Capnography Monitoring in PACU for High Risk Patients

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Abstract

The American population is becoming sicker, increasing the risk of respiratory complications such as hypopnea, hypercapnia, aspiration, and apnea in the Post Anesthesia Care Unit. These problems may be going undetected too long using the current standard of monitoring. Although the implementation of capnography monitoring may prevent adverse respiratory events in the post-anesthesia care unit (PACU), its use is not a standard of care. The goal of this project was to increase SRNA knowledge base regarding postoperative respiratory issues for high risk patients recovering in the PACU and that implementation of capnography monitoring in PACU for high risk patients allows for early intervention, prevention of negative respiratory outcomes, and should be a standard of care. A quantitative pre-post test design was used to determine the effectiveness of increasing the knowledge-base of 22 SRNAs using a paired sample t-test with a pre-determined significance level of $p < 0.05$. There was a significant difference in the pre-test scores $M=.42$, $SD=.17$) and post-test scores ($M=.80$, $SD=.13$) Conditions; $t(21)=(-12.51)$, $p=.000$. The primary implication of these results is that the education of SRNAs broadened their knowledge base of post-operative respiratory issues.

Keywords: capnography, respiratory failure, PACU

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Post-operative respiratory events are a major cause of morbidity and mortality, with severe episodes causing anoxic brain injury, cardiac arrest, or death (Karcz & Papadakos, 2013; Lee et al., 2015). Post-operative respiratory issues, such as hypopnea, hypercapnia, aspiration, and apnea, affect about 1 out of 7 surgical patients (Weingarten, Kor, Gali, & Sprung, 2013; Geralemou, Probst, & Gan, 2016). A hospital stay can double in length and can increase in cost by $53,000 after a single incidence of respiratory failure and such events can increase hospital costs by 30% (Geralemou, Probst, & Gan, 2016; Oofuvong et al., 2015). More than half of anesthesia malpractice claims involving respiratory depression resulted in patient harm or death, and one third of those could have been prevented with better monitoring, such as capnography (Lee, et al., 2015; Langhan, Li, & Lictor, 2016).

The time spent in the post anesthesia care unit (PACU) is a critical time of recovery from high levels of sedation and anesthesia, making adverse events liable to occur. Furthermore, respiratory events in the post anesthesia care unit (PACU) have been associated with cardiac issues like hypotension, hypertension, tachycardia, and new onset arrhythmias (Rose, Cohen, Wigglesworth, & DeBoer, 1994). A high level of nurse vigilance is required to prevent these events (Maramil et al., 2007).

While many factors contribute to respiratory events, the two key causative factors are the use of muscle relaxants and opioids (Karcz & Papadakos, 2013; Lee et al., 2015). Patients, still under the effects of general anesthesia, routinely receive opioids for post-operative pain control (Karcz & Papadakos, 2013; Weingarten et al., 2013). The synergic effects of opioids and general anesthesia include: patient sedation, pharyngeal muscle relaxation, blunting of the hypercapnic drive, and ventilation impairment (Lee, et al., 2015; Weingarten, Warner, & Sprung, 2017).

These effects may ultimately lead to hypoxemia, hypoventilation, hypercapnia, and airway obstruction (Lee, et al., 2015; Weingarten et al., 2017). These respiratory issues have the highest prevalence within the immediate transition time from anesthesia to recovery, indicating a heightened need for surveillance during the immediate post-operative period (Weingarten at al., 2017; McCarter et al., 2008).

Certain patient populations are at increased risk for adverse respiratory events. High-risk populations include: children, patients with higher ASA scores, COPD, OSA, patients undergoing abdominal surgery, and patients receiving neuromuscular blocking agents or opioids (Carlisle, 2015; Kadam & Danesh, 2016; Karcz & Papadakos, 2013, 2013; Langhan, 2016; McCarter et al, 2008; Weingarten et al., 2013). These poulations are at greater risk of airway obstruction, hypoxemia, respiratory failure, muscle weakness, and inability to breathe deeply (Xara et al., 2015).

Patients with OSA are one of the highest risk populations (Xara et al., 2015; Diffee et al., 2012). OSA is largely undiagnosed and can pose a threat to patient safety. The prevalence of OSA has increased at a rate of 37% in men and 50% in women, although OSA continues to be more prevalent in men overall (Franklin & Lindberg, 2015). The surgical population has an even higher probability of having OSA (Franklin & Lindberg, 2015; Xara et al., 2015). In addition, the surgical population has become more obese, resulting in multiple co-morbidities and increasing risks for respiratory issues in PACU (Karcz & Papadakos, 2013; Young, Peppard, & Gottlieb, 2002; Diffee et al., 2012). The population with a BMI > 50 has increased ten times in recent studies, which is thought to be contributing to the increased incidence of OSA (ASA, 2006; Sturm & Hattori, 2013).

