing trend of CO<sub>2</sub> (Huttman et al., 2014). The localized heating from the transcutaneous electrode increases the blood circulation in the capillaries underneath the sensor which gives a capillary CO<sub>2</sub> which is comparable to arterial CO<sub>2</sub> (Huttman et al., 2014). Overall, few studies have assessed the use of transcutaneous CO<sub>2</sub> monitor in the recovery room environment (Fanelli et al., 2008; Kopka et al., 2007).

### **Enhancing Monitoring of Postoperative Safety Variable**

There are definite advantages to providing the additional assessment component of capnography. Upon observing rising levels of CO<sub>2</sub>, clinicians are signaled to reevaluate their patients. Proactive preparation for airway support can be provided if

needed. Also, avoidance of giving additional doses of sedatives until concerns resolve can reduce potential respiratory complications (Green & Pershad, 2010).

There are many strengths of using transcutaneous capnography in surgical patients. Transcutaneous CO<sub>2</sub> readings have the advantage of being easily obtained in patients. The electrode is not easily displaced with movement, and patients do not consider it uncomfortable nor does it disturb their sleep patterns as may be the case with the end-tidal method. The transcutaneous method provides a constant, real-time measurement and is not affected by ventilation/perfusion abnormalities as may be the case with the end-tidal method (Kirk et al., 2006; Torok et al., 2008).

Transcutaneous capnography may increase nursing awareness of trends in altered respiratory function allowing for early nursing intervention. A post-surgical patient can demonstrate gradual increases in his sedation level, especially when receiving opioids. A decrease in opioids provided and more frequent assessment of trends may be required until the patient demonstrates an increase in alertness (Pasero, 2009). When high CO<sub>2</sub> levels occur, the monitor alarm will sound. A benefit of using transcutaneous is that it could provide earlier detection of respiratory issues than pulse oximetry (Kaneko, 1996). Transcutaneous capnography monitoring offers continuous information making it possible for the nurse to detect and follow trends (Torok et al., 2008). One potential benefit of utilizing transcutaneous capnography with its continuous read outs is that it may give nurses increased confidence in monitoring for respiratory distress while increasing or decreasing opioid usage when needed.

**Limitations of Transcutaneous Capnography Monitoring**

Transcutaneous capnography monitoring is not without potential disadvantages. Two significant concerns to healthcare institutions are the potential for thermal injury and the costs of the monitor. According to manufacturer's guidelines, the monitoring site should be changed every 4-6 hours to avoid thermal injury and the electrode must be cleaned and recalibrated before placement at a new site. The complication of thermal burn is rare and primarily occurs when the electrode is left for long periods of time in one location (Coates et al., 2014). The potential for a thermal burn is a significant deterrent to many health care institutions.

Another disadvantage to the use of this monitor is the initial cost to the health care institution in purchasing the equipment. The price of one portable monitor begins at \$20,000.00. The cost does not include the disposable electrodes, conduction gel, and calibration supplies. The cost of the monitor must be thought of in balance with the cost savings of avoiding re-intubation and potentially extended hospital stays from complications of respiratory distress. Overall, research studies indicate that the benefits of transcutaneous capnography are value added.

Documentation of avoided re-intubations due to the early warning of respiratory depression provided by transcutaneous capnography will assist in supporting the proactive use of this monitoring instead of the reactive treatment of events.

**Significance of Measuring Carbon Dioxide in Recovery Room**

Perioperative care is provided in a complex environment. Accurate patient assessment and prompt treatment of ventilatory concerns are necessary to promote patient safety (Greensmith & Aker, 1998). The meaning of patient safety across disciplines

seems to be consistent in regard to the delicate balance of managing postoperative pain and protecting patients from respiratory complications.

In regards to the transcutaneous device, a variety of methods are utilized for obtaining carbon dioxide trends which may have greater safety implications depending on which division the patient is receiving care. Due to the manufacturer's suggested frequency of electrode site changing to be every 4-6 hours, this device is ideal to trial at this specific study institution as the recovery room patients' average length of stay is two hours; however, this device transcending to other divisions within this particular institution may be less likely. Time constraints of nursing staff on divisions whose assignments can include up to five patients may preclude the ability to change the electrode site in the recommended time frame potentially setting the patient up for a thermal burn.

When patients arrive at the recovery room after their operation, most are already extubated, remain drowsy from their anesthesia, and verbalize their discomfort with a request for opioids. There is a gap in the literature in regards to utilizing this type of assessment tool in the immediate recovery room phase of care.

### **Consequences of Post-operative Respiratory Complications**

Intubation and mechanical ventilation are interventions that can be lifesaving in patients but can also increase the potential risk of secondary conditions such as volutrauma, barotrauma, and ventilator-associated pneumonia (VAP). The timing of extubation is related to clinical outcomes and can impact morbidity and mortality. Early extubation is one way of reducing morbidity, but premature extubation may be detrimental. The need for reintubation increases mortality up to 40% in some patient

groups (Glossop, Shepherd, Bryden, & Mills, 2012). In addition to the potential increase in mortality, patients who are reintubated have worse clinical outcomes, increased number of days in the ICU and overall longer hospital stays (Seymour, Martinez, Christie, & Fuchs, 2004). Anesthesia-related, unexpected admission to an ICU is considered a serious outcome associated with anesthesia and has been identified as a clinical indicator acknowledged by the Joint Commission on Accreditation of Healthcare Organizations (Cullen, Nemeskal, Cooper, Zaslavsky, & Dwyer, 1992).

Given the higher cost of ICU care versus ward care, there are also economic implications to consider. If declining respiratory status is noted early, there could be time to allow for a noninvasive form of ventilation to reduce the rates of reintubation in postsurgery patient. Using non-invasive forms of ventilation can reduce the incidence of pneumonia in the postsurgery patient and improve hospital survival (Glossop et al., 2012).

Early identification of patients in the recovery room who have an increasing CO<sub>2</sub> level indicating potential respiratory depression will allow for interventions to increase patient stimulation, reduce opioid administration, and potentially provide naloxone reversal early. Early intervention may assist in avoiding the need for re-intubation and associated increased length of stay within the hospital (Wittekamp, Van Mook, Tjan, & Zwaveling, 2009).

### **Risk Assessment for Safety Variables**

Identification of factors that may predict critical events, such as respiratory depression, in the postoperative patient is of great significance to practice. Implications of complications patients can incur from respiratory compromise can be catastrophic to their

health and safety. Regrettably it is challenging to predict which patients will have respiratory compromise due to a variety of components such as age, length of surgery, type of anesthesia and post-operative opioids.

The immediate postoperative period is a time when even relatively healthy surgical patients undergo significant changes and are vulnerable to the significant risk of experiencing anesthetic and surgical complications. Approximately 10% of all anesthetic accidents occur in the recovery period (Staroverov & Ismailova, 2009).

An opportunity exists to review the current assessment components obtained in postoperative patients, incorporate the additional monitoring of transcutaneous CO<sub>2</sub> monitoring, and trend the patient's data and outcomes. Utilizing a variety of technologies are not meant to be competitive but rather, complementary, offering the ability to combine techniques for assessment enhancement (Huttman et al., 2014). Analysis of the data trends may offer the ability to develop safety and quality improvement protocols which assesses for risks preoperatively for which patients may have postoperative complications. The ability to recognize early in the recovery phase which patients might have an untoward event after surgery could be useful in the management of their care.

The accuracy in the nurse's assessment of their patients' sedation level is crucial in preventing respiratory depression (Pasero, 2009). Nurses impact the ability to reduce adverse outcomes. Transcutaneous capnography can augment the nurse's assessment by providing additional accurate information.

## **Summary**

Chapter 2 described the conceptual framework and model utilized for this study. The literature review discussed the historical concept of patient safety in the American

healthcare system. Also, the recognition of safety for patients in the immediate perioperative environment was reviewed and the safety variables monitored in the immediate recovery room phase. Specifically, understanding the significance of recognizing early rising carbon dioxide levels in patients was studied. The historical use of transcutaneous capnography monitoring was discussed as well as reasons the monitor is not currently used for the assessment of the recovery room patient in spite of documented research advantages.



## **CHAPTER 3: METHODOLOGY**

### **Introduction**

The purpose of this retrospective quasi-experimental study was to generate baseline data to trend patient safety variables and outcomes postoperatively.

Transcutaneous CO<sub>2</sub> levels were assessed for the effects of transcutaneous capnography monitoring on detection of carbon dioxide levels in recovery room patients.

This study had two objectives. One objective was to compare patients on transcutaneous capnography with patients receiving standard postsurgical monitoring to determine if there was a difference in postoperative safety variable trends and outcomes. The second objective of the study was to compare postoperative complications of patients monitored with transcutaneous capnography with patients receiving standard monitoring.

### **Research Questions**

Research Question 1: Are there postoperative differences in trends of safety variables of patients who were monitored with transcutaneous capnography compared to those who received standard monitoring?

Research Question 2: How do patient complication trends relate to the capnography trends and other safety variable trends in recovery room patients?

### **Participants**

The site of the research study was an institution characterized as a 1200-bed, teaching hospital in a large metropolitan city within the Midwest. This hospital was a transplant and level 1 trauma center, spans two campuses, and performs up to 140 surgeries daily.