Capnography monitoring gauges both the presence and adequacy of ventilation and is a standard of care during general anesthesia and monitored sedation cases (AANA, 2013; ASA, 2006). Often, there is little change in patient status from the OR to the PACU. It could be argued that this standard should be extended to the PACU, where patients often arrive heavily sedated or with airway devices in place. The use of capnography in PACU is not standardized but could be implemented at the cost of $4,000 per capnography monitor and $16 per capnography compatible oxygen tubing (ASA, 2006; AANA, 2013; Saunders, Erslon, & Vargo, 2016). This cost is potentially less than the cost of respiratory complications in the PACU.

Since capnography is not standard practice in Advent Health's PACU departments, it is imperative to increase the AHU SRNA's knowledge base regarding the potential hazards associated with the current dependence on pulse oximetry and qualitative assessment methods as well as the potential benefits associated with the implementation of routine capnography to decrease adverse respiratory events.

Project Questions

The clinical problem was addressed by the following question: In high risk patients recovering from surgery (P), what is the effect of capnography monitoring (I), compared to current standard monitoring (C), on respiratory events (O) in the post-operative period (I). Regarding possible innovations, the following question was addressed: In student registered nurse anesthetists (SRNAs) at Advent Health University (P), will a 30-minute (T) educational PowerPoint presentation (I) regarding the use of capnography in PACU to decrease post-operative respiratory complications increase knowledge base (O)?

Literature Review and Synthesis

Current Monitoring Standards

Current standards for PACU monitoring include only: pulse oximetry, blood pressure, temperature, and continuous electrocardiogram (American Association of Nurse Anesthetists, 2013; American Society of Anesthesiologists, 2006). Aside from physical assessment and clinical observation, pulse oximetry remains the only standard monitor used in PACU to monitor respiratory status. Evidence of hypoxemia from a pulse oximeter can lag behind respiratory compromise by two to three minutes (Godden, 2011; McCarter, Shaik, Scarfo, &Thompson, 2008; Fu et al., 2008). In patients that have been monitored with both capnography and pulse oximetry it has been shown that pulse oximetry readings would be more than adequate while capnography identified respiratory depression (McCarter et al., 2008; Godden, 2011; Fu et al, 2004). Even the small amounts of supplemental oxygen that most post-operative patients are given can mask signs of hypoventilation and give falsely reassuring pulse oximetry levels, delaying intervention and leading to worsened outcomes (Fu et al., 2004).

Clinical observation is not always a good measure of respiratory depression, as it can be a poor subjective judge of depth and effort (Burton, Harrah, Germann, & Dillon, 2006; Langhan et al., 2017). It says nothing about what is happening at the alveolar level. Anesthesia providers utilize end-tidal carbon dioxide readings to assess adequacy of ventilation in real time as a standard of care when patients are intubated, and for monitored sedation cases (AANA, 2013). Being able to differentiate obstruction from apnea helps the anesthesia provider determine the best course of action to protect a patient’s airway.

Identifying High Risk Patients

To implement capnography monitoring in the post-anesthesia period, a population of patients who would most benefit has been identified. High risk patients were described as those with advanced age > 60 years old, children < 3 years old, patients with low functional status, COPD, or an ASA score > 2, patients with OSA or screened positive for OSA who are undiagnosed, patients receiving neuromuscular blocking agents or PCA opioids, and patients undergoing high risk or emergency procedures (Carlisle, 2015; Kadam & Danesh, 2016; Karcz & Papadakos, 2013; Langhan, 2016; McCarter et al, 2008; Weingarten et al., 2013). Patients with OSA make up more than a quarter of the population and are most at risk for hypoxemia, hypercapnia, and apnea within the first 24 hours after anesthesia due to increased opioid sensitivity and increased risk of airway obstruction (Karcz & Papadakos, 2013; Kadam & Danesh, 2016).

The incidence of OSA is increasing and the majority of patients with OSA are undiagnosed (Diffee et al., 2012; Weingarten et al., 2013; Godden, 2013). In obstructive sleep apnea, the upper airway becomes obstructed during sleep or sedation and prevents ventilation. This causes episodes of hypoxemia and hypercapnia (Diffee et al., 2012; Godden, 2013; Weingarten et al., 2013). Since the obstruction is intermittent, the ineffective ventilation pattern can go undetected in the PACU and on nursing floors as respiratory rate and oxygen saturations can appear normal (Carlisle, 2015; Godden, 2011; Weingarten et al., 2013; Weingarten, 2017). Those who have an OSA diagnosis often bring their non-invasive positive pressure devices (NIPPV) to the hospital and can use this device for rescue if they exhibit respiratory obstruction in PACU. Those who have only been screened as likely positive for OSA do not have these supportive devices. Detection and early treatment of respiratory compromise prior to deterioration is key in preventing adverse outcomes, whether treatment be NIPPV, insertion of an oral or nasal airway, airway manipulation, stimulation, or increasing FiO_2 (Carlisle, 2015; Diffee et al., 2012; Langhan, 2016; Latham, et al., 2018; Oswald, Zeuske, & Pfeffer, 2016).