This retrospective quasi-experimental study used a convenience sample of all patients undergoing surgery and entering into the recovery room where transcutaneous monitoring occurred in addition to routine care. Data on all patients who had the transcutaneous monitoring device postoperatively were analyzed and compared to an equal number of recovery room patients who received usual care without the transcutaneous monitoring during the same time frame.

Standard monitoring equipment used routinely in the recovery room for surgery patients included; electrocardiography, pulse oximeter (SpO<sub>2</sub>), noninvasive arterial blood pressure measurements, heart rate, and respiratory rate.

Transcutaneous capnography (Radiometer TCM monitoring system, Radiometer Medical, Copenhagen) used a heated sensor which was placed on the skin. The TCM400 monitor was reported to have 95% limits of agreement of +/- 6.84 mm Hg. The sensor caused dilatation and increased gas diffusion through the skin from the capillaries. The heating of the sensor allowed for the diffusion of carbon dioxide and oxygen to the skin at 20 times the normal speed. The signal was converted by the monitor and was shown as a CO<sub>2</sub> value. The correlation of TrCO<sub>2</sub> and arterial CO<sub>2</sub> was reported by the company to be very close,  $r= 0.968$ ,  $p<0.0001$ ; mean bias was 0.75mmHg and a reported sensitivity of 86% and specificity of 80%.

The exclusion criteria were: skin anomalies which affected the anterior chest wall and the ability of the electrode to adhere, and ASA score of 6. There was no exclusion concerning gender, race, ethnicity or geography.

Inclusion criteria included: All recovery room patients  $\geq 18$  years of age, no skin anomalies which affect anterior chest wall access and electrode adherence, with an

American Society of Anesthesiologists (ASA) physical status classification system score of 5 or less. This score was obtained preoperatively on all surgical patients by the anesthesiologist or nurse anesthetist and documented in the electronic medical record.

The ASA score definitions are as follows:

1. A normal healthy patient
2. A patient with mild systemic disease
3. A patient with severe systemic disease
4. A patient with severe systemic disease that is a constant threat to life
5. A moribund patient who is not expected to survive without the operation
6. A declared brain-dead patient whose organs are being removed for donor purposes

### **Measures**

Nine dependent variables were tracked for this study as safety measures. They included:

- 1) Respiratory rate - the number of breaths a person takes during a one-minute period.
- 2) Blood pressure (mean level) - average arterial pressure against the inner walls of the blood vessels comparative to the diameter and elasticity of the blood vessel as well as the heartbeat.
- 3) Heart rate – heart beat in number of beats per minute (bpm).
- 4) Oxygen saturation (SpO<sub>2</sub>) – measures blood attached to hemoglobin molecule; how much oxygen the blood has measured as a percentage of the maximum it could be carrying.

- 5) Pain scores – measures a patient’s pain in intensity on a scale of 0 to 10. Zero equating no pain and ten being the most severe pain level. The pain score will be reported in two ways 1) individually by the patient report on the scale of 0-10 and 2) grouped into categories of reported pain.
- 6) Aldrete scores – a measurement of recovery after anesthesia that includes gauging, oxygen, consciousness, activity, respiration and blood pressure on a scale of 1-10. Two points maximum are given in each category, and a patient must have a score of 9 to 10 to be discharged from the recovery room.
- 7) Opioid doses administered, both individual and total, were also be collected. This collection will include the number of doses administered, amount of Dilaudid given with each dose, and the total amount of Dilaudid administered. Standard opioid administered is Dilaudid .25 mg per dose. Dose amount given is determined by protocol and based from the patient pain score. Pain score grouping was 0-5, 6-8, and 9-10. This categorical grouping coincided with the standardized medication administration orders for administration of Dilaudid according to pain score. The group 0-4 has no pain medication administered, the groups 5-8 have standard orders for 0.25mg Dilaudid to be administered, and 9-10 pain score patients have 0.5mg Dilaudid ordered for treatment. Upon occasions, Morphine is ordered and administered related to patient allergies and past medical history.
- 8) Recovery room time – the total number of minutes a patient remains in the recovery room from the start of Phase I care to the end of Phase I care.

- 9) Recovery room intubation occurrences – the insertion of a tube into the trachea for purposes of anesthesia, airway maintenance, or ventilation. Intubations will be entered as either a yes or no for the occurrence during the recovery room timeframe.

Demographic variables were obtained on all participants. These variables included: diagnosis, surgical procedure, age, gender, height, weight, BMI, and ASA score.

Data points on variables 1 through 7 above were collected and analyzed via repeated measures at three specific time frames. The time frames these dependent measurements were obtained were at admission to the recovery room, 30 minutes after admission, and 60 minutes after admission. Based on the prior use of the monitor within this specific recovery room, if patients were to experience respirator deterioration it would usually occur within the first 30 to 45 minutes of arrival (Davis, 2011). The dependent variables of recovery room time and recovery room intubation were obtained and coded when the patient is discharged from recovery. The demographic variables were coded once.

### **Design**

This study used a retrospective quasi-experimental design. This design allowed for statistical contrasts between control and treatment groups with random assignment to treatment. The time series component of this design referred to measurements (discussed above) made on condition of the patients at three points in time.

Medical records of recovery room patients who met the inclusion criteria were pulled from an extant database, Metavision, which houses electronic medical records.

Participants who had a room assignment with a capnography device in it were automatically included in the treatment group. An equal number of recovery room patients' medical records admitted to room assignments without a capnography monitor in it during this same time frame served as the comparison group. Data on the first seven dependent measures identified above were collected at three points in time. Measures and time were treated as within subject factors.

### **Human Subjects**

The principal investigator completed human subject protection training. The study was approved by the Institutional Review Boards (IRB) at the University of Missouri-St. Louis and also approved through the Study Proposal Review Committee at Barnes-Jewish Hospital for administrative review. The procedures to protect the right of human subjects were implemented, and no problems or confidentiality issues were observed. The participants remained anonymous as codes were assigned to names. Names were removed. All personal information taken from the electronic data system was coded and remains unidentified.

### **Procedures**

This retrospective quasi-experimental study was limited to the south campus recovery room which performs approximately 140 surgeries daily. Although the recovery room on the south campus spans across two floors, the four capnography monitors were located on the second floor recovery room. The control group data was also taken from the second floor recovery room population.

Education was provided by Radiometer Company representatives to all assistant managers, resource nurses and staff nurses for specific operations including calibration

of the monitor, re-membraning the sensor, and application. The training included: application of the electrode, identification of electrode sites, calibration of the monitor, alarm settings, and skin assessments frequency and documentation. The unit educator provided real time instruction if questions arose regarding calibration and application of the electrode to confirm consistency in the process.

The calibration of the monitor was performed prior to placement of the electrode, whenever the sight was changed, and every time the sensor was re-membraned. The steps in calibration included: turning on the power at back of monitor, pressing the on button in front of monitor, press *ON* in front of monitor and *OK* on the screen, inserting the sensor in the calibration chamber and pressing *CALIBRATION*. A signal alerted when the calibration was completed.

The sensor was re-membraned every 1-2 weeks as recommended by the manufacturer. The monitor provided a visual reminder to perform this task which eliminated the possibility of staff forgetting.

The calibration CO<sub>2</sub> gas cylinder was changed whenever the monitor alarm signaled the need. Staff was educated on changing the cylinder which was found to be quick and easy. The empty cylinder was removed by unscrewing it by turning it counter clockwise. A full cylinder required a white protection cap to be removed so the new cylinder could be screwed clockwise onto the monitor.

Staff education also included potential alarms which could have occurred such as changing the sensor ring, gas cylinder, and the fixation ring. The replacement steps instructed were to calibrate the sensor, remove a fixation ring form the protective film, apply the ring to the center of the measuring site and then to press it firmly in place. The

fixation ring then required two to three drops of contact liquid before aligning the arrow on the sensor with the mark on the actual ring. Staff found the process simplistic and easy to perform.

Upon arrival to the preoperative holding area on the day of surgery, the nurse obtained patient demographics and baseline assessment which was entered into the electronic documentation system, Metavision. The anesthesiologist documented a preoperative ASA score. Demographic variables which were assessed were: diagnosis, surgical procedure, age, gender, height, weight, BMI, ASA score, past medical and surgical history.

The transcutaneous capnography monitors (TCM) remained in specific rooms and all patients admitted to that room had the TCM placed by the nurse. The average length of stay in the recovery room for patients was two hours or less. Each room had approximately five patients each admitted to it during one day. As patients completed surgery, the nurse in the operating room called out to the recovery room charge nurse to obtain room assignment. The charge nurse assigned the patient to a room randomly based on which room was available. The room assignment was on a first come, first serve basis.

Upon the patient's arrival to the room, the transcutaneous monitor was calibrated before being placed on each patient's chest. The temperature on the monitoring unit was set, and the monitor's settings were locked at 41 degrees centigrade. Assessment of skin integrity for electrode site was performed and documented in Metavision before placement and after removal.