Patients who have been screened preoperatively as likely positive for OSA, but with no previous diagnosis, may have worse rates of adverse outcomes in the PACU, more ICU admissions, and higher mortality rates overall than those who have been diagnosed with OSA or the general population (Fernandez-Bustamante et al., 2017; Weingarten et al., 2017; Diffee et al., 2012). These patients are considered high risk, as are children. The pediatric population is well known for descending into respiratory decompensation very quickly, and for being difficult to subjectively evaluate for airway obstruction or laryngospasm (Langhan et al., 2017).

Patients who have received neuromuscular blocking agents are at unique risk for respiratory failure – up to 64% of patients in PACU have been inadequately reversed, leading to inadequate chest excursion, airway obstruction, and aspiration (Karcz & Papadakos, 2013; Weingarten et al., 2013; Hunter, 2017). Early detection of inadequate ventilation due to residual weakness from neuromuscular blocking agents can lead to the administration of an emergency reversal agent such as Sugammadex and prevent re-intubation or the requirement of additional airway support (Hunter, 2017). Studies have indicated a higher nurse to patient ratio may prevent adverse events with increased monitoring (Arachchi et al., 2015; Smedly, 2010). With increasing patient acuity and an increase in nurse workload, safety concerns abound and a need for the implementation of an additional non-invasive monitoring tool exists (Maramil et al., 2007; Carlisle, 2015).

Implementing Capnography

The use of capnography in the post anesthesia care unit has clear support. Capnography was found to detect hypoventilation and allow early intervention by nursing staff to prevent apnea or hypercapnia (Langhan et al., 2016; Latham et al., 2016;). Respiratory depression and apnea were prevented by early intervention with the use of capnography, and nursing staff found capnography more effective in alerting them of apnea and hypoventilation than the pulse oximeter (Langhan et al., 2016; Latham et al., 2016; Taylor et al., 2015). High risk patients were identified pre-operatively and given capnography monitoring in PACU and it was again found that nurses detected ventilation issues earlier than when just a pulse oximeter was used (Kadam & Danesh, 2016; Oswald, Zeuske, & Pfeffer, 2016).

The use of capnography detected apnea in 29% of post-surgical patients, preventing episodes of hypoxemia (Langhan et al., 2016) and decreased the incidence of opioid-induced respiratory depression from 4.9 to 4.8 cases per 10,000 patient days (Carlisle, 2015). Its use in PACU, however, is not standardized despite the evidence supporting it. A likely barrier is the cost of implementation at $4,000 per capnography monitor and $16 per disposable capnography tubing, but the cost of post-operative respiratory compromise is expected to rise to $37 billion with most of the cost coming from increased length of hospital stays and ICU admissions (Saunders, Erslon, & Vargo, 2016; Mountfort & Goodwin, 2017). The cost of extra monitoring, legal claims, and lawsuits for damages after a respiratory event surpasses the cost of capnography itself (Saunders, Erslon, & Vargo, 2016).

Assessing risk factors, enhanced monitoring, adequate reversal, and the judicious use of opioids postoperatively have been identified as effective methods to reduce the incidence of post-operative respiratory complications (Melamed et al., 2016; Weingarten et al., 2013;

Geralemou et al., 2013; Langhan et al., 2016; Carlisle, 2015; Godden, 2011). With the publishing of *To Err is Human*, safety promotion is a focus in healthcare where healthcare professionals are encouraged to recognize existing safety deficits and develop solutions (Kohn, Corrigan, & Donaldson, 2000). The implementation of capnography within PACU would align well with IOM recommendations to incorporate additional layers of safety for the improvement of quality of care.

Contribution and Dissemination/Justification

The aim of this project was to address a knowledge gap in AHU SRNAs regarding the use of capnography monitoring in PACU and its effect on post-operative respiratory complications. Per the project timeline, the PowerPoint was be disseminated in a classroom setting during the Fall 2018 trimester as assigned by the AHU NAP faculty. Baseline knowledge of the AHU SRNAs was be assessed via pre-tests and knowledge gained was be assessed via post-tests.

Project Aims

The primary aim of this educational project was to increase the knowledge base of twenty-two AHU SRNAs regarding the use of capnography monitoring for high-risk patients in the PACU and its impact on post-operative respiratory complications. The achievement of the scholarly project aims was indicated by a statistically significant improvement of pre/post test scores.

Project Methods

This scholarly project utilized a quantitative pre-post test design to determine if there was an increase in the knowledge base of 22 SRNAs following a 30-minute an educational PowerPoint during the Fall 2018 trimester. Inclusion criteria was SRNAs enrolled in the AHU

2019 cohort. Exclusion criteria was SRNAs unwilling to sign an informed consent, who are late to class, or who are absent from class on the day of the presentation. As SRNAs were arriving to class on the day of the presentation they were provided with an informed consent and an identical 10-question pre- and post-test to determine their baseline knowledge of capnography monitoring for high-risk patients in the PACU and its impact on post-operative respiratory complications. The post-test was provided in a sealed envelope and the participants were instructed not to open it until after the presentation. All consents and pre-tests were collected before an educational PowerPoint is presented. After the presentation the participants were instructed to open the sealed envelope to complete the post-test of the same 10-questions that were on the pre-test. All post-tests were collected before the end of the class. Participants were instructed not to place any individually identifying information on the tests. Instead pre- and post-tests were identified via matching numbers to protect the participants' privacy. The paper test results were then input and stored on the researchers' password protected personal computer. The paper test results were then destroyed via crosscut shredding and electronic data deleted from the scholarly team members' computers.

Timeline

This scholarly project was initiated May 11, 2018 and was be completed April 2019. In the Summer Trimester (May 2018 – August 2018), the research topic was be identified and approved, literature review was be initiated, and a mentor was be selected. CITI certifications were completed and submitted. The scholarly project proposal was then written, approved, and submitted to IRB and SRC. A PowerPoint presentation and pre-test/post-test was developed. In the Fall Trimester (August 2018 – December 2018), the project implementation phase began with the development and approval of a PowerPoint presentation. The teaching plan was implemented, as assigned by the NAP. Post-implementation data was collected at the end of the PowerPoint presentation and sent for analysis. In the Spring Trimester (January 2019 – April 2019), the final draft of the project paper was completed and submitted. A poster was designed, printed, and presented at the Spring 2019 student poster presentation.

Data Collection Plan

Data collection and implementation took place in the MSNA 504 Clinical Conference III course. Data collection then took place in which a 10 question multiple choice pre-test was administered prior to the educational PowerPoint and the same test was administered after the PowePoint. The pre-tests and post-tests were labeled with matching numbers to allow for statistical comparison and to ensure each student only received one pre-test and post-test. Data was collected anonymously, entered into an Excel spreadsheet, and emailed to Dr. Roy Lukman for statistical analysis using SPSS. Results were evaluated using a paired t-test with a pre-determined statistical significance level of $p < 0.05$. A total of six exchanges occurred with the students and project members: consents, pre-tests and post-tests. The statistical analysist and scholarly project team members, LeeAnn Brown and KiAnne Smith, were the only persons with access to the data. After the scholarly project was complete the data and test results were deleted from the personal computer listed above.

Evaluation

This scholarly project was evaluated by data gathered from pre-tests and post-tests. The 10-question pre-tests determined the participants' baseline knowledge regarding the use of capnography monitoring in the PACU. The identical 10-question post-test determined the knowledge gained after a 30-minute educational PowerPoint presented by the project team members. The data was analyzed, and statistical significance was achieved, indicating the

PowerPoint was effective in achieving the project aim. Results will be disseminated via poster presentations to the campus and will be available in digital form on the library website.

Results/Findings

The team members scored the pre-tests and the post-tests yielding a mean pre-test score of 42% and a mean post-test score of 81% with a mean score improvement of 39%. These results were sent to Dr. Roy Lukman for additional analysis in which a paired t-test in SPSS was performed and indicated a statistically significant increase in mean scores between the pre-tests and post-tests with a p-value of < 0.000 and a t-value of -12.151. Based on the results, the Powerpoint was considered successful in increasing the knowledge base of SRNAs regarding the use of capnography monitoring in PACU. The entire statistical analysis can be found in appendix D.

Conclusions/Limitations

In conclusion, the educational presentation was successful in improving the knowledge base of the participating SRNAs regarding the use of capnography in PACU, based on knowledge of basic research there were a few anticipated limitations of the study. The study included a small homogenous sample of just twenty-two participants. The participants were all senior SRNAs at the time of the presentation and therefore, had increased baseline knowledge, which may have affected the results of the study. The participants then took a post-test right after the PowerPoint presentation, therefore, only short-term memory was tested.

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Appendix A: Informed Consent

AHU NAP CAPSTONE PROJECT – INFORMED CONSENT

We are MSNA students in the Nurse Anesthesia Program (NAP) at Advent Health University (AHU). We are doing a Capstone Project called *Capnography Monitoring in PACU for High Risk Patients* that is supervised by a project chair within the Nurse Anesthesia Program. The main purpose of this form is to provide information about the project so you can make a decision about whether you want to participate.

WHAT IS THE PROJECT ABOUT?

The purpose of this project is increase the knowledge base of AHU SRNAs regarding

the use of capnography monitoring for high-risk patients in the PACU and its impact on post-operative respiratory complications.

WHAT DOES PARTICIPATION IN THIS PROJECT INVOLVE?

If you decide to participate in this project, you will be asked to complete an anonymous pre-assessment, attend a classroom presentation, and then complete an anonymous post-assessment. The assessment will address use of capnography in PACU for high risk patients. Your participation by attendance at the presentation and completion of the survey is anticipated to take approximately 45 minutes.

WHY ARE YOU BEING ASKED TO PARTICIPATE?