The electrode placement was on the anterior chest wall and not placed over an internal pacemaker or on top of previous scar tissue. The patient's chest wall was dry and



was shaven if hair prohibited adequate contact of electrode to skin. The staff applied the transcutaneous electrode and ensured the monitor was tracking the CO<sub>2</sub> levels. The electrode was removed after two hours.

Standard care provided routinely in the recovery room for surgical patients included: electrocardiography, pulse oximeter (SpO<sub>2</sub>), noninvasive arterial blood pressure measurements, heart rate, and respiratory rate. Additional orders for end-tidal capnography might have been obtained based on physician preference. The data was automatically downloaded into the monitor, recorded, and saved within Metavision, the electronic medical record. In addition to this usual care, transcutaneous capnography (TrCO<sub>2</sub>) data which is visual continually on the monitor was manually recorded every ten minutes into the same electronic database by the staff. Arterial blood gases were obtained only if clinically indicated and were obtained from the arterial line, which was placed before surgery.

All documentation of opioid administration was captured electronically by dose amount and time given within Metavision. Also, all vital signs, pain scores, oxygen saturation and capnography levels (both end-tidal and transcutaneous) were electronically documented into the patient's electronic medical record every ten minutes. Patients were assessed by Modified Aldrete score upon admission and every thirty minutes until discharge from the recovery room. The score was manually entered into the documentation system by the nursing staff.

The ideal direction variables should take postoperatively was a respiratory rate stabilizing between twelve and twenty, mean blood pressure < 80, heart rate <80, oxygen

saturation increasing > 92%, pain scores decreasing < 5, Aldrete increasing to 9-10, and a RASS score increasing to 0.

All information except for the arterial blood gas levels was automatically collected and stored in the Phillips monitor and system every ten minutes. Arterial blood gas results were entered by into the documentation system by hospital laboratory staff.

### **Data Management and Analysis**

Data points were be retrieved by the Perioperative Information System (IS) Department, formatted and saved in an Excel spreadsheet on a hard drive. A summary of descriptive statistics were obtained from the Performance Improvement Department with on the data retrieved with the frequencies, percent, means, median, and standard deviation of all information (age, BMI, gender). The data on the hard drive was kept in a locked perioperative office and access to the office was limited to the principal investigator. The principal investigator assessed the data for any missing data points on demographic information and manually imputed results into the Excel spreadsheet.

Data were analyzed via a group (treatment vs. control), by measures (respiratory rate vs. blood pressure vs. heart rate vs. oxygen saturation vs. pain score vs. Aldrete score vs. opioid doses) and by time (admission vs. 30 minutes vs. 60 minutes) multivariate analysis of variance (MANOVA). The latter two measures were treated as within-subject factors. Significant interactions were investigated using appropriate posthoc analyses. Recovery time was assessed at discharge only and was analyzed via an independent *t* test. Reintubation was assessed at discharge and analyzed using a 2 (treatment vs. control) by 2 (yes vs. no) Chi-Square.

**Summary**

The purpose of the study was to examine variables for trends on recovery room patients utilizing the transcutaneous monitor compared to patients with standard monitoring alone. Comparison of opioids administered between both groups in addition to complications incurred could allow for the development of protocols in the management of high-risk patients. Identifying patients early who have an increased risk of developing respiratory depression in the recovery room may facilitate prevention through reduction of opioid administration and early treatment. The need for re-intubation and associated increased length of patient stay may be reduced or eliminated (Wittekamp et al., 2009).

## CHAPTER 4:

### RESULTS

This chapter presents the findings of this retrospective quasi-experimental study. Data were gathered retrospectively from the dates January 2, 2015 to July 30, 2015. This chapter presents descriptions of the overall sample, including their characteristics, and any potential differences between the groups. Also in this chapter are the comparison between groups of time in Phase I recovery, opioids administered, review of all data variables, and summary of results. The specific findings related to each research question are also presented.

#### **Data Analysis Decisions**

There were 833 patients, aged 18 years or older, available for study participation. Seventeen patients were found to have multiple encounters in the PACU data, so only data from their first encounter were included in the study. For this group, the presence of multiple entries was not associated with the TrCO<sub>2</sub> study group (3.5% in Control group vs. 2.1% in TrCO<sub>2</sub> study group,  $p=0.234$ ). After applying the above criteria, 17 subjects were eliminated from the study resulting in a final sample size of 816 subjects with 397 (48.7%) in control group and 419 (51.3%) in TrCO<sub>2</sub> study group.

Numerous demographic, patient safety, and medication utilization variables of interest were recoded into categorical measures to improve statistical power and clinical interpretation. Patient's body mass index (BMI) was calculated using recorded patient height and weight values. Age, BMI, and PACU Time in Phase I was recoded into categorical variables. Patient safety scores were recoded as categorical variables at clinically-relevant cut points and change from PACU admission score to 30- or 60-minute measurements.

Dosing of the opioid medications hydromorphone, fentanyl, and morphine were classified as “High” (greater than or equal to: 0.50 mg, 50 mcg, and 4 mg, respectively) or “Low” (less than: 0.50 mg, 50 mcg, and 4 mg, respectively). Further, medication administration was stratified in relation to time of PACU admission (less than or equal to 15 minutes), 16 – 30 minutes, 31 – 60 minutes, or greater than 60 minutes. A tally of these stratified dosing counts was aggregated by dosing strength and timeframe.

A series of independent samples *t*-tests were conducted to compare continuous variables between study groups. Non-parametric Mann-Whitney *U* tests were used when parametric assumptions were not upheld. A series of Chi-square tests were used to assess the association of categorical variables by study group. Fisher’s exact tests were calculated when expected cell sizes were too small. Alpha was preset at .05 for all significance testing. Statistical analysis was performed using *IBM SPSS Statistics for Mac* version 24.0 (IBM Corporation, Somers, NY, USA).

### **Description of the Overall Sample**

The data were analyzed for a total of 419 patients (TrCO<sub>2</sub> study group) and 397 patients (control group) who received care during the same time frame. Sixty-six patients had more than one encounter that may have been from multiple visits to the operating room. For the multiple encounter patients, data from the first surgeries only were included for this analysis.

Demographic and clinical summary statistics by study group are reported in Table 4. The participants ranged in age from 14 to 95 years in the control group and 17 to 93 years in the TrCO<sub>2</sub> study group. Gender for both groups was slightly greater in female participants. BMI was categorized into groups of underweight (<18.5), healthy (18.5-

24.9), overweight (25-29.9), and obese (> or equal 30) with the obese group having the majority of patients for both control and TrCO<sub>2</sub> study groups.

The study groups were equivalent with the exception of one variable. ASA was significantly associated with the TrCO<sub>2</sub> study group:  $X^2(4, N = 816) = 16.089, p = 0.003$ . However, the TrCO<sub>2</sub> study group participants were more likely to have had a missing ASA. When missing ASA participants were excluded (Table 2), ASA remained significantly associated with the TrCO<sub>2</sub> study group:  $X^2(3, N = 222) = 12.600, p = 0.006$ . Thus, TrCO<sub>2</sub> study group participants were more likely to have had a higher ASA when compared to the control group. The proportion of missing ASA is high (TrCO<sub>2</sub> = 76% vs. Control = 70%), which may warrant exclusion from subsequent adjustments in the analysis.

Table 4

*Demographic and clinical summaries by Study Group (N = 816)*

Variable	Control <i>n</i> = 397		TrCO <sub>2</sub> <i>n</i> = 419		Difference			
	Mean	<i>SD</i>	Mean	<i>SD</i>	Mean	<i>t</i>	<i>df</i>	<i>p</i> -value
Age (years)	57.30	15.5	56.12	15.6	-1.18	1.083	814	0.279
Height (centimeters)	170.30	11.0	170.53	10.4	0.23	-0.302	794	0.763
Weight (kilograms)	87.14	24.5	86.81	26.6	-0.33	0.179	771	0.858
BMI	29.94	7.7	29.97	8.8	0.03			0.557 †

Variable	Control		TrCO <sub>2</sub>		Difference			
	<i>n</i>	%	<i>n</i>	%	%	Chi-square	<i>df</i>	<i>p</i> -value
Age						1.521	1	0.217
18 - 59	197	49.6	226	53.9	4.3			
≥ 60	200	50.4	193	46.1	-4.3			
Gender						0.016	1	0.899
Male	183	46.1	195	46.5	0.4			
Female	214	53.9	224	53.5	-0.4			
BMI						3.608	3	0.307
Underweight (< 18.5)	8	2.1	12	3.2	1.1			
Healthy (18.5 - 24.9)	88	22.6	98	25.9	3.3			

Overweight (25.0 - 29.9)	132	33.9	108	28.5	-5.4			
Obese ( $\geq 30$ )	161	41.4	161	42.5	1.1			
ASA						16.089	4	0.003
1	6	1.5	9	2.1	0.6			
2	75	18.9	44	10.5	-8.4			
3	39	9.8	44	10.5	0.7			
4	0	0.0	5	1.2	1.2			
Missing	277	69.8	317	75.7	5.9			
Facility						6.784	5	0.237
Pod 1	108	27.2	122	29.1	1.9			
Pod 2	163	41.1	157	37.5	-3.6			
Pod 3	59	14.9	62	14.8	-0.1			
Pod 5	62	15.6	62	14.8	-0.8			
Remote Anesthesia	2	0.5	10	2.4	1.9			
CPC	3	0.8	6	1.4	0.6			

† Mann-Whitney U Test

The frequency distribution for the ASA data is shown in Table 5. The groups remained significantly different even when missing data were excluded. There was a possibility that the missing data were located in an undetermined area of the extant database where it could not be found, if it was documented in the electronic medical record at all. Opportunities existed to ensure the ASA score was performed and documented in one location within the hospital’s documentation system. This would promote consistency so that all team members would have access for review.

Table 5

*Frequency Table: ASA*

ASA	Frequency	Percent	Valid Percent
1	15	1.8	6.8
2	119	14.6	53.6
3	83	10.2	37.4
4	5	.6	2.3
Total	222	27.2	100.0
Missing	594	72.8	
Total	816	100	

Originally the surgical procedures data were retrieved by the primary service providing the care (Table 6). A total of 18 categories of surgery were identified, far too many to be useful as a predictor of outcomes. The size of some of the categories caused the variable to be statistically different by study group. This data was then represented in a descriptive format as a variety of surgery services represented among the sample participants.

Table 6

*Surgery Frequency by Primary Service*

Service	Frequency	Percent	Cumulative %
ACCS	16	2.0	2.0
Anesthesiology	11	1.3	3.3
Cardiothoracic	40	4.9	8.2
Cardiovascular	9	1.1	9.3
Colorectal	26	3.2	2.5
Gastroenterology	4	.5	13.0
General Oncology	3	.4	3.4
GYN	99	12.1	25.5
Hepatobiliary	23	2.8	28.3
Minimally Invasive	15	1.8	30.1
Neurosurgery	71	8.7	38.8
Ophthalmology	1	.1	39.0
Orthopaedic	293	35.9	74.9
Otolaryngology	55	6.7	81.6
Plastic	9	1.1	82.7
Transplant	17	2.1	84.8
Urology	74	9.1	93.9
Vascular	50	6.1	100.0
Total	816	100	



Patients arrived to the recovery room from several operating room divisions, also known as “POD”s (perioperative division). Each POD performs various surgical specialties:

- POD 1: gynecology, genitourinary, colorectal
- POD 2: orthopedics, trauma, plastic surgery
- POD 3: hepatobiliary, transplant, vascular, cardiac, and thoracic
- POD 4: located on the north campus and not included in this study
- POD 5: neurology, ear-nose-throat
- CPC: cardiac procedure lab
- Remote: patients who had a “procedure” performed outside of the PODs that required anesthesia support, i.e. MRI, in vitro fertilization

Patients were categorized by the division in which their surgery was performed. There were six potential divisions in which patient could have their procedures performed. When patients were categorized by the division in which their surgery was performed, there was no significant difference between study groups (Table 7). Most of the samples were in PODs 1 through 4, with nine patients in CPC and 12 in Remote Anesthesia.

Table 7

*Surgeries Categorized by Operating Room PODs*

	Frequency	Percent	Cumulative %
POD 1	230	28.2	28.2
POD 2	320	39.2	67.4
POD 3	121	14.8	82.2
POD 5	124	15.2	97.4
Remote Anesthesia	12	1.5	98.9
CPC	9	1.1	100.0
Total	816	100.0	

**Time in Phase I Recovery**

Upon arrival to the recovery room, clinical processes classified a patient as being in Phase I care. This was the immediate recovery phase as the patient recovers from the effects of anesthesia. Upon completion of phase I recovery, patients were admitted to the hospital or discharged to home if they had a small same day surgical procedure. The average length of stay in the recovery room for Phase I level of care was approximately 2 hours. Time in Phase 1 was recorded in minutes as a continuous variable in the dataset and also as a categorical variable (less than versus greater than and equal to 120 minutes, based on typical care).

Time in Phase I by study group is reported below in Table 8 and displayed in Figure 2. Time in Phase I as a continuous variable was significantly shorter for the TrCO<sub>2</sub> study group ( $M=128.4$  minutes) as compared to the control group ( $M=151.1$  minutes).

Table 8

*Time in Phase I by Study Group (N = 816)*

Variable	Control <i>n</i> = 397		TrCO <sub>2</sub> <i>n</i> = 419		Difference		
	Mean	<i>SD</i>	Mean	<i>SD</i>	Mean	<i>U</i>	<i>p</i> -value
Time in Phase I (minutes)	151.1	54.5	128.4	60.8		60382.0	<.001 †

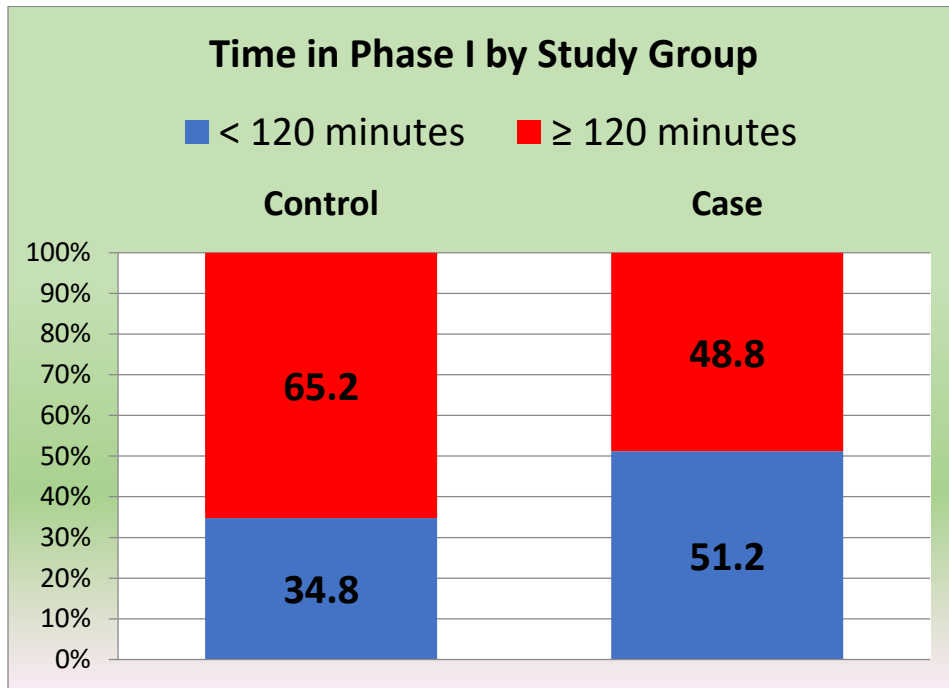
  

Variable	Control		TrCO <sub>2</sub>		Difference			
	<i>n</i>	%	<i>n</i>	%	%	Chi-square	<i>df</i>	<i>p</i> -value
Time in Phase I (minutes)						22.382	1	<.001
< 120	138	34.8	213	51.2	16.4			
≥ 120	259	65.2	203	48.8	-16.4			

† Mann-Whitney U Test

The average length of stay in the recovery room was less than two hours. When time in Phase I was reviewed as a categorical variable, the TrCO<sub>2</sub> study group showed significantly less time spent in the recovery room overall compared to the control group.

Figure 2. Comparison of Phase 1 Time in Minutes by Control and TrCO<sub>2</sub> study groups



**Opioid Administration**

Overall administration of opioids was significantly less for the TrCO<sub>2</sub> study group as compared with the control group. This difference included administration of fewer opioids and, particularly in later time frames, lower doses of opioids. This difference was offset somewhat because the control group had more opportunities for opioids to be administered due to their longer timeframe in Phase I recovery.

Opioid administrations provided to patients were categorized by four time periods from patient’s arrival to the recovery room to the first dose administered. The categories were: < 15 minutes of arrival in the division, between 16-30 minutes, 31-60 minutes, and

> 60 minutes (Table 6). The TrCO<sub>2</sub> study group had significantly lower doses administered upon review of an overall number of doses and doses occurring at the > 60 minutes period. Any “unusual values” recorded for opioid doses were excluded from analysis as the recovery room nurse provides doses according to standardized order sheets. Doses administered with unusual values may have been provided by the anesthesiology department as they tend to provide doses outside recovery’s standard orders.

In order to categorize the medications by dose, high and low dose definitions were specified for each of the three major opioids used in the recovery room. Hydromorphone doses of < 0.50 mg were considered as low and  $\geq 0.50$  mg were coded as high. Fentanyl doses of < 50 mcg were recorded as low and  $\geq 50$  mcg were considered high. Finally, morphine of < 4 mg was considered as low and  $\geq 4$  mg were recorded as high.

Each opioid dose given to the patient was counted as an encounter, recognizing that the doses may not be equivalent across the medications but are all Schedule 2 drugs (e.g., one hydromorphone + 2 fentanyl = 3 opioids). Because some administrations are stronger than others, opioids were also grouped across medications by their binary dose (e.g., two low dose hydromorphone and 1 low dose of fentanyl = 3 low dose opioids; see Table 6). Doses of opioids administered, categorized as high versus low, were found to be significantly lower at several time frames for the TrCO<sub>2</sub> study group as compared with the control group.