Your participation in this study is voluntary. You may choose to not to participate. The decision to participate or not participate in this research study is completely up to you. If you choose not to participate your refusal to participate in this research study will involve no penalty or loss of benefits to you. If you choose to participate, you can change your mind later and withdraw your consent and discontinue participation from this study at any time. If you chose to withdraw informed the PI of your wishes.

WHAT ARE THE RISKS INVOLVED IN THIS PROJECT?

Although no project is completely risk-free, we do not anticipate that you will be harmed or distressed by participating in this project.

ARE THERE ANY BENEFITS TO PARTICIPATION?

We do not expect any direct benefits to you from participation in this project. The possible indirect benefit of participation in the project is the opportunity to gain additional knowledge about the use of capnography in PACU for high risk patients.

HOW WILL THE INVESTIGATORS PROTECT PARTICIPANTS' CONFIDENTIALITY?

The results of the project will be published, but your name or identity will not be revealed. To maintain confidentiality of assessments, the investigators will conduct this project in such a way to ensure that information is submitted without participants' identification. Participants will be instructed not to place any individually identifying information on the tests. Instead pre- and post-tests will be identified via matching numbers to protect the participants' privacy. The paper test results will then be input and stored on the researchers' password protected personal computer. The paper test results will then be destroyed via crosscut shredding. After the scholarly project is complete the data and test results will be deleted from the personal computer listed above. Thus, the investigators will not have access to any participants' identities.

WILL IT COST ANYTHING OR WILL I GET PAID TO PARTICIPATE IN THE PROJECT?

Your participation will cost approximately 45 minutes of your time, but will require no monetary cost on your part. You will not be paid to participate.

VOLUNTARY CONSENT

You do not have to participate in this research study and choosing not participate in this study will not involve any penalty or loss of benefit to you. The decision to participate or not participate in this research study is completely up to you. If you choose to participate, you can change your mind later and withdraw your consent and discontinue participation from this study at any time. If you chose to withdraw from the study informed the PI of your wishes. If you have concerns about the project process or the investigators, please contact the Nurse Anesthesia Program at (407) 303-9331.

____ **Date** ___________________

Participant Signature/ Participant Name (PRINTED LEGIBLY)

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Participant Name (PRINTED LEGIBLY)

Appendix B: Pre-Test and Post-Test Questionnaire

Pre/Post Test on Use of Capnography in PACU for High Risk Patients

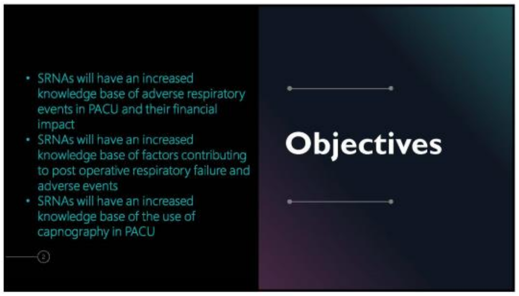
1. Respiratory events in PACU are associated with which other adverse effects? (select all that apply)
    a. Arrhythmias
    b. Hypotension
    c. Heart failure
    d. Hypertension
2. What are **two** of the most common factors in PACU that contribute to respiratory complications?
    a. Use of airway support devices
    b. Use of neuromuscular blockers
    c. Overuse of supplemental oxygen
    d. Use of opioids
3. Which is NOT a high-risk population for adverse respiratory events?
    a. Patients with OSA
    b. Patients who have received neuromuscular blockers
    c. Children < 2 years old
    d. ASA 2
4. How long can a change in pulse oximetry readings lag behind respiratory depression?
    a. 2 minutes
    b. 30 seconds
    c. 15 seconds
    d. 1 minute
5. Which is true of patients who have been screened as positive for OSA, but are not diagnosed? (select all that apply)
    a. They are at no more risk than the general population for adverse respiratory events in PACU
    b. They have worse outcomes than patients previously diagnosed with OSA
    c. They are less likely to be admitted to ICU than the general population

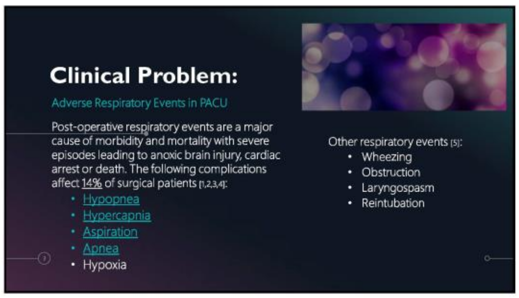
   d. They are more likely to be admitted to ICU than those who have been diagnosed with OSA