Opioid administration by both groups is reported in Table 9 and displayed graphically in Figure 3. Overall opioid administration, combined across all times and

doses, was significantly lower among the TrCO<sub>2</sub> study group compared to the control group.

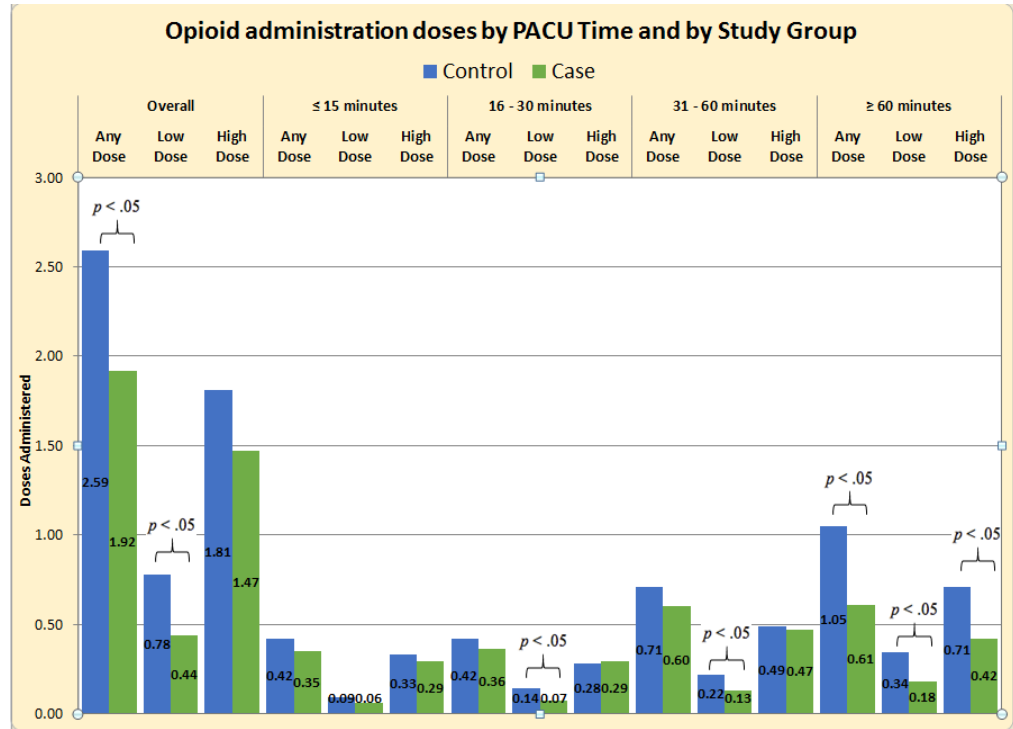
Table 9

*Opioid Administration Doses by PACU Time and by Study Group (N = 816)*

Variable	Control <i>n</i> = 397		TrCO <sub>2</sub> <i>n</i> = 419		Difference		
	Mean	SD	Mean	SD	Mean	<i>U</i>	<i>P</i> -value
Opioid	2.59	3.1	1.92	2.4	-0.67	73519.5	0.003 †
≤ 15 minutes	0.42	0.7	0.35	0.7	-0.07	78813.5	0.100 †
16 - 30 minutes	0.42	0.7	0.36	0.6	-0.06	79953.0	0.241 †
31 - 60 minutes	0.71	0.9	0.60	0.9	-0.11	78233.5	0.098 †
> 60 minutes	1.05	1.8	0.61	1.2	-0.4	70179.0	<.001 †
Opioid, Low Dose	0.78	1.4	0.44	1.0	-0.34	75013.0	0.002 †
≤ 15 minutes	0.09	0.3	0.06	0.3	-0.03	80881.5	0.114 †
16 - 30 minutes	0.14	0.4	0.07	0.3	-0.07	78785.0	0.009 †
31 - 60 minutes	0.22	0.6	0.13	0.4	-0.09	79005.0	0.030 †
> 60 minutes	0.34	0.8	0.18	0.6	-0.2	76561.5	0.001 †
Opioid, High Dose	1.81	2.7	1.47	2.2	-0.34	77725.0	0.083 †
≤ 15 minutes	0.33	0.7	0.29	0.6	-0.04	80931.0	0.365 †
16 - 30 minutes	0.28	0.6	0.29	0.6	0.01	82334.5	0.735 †
31 - 60 minutes	0.49	0.8	0.47	0.8	-0.02	82675.5	0.858 †
> 60 minutes	0.71	1.5	0.42	1.0	-0.3	74027.5	<.001 †

† Mann-Whitney U Test

Figure 3. Opioid Administration



**Patient Safety Variables**

Although there was no statistical difference in the overall sample population, the results of the patient safety variables over time show significant initial baseline differences between the control and TrCO<sub>2</sub> study group in several categories (Table 10 and Figure 4).

Table 10

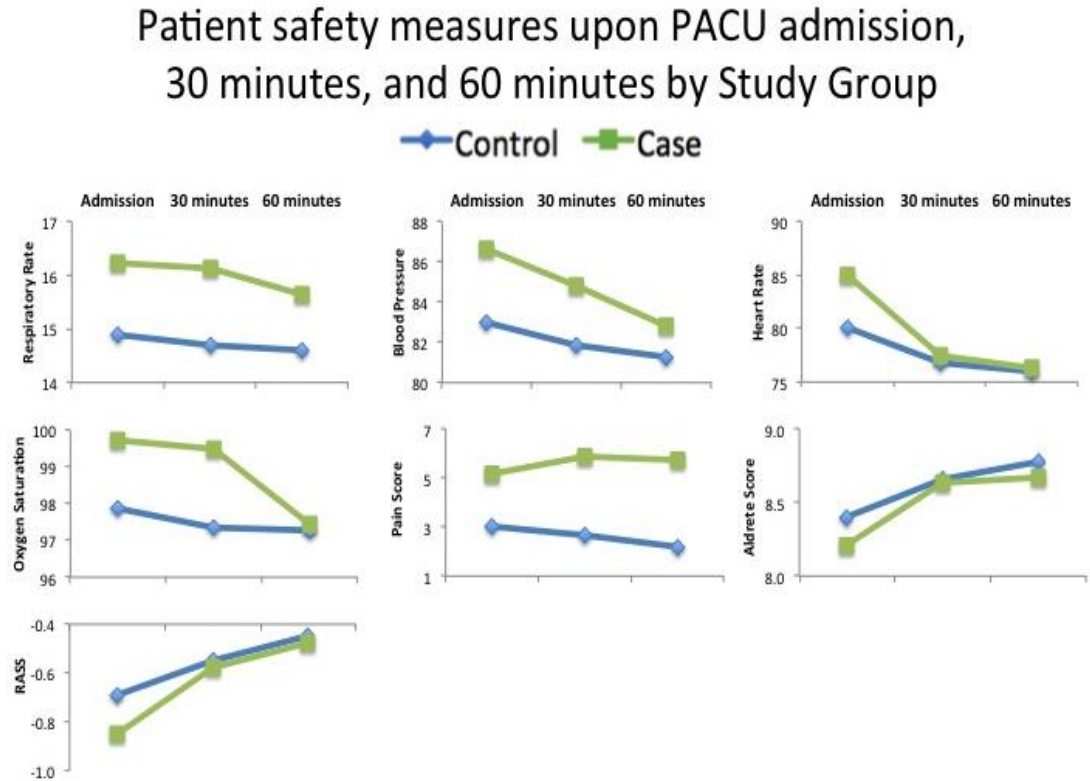
*Patient Safety Variables upon PACU Admission and Over Time (N = 816)*

Variable	PACU Time	Control n = 397		TrCO <sub>2</sub> n = 419		Difference		p-value	
		Mean	SD	Mean	SD	Mean	U		
Respiratory Rate	Admission	14.88	4.5	16.22	5.6	1.34	69135.0	<.001	†
	30 minutes	14.69	4.1	16.13	5.1	1.44	68617.0	<.001	†
	60 minutes	14.60	5.7	15.64	6.2	1.04	69504.5	0.001	†
Blood Pressure, mean level	Admission	82.99	15.0	86.67	15.9	3.68	69541.5	0.001	†
	30 minutes	81.88	13.9	84.82	15.6	2.94	73074.0	0.006	†
	60 minutes	81.27	13.1	82.77	14.0	1.50	75805.0	0.073	†

Heart Rate	Admission	80.04	15.9	85.02	53.1	4.98	75733.0	0.041	†
	30 minutes	76.87	16.4	77.44	16.5	0.57	81618.0	0.825	†
	60 minutes	75.95	16.9	76.23	16.7	0.28	80744.0	0.944	†
Oxygen Saturation (SpO <sub>2</sub> )	Admission	97.87	2.6	99.70	44.8	1.83	76121.5	0.066	†
	30 minutes	97.36	2.7	99.49	44.6	2.13	78892.5	0.346	†
	60 minutes	97.27	2.7	97.42	3.0	0.15	80824.5	0.820	†
Pain Score	Admission	3.05	3.9	5.16	4.6	2.11	56106.5	<.001	†
	30 minutes	2.68	3.5	5.83	4.3	3.15	45140.5	<.001	†
	60 minutes	2.19	3.0	5.73	4.2	3.54	38379.5	<.001	†
Aldrete Score	Admission	8.40	0.8	8.21	0.7	-0.19	70282.5	0.001	†
	30 minutes	8.66	0.8	8.63	0.8	-0.03	77118.0	0.715	†
	60 minutes	8.77	0.9	8.67	1.1	-0.10	74724.0	0.610	†
RASS	Admission	-0.69	0.9	-0.85	1.0	-0.16	70035.5	0.006	†
	30 minutes	-0.55	0.7	-0.58	0.8	-0.03	68938.0	0.716	†
	60 minutes	-0.45	0.7	-0.48	0.9	-0.03	65783.5	0.361	†

† Mann-Whitney U Test

Figure 4. Patient Safety Variables Baseline & Over Time



Since the two groups had baseline differences seen in their mean scores represented in Table 10, a target number for each safety variable was established and then a percent of change from the target (Table 11). The ability of the variable to be close to the established target was then measured upon admission as well as 30 and 60 minutes afterward by study groups.