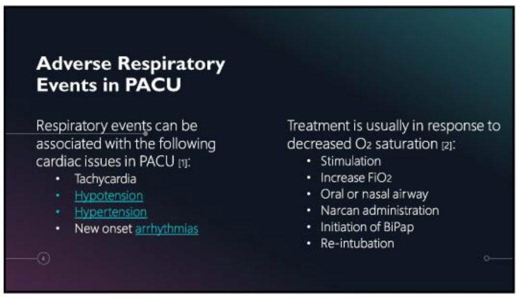
6. What percentage of surgical patients experience post-operative respiratory complications such hypopnea, apnea, hypercapnia, and aspiration?
   a. 50%
   b. 18.2%
   c. 64.8%
   d. 14.2%
7. A single incidence of respiratory failure can increase hospital costs by how much? (Select 2)
   a. 30%
   b. $53,000
   c. 60%
   d. $28,000
8. The synergistic effects of opioids and general anesthesia include: (Select all that apply)
   a. Blunting of the hypercapnic drive
   b. Pharyngeal muscle relaxation
   c. Sedation
   d. All of the above
9. What is the cost of one capnography compatible oxygen tubing?
   a. $2.19
   b. $8.50
   c. $16
   d. $10.99
10. What is the incidence of post-operative respiratory complications in surgical patients?
   a. 1 in 10
   b. 1 in 7
   c. 1 in 4
   d. 1 in 15

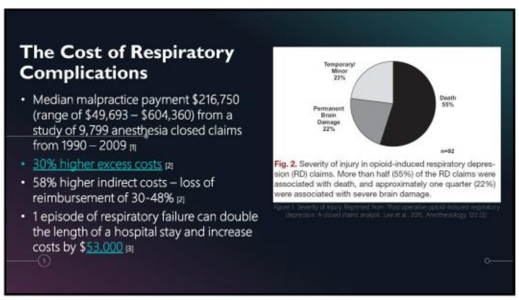
Appendix C: PowerPoint Presentation

10.10.2018









Motivation

- An aging society creates patients with more co-morbidities requiring surgery
- Production pressure from hospitals and surgeons means more cases in a shorter amount of time
- Patients are transferred to PACU while still sedated and prone to respiratory issues
- SRNAs do not often get to see how their patients recover in PACU as they are rushed from case to case

CASE STUDY

Preop:

- A 115kg 64 year old male presents for an open ventral hernia repair
- He has a history of COPD, uncontrolled HTN, DM, and ischemic cardiomyopathy with an EF of 45% (ASA III)
- He says he snores at night, but has never been diagnosed with OSA
- Mallampati class III
- Versed 2mg administered upon transfer to OR

CASE STUDY

Intra-op:

- Uneventful intubation using a McGrath , 100mcg fentanyl, 100mg propofol, 30mg ketamine, and 50mg of rocuronium is administered.
- 100mcg of fentanyl administered halfway through surgery and 1mg of Dilaudid upon emergence. TOF ¼ reversed with 3mg of neostigmine and 0.4mg of glycopyrrolate. Opening eyes to command and spontaneously breathing a Vt of 3mL/kg.
- He is then extubated and immediately begins obstructing so a nasopharyngeal airway is placed and 4L of O_2 via nasal cannula applied.

CASE STUDY

Post op:

- Report is given to PACU and the patient appears to be more alert as he is complaining of 3/10 pain. The nasopharyngeal airway is removed and the patient receives another 1mg of Dilaudid from the PACU nurse.
- The CRNA leaves to start another case. 30 minutes later, the anesthesiologist is called to PACU because the patient is desaturating and unarousable. The patient desaturates to 45%. An oral airway is placed prior to administering rescue breaths and Naloxone is administered.

Literature Review

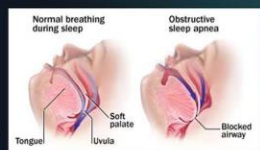
I. High Risk Patients/Risk Factors
   i. OSA
   ii. Muscle Relaxant Use
   iii. Opioid Use
   iv. Pediatric
II. Current Monitoring Standards
III. Capnography Monitoring
   i. Implementation
   ii. Results
   iii. Cost
IV. Conclusion

High Risk Patients/Risk Factors

- Age > 60 years old
- Children < 3 years old
- Low functional status
- COPD
- ASA > 2
- OSA, or screened positive for OSA
- Emergency/High Risk Procedures
- Use of NMB (key factor)
- Use of opioids (key factor) [1]

Obstructive Sleep Apnea (OSA)

- Obstruction of the upper airway while the patient is sleeping or sedated
- Majority of patients are undiagnosed
- OSA patients constitute ¼ of the population [2]
- Prevalence increases with age > 60 [3]
- Incidence increases as population ages and becomes more obese [3]
- Increased risk for apnea, hypoxemia, hypercapnia, and other adverse events in PACU [4]
- More sensitive to opioids
- Increased risk for undetected airway obstruction



(2018). University of Nebraska Medical Center, Obstructive Sleep Apnea, https://www.unmc.edu/intmed/divisions/geriatrics/education/resources/anesthesia-modules/obstructive-sleep-apnea.html

Undiagnosed OSA

- Majority of patients with OSA are undiagnosed
- Surgical population is more likely to have OSA
- Those screened as likely positive for OSA, but have no diagnosis carry higher mortality rates than the general population or those who have been diagnosed
- May have higher rates of adverse outcomes in PACU
- More likely to have ICU admissions post-operatively [1,2,3]

OSA – Guidelines for Care

- Pre-op [1,2]
  - Screening, STOP BANG
  - High BMI, HTN, abnormal cephalometric measurements
  - History of snoring, desaturation while sleeping, congenital abnormality
  - Use of CPAP/NIPPV
- Intraoperative [1]
  - Use of regional when applicable
  - Awake extubation
  - Capnography monitoring
  - Judicious use of respiratory depressant medications
  - Secure airway is preferential to unsecured with deep sedation
  - Verify full reversal of NMB
- Post-operative [1,2]
  - Judicious use of opioids
  - Administer O_2 post-extubation
  - Monitor continuous SpO_2
  - If frequent obstruction, use NIPPV
  - *Closely monitor ventilation for obstruction*

(2018). Fresenius Kabi, Rocuronium, http://products.fresenius-kabi.us/product-186.html

Muscle Relaxant Use

- Use of intermediate acting NMBs can contribute to post-operative oxygen desaturation [1]
- Up to 64% of patients in PACU have been inadequately reversed [1]
  - Inadequate chest excursion
  - Airway obstruction
  - Aspiration
  - Depression of chemosensitivity [1]
  - 1/3rd of participants in study of OSA patients had difficulty breathing deeply in PACU with 15% of those experiencing hypoxemia

Opioid Use

- The most common treatment of post operative pain is opioids
- Many of the effects of opioids are synergistic with general anesthesia
- Opioids are known respiratory depressants
  - Leads to an increase in CO_2, while chemoreflex is blunted by opioids
  - Can cause pharyngeal muscle relaxation
  - Requires close monitoring to detect apnea
  - Most common cause of respiratory failure is decreased levels of consciousness with depressed respiratory drive
- Use of opioids is associated with higher risk of respiratory failure [1]

Opioid Use

- Patients with OSA are more susceptible to the effects of opioids
  - Increased risk of requiring ventilatory support post operatively
- Use of opioids in other high risk patients is associated with increased incidence of respiratory depression
  - Obesity
  - Advanced age
  - Pulmonary and cardiac disease
  - Longer anesthesia times
- Adverse respiratory events can prolong hospitalization by 4 days and increase costs by $25,000 [1]

Pediatric

- Pediatric emergence from anesthesia differs from adult emergence. [1]
- Hypoventilation, hypoxemia, and upper airway obstruction are the most common respiratory events that occur in PACU [2]
  - More common in obese children, children with OSA, and after tonsil surgery [1]
- Hypoxia is more rapid, and can be more profound during emergence [1]
- Incomplete recovery from anesthesia can lead to upper airway obstruction [1]

Current Monitoring Standards

Pulse Oximetry

EKG

NIBP

Temperature

- Current monitoring standards in the PACU are limited to:
  - Pulse oximetry
  - Continuous electrocardiogram
  - Noninvasive blood pressure
  - Temperature [1]
- For patients at high risk of respiratory issues in PACU, these monitors alone may not be enough to detect impaired ventilation early.
- Use of pulse oximetry to detect respiratory issues:
  - Can lag behind an episode of desaturation by up to 3 minutes [2]
  - Does not indicate adequate gas exchange or quality of ventilation [3]
  - Use of supplemental oxygen can mask signs of hypoventilation and delay intervention, leading to worsened outcomes [4]

Capnography

- Capnography is a non-invasive tool that can quickly provide life saving information
  - Particularly useful in identifying hypoventilation, bradypnea, and airway obstruction [1]
  - Capnography identifies respiratory compromise earlier than use of pulse oximetry alone [2]
- Clinical observation of ventilation is subjective and a poor measure of depth and effort [3]
- Capnography monitoring in PACU is not currently a standard
- Quality improvement measures for PACUs are including the implementation of capnography with good results

Implementation

Identify

- High risk patients identified pre-operatively and assigned post-operative capnography monitoring [1,2]

Detect

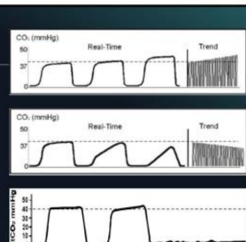
- Capnography detected respiratory depression up to 3 minutes faster than pulse oximetry alone [3,4,5]
- Respiratory depression and apnea prevented by PACU nurses using capnography [1,2,3,4]
- Nurses thought capnography was more effective than pulse oximetry at identifying hypoventilation [3]
- Use of supplemental oxygen can mask signs of hypoventilation when using pulse oximetry [7,8,9,10,11]

Prevent

- Capnography decreased incidence of opioid-induced respiratory depression [6]
- Detected apnea in 29% of post-surgical patients and prevented episodes of hypoxemia [3]
- Detected hypopnea and bradypnea in children preventing episodes of hypoxemia through stimulation or airway maneuvers [3]