The TrCO<sub>2</sub> study group, as compared with the control group, was less likely to achieve their target respiratory rate of  $\leq 20$  breaths per minute upon admission and at 30- and 60-minutes after admission. The TrCO<sub>2</sub> study group was less likely to achieve a target blood pressure mean level of  $\leq 80$  upon admission and at 30-minutes after admission as compared with the control group while they also were less likely to achieve a target pain score of  $\leq 5$  at 30 and 60-minutes after admission as compared with the control group. Upon admission, the TrCO<sub>2</sub> study group as compared with the control group was less likely to achieve a target Aldrete Score of  $\geq 9$  or a RASS of  $\geq 0$ . However upon 30 and 60 minute measurements both improved. There were significantly fewer patients with pain scores less than 5 at 30 and 60 minutes in the TrCO<sub>2</sub> study group. The Richmond Agitation Scale Score (RASS) was notably more improved, a higher number, indicating the patient is more awake and alert.

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Table 11

*Patient Safety Measure Target Achieved upon Admission and Over Time (N=816)*

Variable	Target	PACU Time	Control <i>n</i> = 397		TrCO <sub>2</sub> <i>n</i> = 419		Difference			
			<i>n</i>	%	<i>n</i>	%	%	Chi-square	<i>df</i>	<i>p</i> -value
Respiratory Rate	≤ 20	Admission	363	91.9	335	81.1	10.8	19.968	1	<.001
		30 minutes	364	92.2	346	83.6	-8.6	13.846	1	<.001
		60 minutes	364	92.2	353	86.9	-5.3	5.781	1	0.016
Blood Pressure, mean level	≤ 80	Admission	178	45.1	154	37.6	-7.5	4.673	1	0.031
		30 minutes	188	47.6	165	39.7	-7.9	5.185	1	0.023
		60 minutes	194	49.1	182	44.0	-5.1	2.157	1	0.142
Heart Rate	≤ 80	Admission	204	51.6	200	47.8	-3.8	1.172	1	0.279
		30 minutes	244	61.8	259	62.1	0.3	0.010	1	0.921
		60 minutes	244	61.8	255	62.2	0.4	0.015	1	0.902
Oxygen Saturation (SpO <sub>2</sub> )	≥ 92	Admission	385	97.5	401	96.6	-0.9	0.499	1	0.480
		30 minutes	382	96.7	400	96.4	-0.3	0.063	1	0.801
		60 minutes	386	97.7	404	97.8	0.1	0.009	1	0.924
Pain Score	≤ 5	Admission	265	67.1	198	63.9	-3.2	0.798	1	0.372
		30 minutes	280	70.9	165	55.6	15.3	17.359	1	<.001
		60 minutes	320	81.0	185	69.3	11.7	12.104	1	0.001
Aldrete Score	≥ 9	Admission	148	37.5	109	27.1	10.4	9.776	1	0.002
		30 minutes	210	53.2	209	52.8	-0.4	0.012	1	0.913
		60 minutes	227	57.5	233	60.8	3.3	0.912	1	0.340
RASS	≥ 0	Admission	153	38.7	115	29.0	-9.7	8.295	1	0.004
		30 minutes	196	49.6	172	48.6	-1.0	0.080	1	0.778
		60 minutes	223	56.5	182	52.8	-3.7	1.019	1	0.313

To better compare the control versus TrCO<sub>2</sub> study group, the percent of change noted over time (target change) was incorporated to assess the degree the subjects had a change from their own baselines for each metric as an indicator of improvement or worsening of variables (Table 12). This approach was helpful in adjusting for the different starting points at admission to show actual improvement in the TrCO<sub>2</sub> study group.

Patient safety measure target change upon PACU admission as well as 30 and 60 minutes afterward by study groups were reported. As compared with the control group, the TrCO<sub>2</sub> study group was more likely to:

1. Decrease heart rate by at least 20% from PACU Admission to 60-minutes
2. Less likely to maintain a pain score of less than or equal to 1 point from PACU Admission to 30 minutes and from PACU Admission to 60 minutes.
3. More likely to increase their Aldrete Scores by at least 1 point from PACU Admission to 30 minutes and from PACU Admission to 60 minutes.
4. More likely to increase RASS by at least 1 point from PACU Admission to 30 minutes and from PACU Admission to 60 minutes.

The TrCO<sub>2</sub> study group may have improved patient management via Aldrete/RASS over time, but their pain became more pronounced. Assessment was based upon the "success" of target change. The target change was determined based on expected percent of changed noted in vital signs for patients after surgery as defined by use of the Aldrete scoring definitions. For example, a mean blood pressure (MBP) target change of  $\leq 10\%$  means that, ideally, MBP remained the same or only slightly increased (by no more than 10%).

Table 12

*Patient Safety Measure Target Change from PACU Admission & Over Time (N = 816)*

Variable	Target Change	PACU Time	Control		TrCO <sub>2</sub>		Difference			
			n = 397		n = 419		%	Chi-square	df	p-value
			n	%	n	%				
Respiratory Rate	Decrease ≤ 20% [Admin ≥ 8]	30 minutes	92	24.0	102	25.6	1.6	0.271	1	0.603
		60 minutes	112	29.2	125	32.0	2.8	0.717	1	0.397
Blood Pressure, mean level	Increase ≤ 10%	30 minutes	317	80.3	343	83.9	3.6	1.781	1	0.182
		60 minutes	312	79.0	336	82.8	3.8	1.843	1	0.175
Heart Rate	Decrease ≤ 20%	30 minutes	32	8.1	39	9.4	1.3	0.398	1	0.528
		60 minutes	46	11.6	72	17.6	6.0	5.627	1	0.018
Oxygen Saturation (SpO <sub>2</sub> )	Increase ≥ 0	30 minutes	116	29.4	107	25.9	-3.5	1.209	1	0.272
		60 minutes	114	28.9	103	25.1	-3.8	1.478	1	0.224
Pain Score	Increase ≤ 1	30 minutes	347	87.8	278	73.9	13.9	24.287	1	<.001
		60 minutes	336	85.1	240	67.4	17.7	32.628	1	<.001
Aldrete Score	Increase ≥ 1	30 minutes	100	25.3	143	37.3	12.0	13.081	1	<.001
		60 minutes	139	35.2	169	45.6	10.4	8.545	1	0.003
RASS	Increase ≥ 1	30 minutes	91	23.0	118	33.4	10.4	9.994	1	0.002
		60 minutes	131	33.2	148	42.9	9.7	7.429	1	0.006

### Transcutaneous Monitoring Subset Analysis

TrCO<sub>2</sub> readings were captured for participant cases only. The readings were performed repeatedly during each participant's time in the PACU, but for different durations and at inconsistent intervals (though most maintained a 10 minute interval). Participant cases were excluded from this subset analysis if the initial TrCO<sub>2</sub> reading was zero or missing as well as if the average of subsequent readings was zero or missing. After 7 (2%) of cases were excluded, 412 valid cases were analyzed as a case-only subset.

On average, the initial TrCO<sub>2</sub> reading was 36.6 (*SD*=8.7, range 9.0 to 65.0). The average of subsequent TrCO<sub>2</sub> readings was 43.3 (*SD*=7.2, range 21.3 to 82.3). The initial TrCO<sub>2</sub> readings for each participant were compared to the average of subsequent readings

in order to assess directional change and management of TrCO<sub>2</sub>. Among the 412 subset cases, 37 (9.0%) decreased by at least 5% from the initial TrCO<sub>2</sub> reading to the average of subsequent readings.

As reported in Table 13, the cases which reported pain scores of  $\leq 5$  at PACU admission were less likely to decrease their TrCO<sub>2</sub> from initial reading to average of subsequent readings (6.7% vs. 13.4%,  $X^2(1, N = 305) = 3.825, p = .050$ ). The average of subsequent TrCO<sub>2</sub> readings ( $M=42.4; Mdn=41.5$ ) was significantly lower for those reporting a pain score of  $\leq 5$  at PACU admission ( $M=43.4; Mdn=43.0; U=9323.0, p = 0.039$ ). The comparisons of average subsequent TrCO<sub>2</sub> readings by binary pain score in PACU at 30 and 60 minutes were not significantly different.

The average of subsequent TrCO<sub>2</sub> readings was significantly correlated with opioid administration of low doses after 60 minutes. Also, there was a weak, positive correlation,  $r = 0.107, n = 412, p = 0.030$ . The average of subsequent TrCO<sub>2</sub> readings was also significantly correlated with pain score at admission and at 30 minutes. Both pain score results were weak, positive correlations: admission:  $r = 0.116, n = 391, p = 0.022$  and 30 minutes:  $r = 0.101, n = 383, p = 0.049$ .

The time in Phase I did not differ by whether TrCO<sub>2</sub> readings decreased. The time in Phase I was not correlated with either initial TrCO<sub>2</sub> readings or the average of subsequent readings.

Table 13

*TrCO<sub>2</sub> Subset: Average of Subsequent Readings by Pain Score (N = 412)*

Variable	Pain Score 0-5 <i>n</i> = 194		Pain Score 6- 10 <i>n</i> = 112		Difference		
	Mean	<i>SD</i>	Mean	<i>SD</i>	Mean	<i>U</i>	<i>p</i> - value
Average of Subsequent TrCO <sub>2</sub> Readings	42.4	6.8	43.4	6.9	1.0	9323.0	0.039 †

Variable	Pain Score 0 - 5		Pain Score 6 - 10		Difference			
	<i>n</i>	%	<i>n</i>	%	%	Chi- square	<i>df</i>	<i>p</i> - value
Change from Initial to Average of Subsequent TrCO <sub>2</sub> Readings						3.825	1	0.050
≥ 5% Decrease	13	6.7	15	13.4	6.7			
No Change	181	93.3	97	86.6	-7			

† Mann-Whitney U Test

### Results for Research Questions

Patient safety was a focus of this study. Patient safety variables included respiratory rate, mean blood pressure, heart rate, oxygen saturation, pain score, Aldrete score and RASS score. The two research questions addressed patient safety variables in the following ways.

**Research Question 1:** Are there postoperative differences in trends of safety variables for patients who were monitored with transcutaneous capnography compared to those that received standard monitoring?

With the exception of ASA, demographics and clinical variables were equivalent between study groups. The majority of patients in the sample were female and obese. Noteworthy is that the ASA scores, which is the expected scoring of the patients by the anesthesiology team preoperatively to provide potential risk identification, were

frequently missing in both groups. When the missing data was excluded, ASA remained significantly different between the study groups

Patients were categorized by the divisions their surgery was performed which provided six categories. These categories did not differ statistically by study group.

Time in Phase I was noted to be statistically significant as shorter stays were found in the TrCO<sub>2</sub> study group both as continuous measurements and as binary. Categorical times were applied in minutes as well and were still found to be significant. Overall administration of opioids was less for the TrCO<sub>2</sub> study group versus the control group. Also, fewer opioids were administered to the TrCO<sub>2</sub> study group particularly in later time frames and among low dosing. It was noted the control group had more opportunities for opioids to be administered due to their longer timeframe in Phase I recovery.

Although there was no statistical difference in the overall sample population, the results of the patient safety variables over time show significant initial baseline differences between the control and TrCO<sub>2</sub> study group in several categories. The pain scores were worse (higher) among the TrCO<sub>2</sub> study group as compared to the control group and worsened over time. The RASS score was notably more improved (higher).

The percent of change noted over time (target change) was incorporated to assess the degree the subjects had a change from their own baselines for each metric as an indicator of improvement or worsening of variables. Further consistency in the juxtaposition of pain and Aldrete/RASS was noted. Again, the TrCO<sub>2</sub> study group may improve patient management via Aldrete/RASS, but pain becomes more pronounced.

The trends of TrCO<sub>2</sub> were reviewed using a reference point for a normal CO<sub>2</sub> range of 35-45 mm Hg. Initial readings were compared to subsequent readings to show directional improvement in TrCO<sub>2</sub>. A level of 5% decrease was used to analyze. There were very few TrCO<sub>2</sub> study group participants who had a decrease of  $\geq 5\%$  from initial CO<sub>2</sub> reading to their subsequent CO<sub>2</sub> readings. It was noted that 6.1% had a 5% or more decrease in change from their first reading versus their subsequent maximum. Also, there were 9.0% of the participants who had a 5% or more decrease in change from their first reading versus their subsequent average.

Most notably, average of subsequent TrCO<sub>2</sub> readings were lower among patients with low pain score ( $\leq 5$ ) at admission. However, the pain score accompanied with the opioid difference might offer consideration as to whether readings of TrCO<sub>2</sub> as a means to detect patients who do (or don't) require pain management (even if this initial group of nurses were less familiar with TrCO<sub>2</sub>'s application in the PACU).

**Research Question 2:** How do patient complication trends relate to the capnography trends and other safety variable trends in recovery room patients?

To answer this research question, administration of naloxone was examined. Naloxone administrations were pulled from the patients' electronic records during the same recovery room time frame (admission and 30- and 60-minutes after admission). Of the 816 participants, there were only two doses of naloxone administered, and both were administered to the same patient. That patient was in the control group. Therefore, there were no trends that could be examined in complication trends.

**Summary**

This chapter reported the findings from this study. This complex evaluation compared patient variables that were monitored with transcutaneous capnography as compared to variables from patients who received standard monitoring.



## **CHAPTER 5: DISCUSSION**

The purpose of this retrospective quasi-experimental study was to generate baseline data to trend patient safety variables and outcomes post-operatively. Transcutaneous CO<sub>2</sub> levels were assessed for the effects of transcutaneous capnography monitoring on detection of carbon dioxide levels in recovery room patients. Trends in data on 816 subjects were obtained retrospectively from an extant database. The summary of the study's objectives and results are discussed, as well as the limitations and implications for nursing practice and future research.

### **Summary of Objectives**

This study had two objectives. The first was to compare patients on transcutaneous capnography with patients receiving standard post-surgical monitoring to determine if there was a difference in postoperative safety variable trends and outcomes. The second objective was to compare postoperative complications of patients monitored with transcutaneous capnography with patients receiving standard monitoring. The final sample consisted of 816 patients (control group = 397; TrCO<sub>2</sub> study group = 419). Trends in the identified safety variables were tracked over time (admission to recover, 30 and 60 minutes after admission) to provide comparative data.

### **Summary of Results**

The TrCO<sub>2</sub> study group monitored with transcutaneous capnography showed a shorter length of stay in the recovery room. The time in Phase I as a continuous variable was significantly shorter among the TrCO<sub>2</sub> study group ( $M=128.4$  minutes) compared to the control group ( $M=151.1$  minutes). The TrCO<sub>2</sub> study group participants (51.2%) were

more likely to have had a Time in Phase I of less than 120 minutes as compared to the control group (34.8%). Overall opioid administration, combined across all times and doses, was significantly lower among the TrCO<sub>2</sub> study group compared to the control group. The total dose of opioids overall for the control group was 2.59 administered doses compared to 1.92 doses administered in the TrCO<sub>2</sub> study group. Unfortunately, the TrCO<sub>2</sub> study group was less likely to achieve a target pain score of  $\leq 5$  at 30 minutes and 60 minutes after admission.

When comparing the percent of change noted over time (target change) from baseline metrics as an indicator of improvement or worsening of a variable, the TrCO<sub>2</sub> study group was more likely to decrease heart rate by at least 20% from admission to 60 minutes. Also, the TrCO<sub>2</sub> study group was more likely to increase both their Aldrete score and RASS scores by at least 1 point from admission to 30 minutes and admission to 60 minutes. Both the Aldrete and the RASS scores demonstrated the patient's increasing level of consciousness and their return to baseline level of awareness sooner than the control group. Although the subjective pain scores of the patients were above the control at 30 and 60 minutes from admission, the delicate balance between pain control and sedation levels is showcased. The balance of potentially administering less opioid to allow for the patient to wake up faster and breathe deeper can be tenuous. The quicker a patient returns to their baseline, the shorter their potential stay in the recovery room. Patients must demonstrate they are awake enough to breathe effectively and deeply on their own.

Typical length of stay for patients to recover from the effects of anesthesia in this study was approximately 1 ½ to 2 hours which is within expected parameters. Early

release from recovery could have cost saving benefits related to the expedited safe care administered. The patients in this study who did not have the additional monitoring of capnography had an overall increase in both opioid administration and stay in recovery. Patients who receive higher doses of opioids tend to remain more sedated for longer periods of time. The combination of sedation from opioids and anesthesia can enhance sedation prolonging the patient's stay in recovery and potentially increasing the costs of care.

Fear of respiratory depression can be a barrier to effective pain management with opioids. It is unrealistic to think patients will be pain free after surgery. Pain score levels of 5 or less are the goal for recovery room management. Clinically significant respiratory depression may be prevented by identification of high-risk patients, individualizing their analgesic regimes, and close monitoring of their respiratory and sedation status. There are many processes hospitals can implement to enhance patient safety (Pasero, 2014). Respiratory depression is rare but can be life threatening complication of opioid use. Perhaps utilizing transcutaneous capnography provided improved management of opioids which could help speed up the level of consciousness (RASS) but inadvertently heightened awareness of pain.