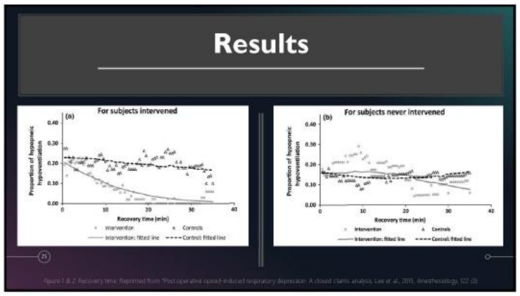
Useful Waveforms For PACU Nurses

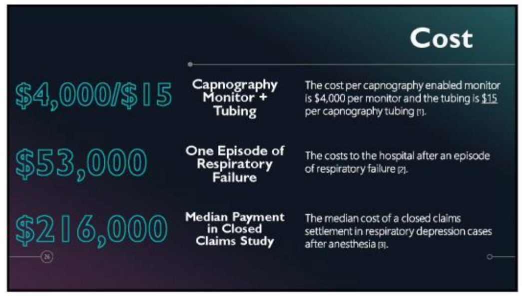
- Useful waveforms for PACU nurses include [1]:
  - Hypercapnia
  - Obstruction
  - Apnea
- An increase in waveform indicates hypoventilation, or partial airway obstruction which could indicate over sedation or a need for an airway intervention [1]
- A decrease or disappearance of a waveform could indicate obstruction or apnea [1]



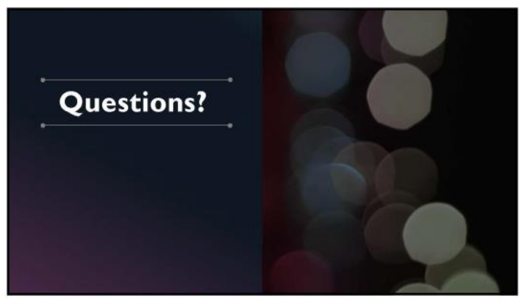
Implementation

1. **Identify High Risk Patients**
   - Age > 60 years old
   - Children < 3 years old
   - Low functional status
   - COPD
   - ASA > 2
   - OSA, or screened positive for OSA
   - Emergency/High Risk Procedures
   - Use of NMB or opioids
2. **Implement Capnography in PACU**
   - Non-invasive
   - Objective measurement of ventilation
   - Early recognition of:
     - Hypopnea
     - Hypercapnia
     - Bradypnea
     - Airway obstruction
     - Apnea
3. **Prevent Adverse Respiratory Events**
   - Early intervention
     - Stimulation
     - Airway maneuvers
     - Airway placement
     - Narcan/flumazenil administration
   - Prevent hypoxia
   - Prevent over sedation
   - Prevent decompensation
   - Prevent reintubation
   - Prevent death/anoxic injury

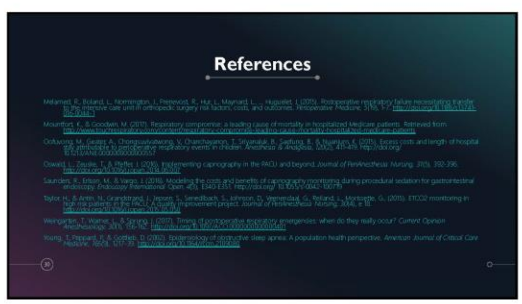

Results
For subjects intervened
For subjects never intervened
Proportion of hypoxemic hypoventilation
Recovery time (min)
Intervention
Controls
Intervention: fitted line
Control: fitted line


Cost
$4,000/$15
Capnography Monitor + Tubing
The cost per capnography enabled monitor is $4,000 per monitor and the tubing is $15 per capnography tubing [1].
$53,000
One Episode of Respiratory Failure
The costs to the hospital after an episode of respiratory failure [2].
$216,000
Median Payment in Closed Claims Study
The median cost of a closed claims settlement in respiratory depression cases after anesthesia [3].


SUMMARY
The cost of extra monitoring, legal claims, and lawsuits for damages after a respiratory event surpasses the cost of capnography itself [1]
Assessing risk factors, enhanced monitoring, adequate reversal, and the judicious use of opioids postoperatively have been identified as effective methods to reduce the incidence of post-operative respiratory complications [2,3]
With the publishing of To Err is Human, safety promotion is a focus in healthcare where healthcare professionals are encouraged to recognize existing safety deficits and develop solutions [2,3]
The implementation of capnography in PACU would align well with the IOM recommendations to incorporate additional layers of safety for the improvement of quality of care. [2,3]


Questions?


References


References

Appendix D: Results Analysis Chart

Paired Samples Statistics

		Mean	N	Std. Deviation	Std. Error Mean
Pair 1	PreTest	.4182	22	.17081	.03642
	PostTest	.8091	22	.13420	.02861

Paired Samples Test

		Paired Differences					t	df	Sig. (2-tailed)
		Mean	Std. Deviation	Std. Error Mean	95% Confidence Interval of the Difference				
					Lower	Upper			
Pair 1	PreTest - PostTest	-.39091	.15090	.03217	-.45781	-.32400	-12.151	21	.000