Potential complications associated with respiratory complications include the use of naloxone to reverse the opioid effects. More serious would be the need for reintubation of the patient to protect their airway and artificially assist in their ventilation. Patients who require ventilatory support require intensive care unit monitoring until they are extubated from their breathing support. Intensive care unit level of care is significantly

more costly than floor care. Also, there is an associated increased length of overall stay by days for patients who require ventilatory support.

### **Findings as Applied to General Systems Theory**

The conceptual framework of general systems theory (GST) provided the structure for this study and directly supported the efforts of patient safety in the healthcare environment. As patients enter the recovery room after surgery, the nurses provided ongoing assessment of stability. The goal was for the patient to rapidly recover from the potential effects of anesthesia while providing early identification and immediate treatment of any change in status caused by either anesthesia or the surgery before the patients deteriorate (Vimlati et al., 2009).

Monitoring of postoperative patient safety variables for changes and intervening when appropriate in the feedback loop was similar to the GST model. Identifying and understanding the components of which safety variables in the recovery room had a significant impact offered an opportunity to improve patient outcomes with early interventions. Immediate and ongoing trends of capnography provided real-time opportunity for information regarding the patient's respiratory status. If a patient's respiratory status was noted to be compromised through the feedback of trending, staff could intervene early by lowering opioid doses if applicable to prevent further sedation.

Using this framework allowed for the consideration of internal and external factors impacting a patient's postoperative course, ongoing assessment of standard monitoring, interventions employed and reassessment based on feedback loop and outcomes. Also noted was the feedback from the electronic medical records documentation was a definite limitation. The inability to locate and retrieve certain data

points demonstrated a failure. Input from a variety of locations in the system were not succinctly working together to allow for an accurate analysis of the research questions.

### **Limitations**

The results were generalizable to the sample normally seen in recovery rooms. Inclusion criteria were broad to offer the opportunity to be able to generalize to most populations presenting. A potential weakness of the study was the use of a retrospective quasi-experimental design which is not as strong as other designs, such as randomized controlled trials. Capnography monitoring is considered instrumental in assessing ventilatory status in patients, transcutaneous capnography is not as frequently performed primarily related to the cost of the equipment and supplies. A retrospective design was performed to generate baseline data on trends in patient safety variables to assess for significant trends in the variables. It would be beneficial to develop risk assessment tools to identify patients preoperatively that may be at greater risk of respiratory compromise post operatively.

The use of the electronic medical record was strength and a limitation. Documentation was sometimes missing, specifically when timed variables should have been entered, or in some cases, this was provided in another section of the patient's record where providers had not expected it to be located. Many electronic patient files were missing Aldrete variables at exactly the 30 minute time frame. Aldrete scores documented either immediately before or after the time frame were used in this study. Accuracy of documentation cannot be addressed.

Patient vital signs automatically download into the computerized documentation system eliminating the potential of staff being distracted from documenting at specific

times. The logistics of the transcutaneous monitor did not allow for automatic download of the transcutaneous readings. Although vital signs are automatically downloaded, the transcutaneous levels were not. Transcutaneous levels were manually entered by staff into the electronic documentation system. Although this was additional work, the staff were able to accommodate this activity easily. Also, staff verbalized ease in the manual documentation required. In the future, purchasing the additional hardware required to allow the automatic capturing of this variable would allow for easy download into documentation.

Another noted variable not easily found in documentation was the ASA score provided by the anesthesia attending staff. Even with the large number of missing scores from both groups, this variable remained significantly different between groups even when missing data were excluded. There is a possibility that the data retrieved from the extant database could not find the location in the electronic medical records where the score was documented, if indeed it was documented. Opportunities exist to ensure the ASA score is performed and documented in one location within the hospital's documentation system. This will promote consistency so that all team members will have access for review.

A significant limitation in identifying patient complications was searching the documentation system for record of naloxone administration and reintubations of patients. The search for naloxone administration was limited to the same time frame as the patient's stay in the recovery room. However, it is recognized that naloxone is sometimes administered by anesthesia immediately before the patient's admission into recovery and upon their discharge of the patient to the inpatient division. Future studies

would be strengthened with a prospective randomized trial where complications would be captured when they occur as opposed to a retrospective data pull which is showing inconsistent practices in the location of documentation specifics.

Limitations of the transcutaneous monitor itself include the possibility of electrical drifts of the signal, the requirements of regular maintenance, the need to change the electrode membrane, and risk of thermal burns. These limitations are overcome with training staff to calibrate the equipment, change the electrode, and ensure the electrode is removed after two hours of use.

The cost of the monitor itself is over approximately \$20,000.00. This charge does not include the consumable items required for use. The calibration gas lasts approximately three to four months. The canister contains enough CO<sub>2</sub> to complete 180 calibrations. The membrane kit contains 12 membranes per kit. The membrane needs to be changed once a month so the kit typically lasts 1 year. The fixation rings contain 60 adhesive rings and the bottle of contact solution for patient application. Normal use is one ring per patient. The sensor itself is a permanent piece of equipment. The membrane piece of the electrode is what requires changing.

Based on the above usage the daily cost of use is approximately \$8.45. The daily cost was calculated on a single patient per day. If the monitor were run on multiple patients per day the cost would increase by \$3.68 per additional patient for the single use fixation rings. The cost of three patients per day would be \$15.81. Staff found the monitors to be user-friendly. Set up was not complicated or time-consuming. Patients were not bothered with the electrode. The comfort in using an electrode was greater accepted than patients who had to utilize awkward masks for oxygen. Patients were not

limited in mobility in the bed from the electrode. Most did not realize it was even on as it is light weight.

### **Implications for Nursing Practice**

Standard of care requires that pain documentation should occur upon admission into the unit, with the administration of opioids, and 30 minutes after opioid administration to assess the outcome of dose. Many charts were missing repeat pain score assessments and simply commented on the patient “being asleep.” Thus, opportunities exist to improve practice to the recommended standard of care. In 2001, The Joint Commission implemented standards specifically addressing documentation and assessment of pain. Assessment and reassessment were incorporated into the required standards (Gordon et al., 2008). Education regarding policy guidelines in pain assessment could be provided to staff. Routine documentation audits could assess compliance with documentation guidelines and ongoing sustainment. There is a need to establish one consistent location to document ASA scores and naloxone administration to allow for easier retrieval.

Findings indicated that there is an opportunity to develop a predictive risk model that could be used preoperatively to prevent events. With a risk assessment model, there are several quality improvement initiatives that could be implemented. Patients with a known history of over-sedation could be identified before admission into recovery. There could be a separate protocol to increase monitoring for patients with risk factors that may cause over-sedation. This could include recommendations for health care providers to use adjunctive opioid sparing non-sedation medications. Utilizing risk assessment protocols could allow for ongoing priority to patient safety initiatives.



**Future Research**

Future studies include randomization of patients to strengthen the outcome for cause and effect. Coding the types of surgery may help to identify procedures that would be important for the recovery room to focus attention towards. Also, the length of surgery and type of anesthesia could be captured to assess the contribution of variables on patient outcomes. With a prospective approach, variables which were difficult to track retrospectively such as ASA scores, naloxone administrations, intubation rates, could be better accounted for in the process. Also, recognizing the study groups had statistically significance differences in their safety variables at baseline measurement, a randomized study could also better assess variables which may have been unaccounted for in a retrospective approach.

There is an opportunity to explore the financial implications associated with prevention of respiratory events by avoidance of intensive care unit stay and increased days hospitalized from an untoward event. As it was noted in the TrCO<sub>2</sub> study group that length of time in the recovery room was significantly less than the control group, associated costs savings could be reviewed for the shorter time frame required.

Patients with multiple case encounters for surgery were distinguished clinically from the rest of the sample. Retaining the data from this subgroup provides an opportunity to explore how patients with a repeat surgery trends at a later date. The opportunity to assess if this group is significantly different in their trending of safety variables than the group of patients with one encounter exists. It could be interesting to assess how a multimodal pain approach preoperatively can impact outcomes on patients.

**Conclusions**

Adequacy of postoperative pain control is a factor in determining when a patient can be safely discharged from the recovery room. Using opioids may cause respiratory depression which may be inconsequential most of the time but becomes significant with some patients. It would seem logical that there is clinical benefit to reducing the number of opioids administered to patients after surgery for both reduced sedation potential and a decreased length of stay in the recovery room.

Knowing that systematic assessment of respiratory status and sedation levels should be conducted on all patients who receive opioids. Capnography monitoring may improve confidence in assessing whether opioid doses can be safely administered to more effectively manage postoperative pain. Transcutaneous carbon dioxide monitoring is an easy and sensitive monitor of respiratory depression. Although controlling postoperative pain is an important goal, patient safety must not be compromised. It is a balance between administration and ongoing patient assessment. Various technologies exist that are both invasive and noninvasive. Different clinical scenarios may require the combination of different techniques. The use of capnography offers a reliable trend as an early indication of changes in a patient's respiratory status in the recovery room.

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