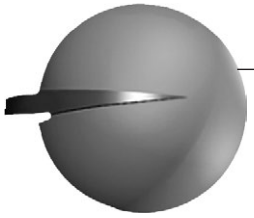

Original Article

Identifying Patients Experiencing Opioid-Induced Respiratory Depression During Recovery From Anesthesia: The Application of Electronic Monitoring Devices

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Key words
opioid-induced respiratory depression, capnography, pulse oximetry, minute ventilation, opioid, hospital, adults, comparative effectiveness, PACU, pain

ABSTRACT

Background: Postsurgical patients experiencing opioid-related adverse drug events have 55% longer hospital stays, 47% higher costs associated with their care, 36% increased risk of 30-day readmission, and 3.4 times higher risk of inpatient mortality compared to those with no opioid-related adverse drug events. Most of the adverse events are preventable.

General Aim: This study explored three types of electronic monitoring devices (pulse oximetry, capnography, and minute ventilation [MV]) to determine which were more effective at identifying the patient experiencing respiratory compromise and, further, to determine whether algorithms could be developed from the electronic monitoring data to aid in earlier detection of respiratory depression.

Materials and Methods: A study was performed in the postanesthesia care unit (PACU) in an inner city. Sixty patients were recruited in the preoperative admissions department on the day of their surgery. Forty-eight of the 60 patients wore three types of electronic monitoring devices while they were recovering from back, neck, hip, or knee surgery. Machine learning models were used for the analysis.

Results: Twenty-four of the 48 patients exhibited sustained signs of opioid-induced respiratory depression (OIRD). Although the SpO_2 values did not change, end-tidal CO_2 levels increased, and MV decreased, representing hypoventilation. A machine learning model was able to predict an OIRD event 10 min before the actual event occurred with 80% accuracy.

Linking Evidence to Action: Electronic monitoring devices are currently used as a tool to assess respiratory status using thresholds to distinguish when respiratory depression has occurred. This study introduces a potential paradigm shift from a reactive approach to a proactive approach that would identify a patient at high risk for OIRD. Capnography and MV were found to be effective tools in detecting respiratory compromise in the PACU.

SIGNIFICANCE

Although the incidence of opioid-induced respiratory depression (OIRD) resulting in sentinel events occurs in <2% of all patients on opioids while in the hospital, the OIRD-related cost is substantial to the patient and the healthcare system. Postsurgical patients experiencing opioid-related adverse drug events have the following: (a) 55% longer hospital stays, (b) 47% higher costs associated with their care, (c) 36% increased risk of 30-day readmission, and (d) 3.4 times higher risk of inpatient mortality compared to those with no opioid-related adverse drug events (Kessler, Shah, Gruschkus, & Raju, 2013). Furthermore, adverse opioid-related sentinel events cost the healthcare system $2.5 million USD per claim on average (Fouladpour, Jesudoss, Bolden, Shaman, & Auckley, 2015).

BACKGROUND

There are several terms used to describe respiratory depression. Understanding these terminologies will aid in building evidence-based, respiratory-related nursing care. Respiratory compromise is described as the deterioration in respiratory function with high likelihood of respiratory insufficiency, failure, or arrest occurring. Researchers and clinicians have used several definitions that represent respiratory insufficiency: (a) apnea—cessation of breath

for >30 s (Cacho et al., 2010); (b) bradypnea—respiratory rate (RR) < 10 per min for more than 3 min (Overdyk et al., 2007); (c) respiratory depression—RR < 8 per min or oxygen saturation <90% (Hanna, Elliott, & Fung, 2005); and (d) hypoxemia—SpO_2 <90% for 10 min (Sun et al., 2015).

Opioid-induced respiratory depression is a phenomenon involving excessive relaxation of the pharyngeal muscles and depression of the respiratory center responses to rising carbon dioxide (CO_2) and decreasing oxygen levels. Respiration is controlled by chemoreceptors and the respiratory center in the central nervous system. When patients experience respiratory depression, they will first exhibit hypoventilation (decreased volume of air movement), then a rise in CO_2 level, and then a decrease in oxygen saturation. Two disorders are highly associated with OIRD: obstructive sleep apnea (OSA) and obesity hypoventilation syndrome (OHS). Current recommendations for preoperative screening for OIRD include using the STOP-BANG questionnaire that has been validated in screening for OSA.

Obstructive sleep apnea involves abnormal collapsibility of the pharyngeal airway during sleep that results in apneic episodes and oxygen desaturation. The combination of the apneic episode and oxygen desaturation causes an inflammatory response in the vascular wall, as well as activation of the stress response. The result is a surge in blood pressure and pulse rate. The combination of the stress response and the inflammatory response results in hypertension, enlargement of the heart muscle, atrial fibrillation, altered glucose metabolism, and disturbed sleep. Patients with OSA overall have poorer health outcomes when hospitalized. Nurses can screen for OSA using the STOP-BANG questionnaire and institute treatment using positive airway pressure therapy during hospitalization (Chung, Nagappa, Singh, & Mokhlesi, 2016). Although OSA is present in 9%–24% of the U.S. population, the majority of the cases remain undiagnosed (Singh et al., 2013), and the STOP-BANG questionnaire can miss up to 18% of patients that exhibit signs of OIRD (Chung, Chan, & Liao, 2017; Chung, Liao, & Farney, 2015). Thus, nurses need better tools than the STOP-BANG questionnaire to assist in identifying OIRD before an adverse event occurs.

Obesity hypoventilation syndrome is a condition in which severely overweight people fail to breathe rapidly enough or deeply enough, resulting in low blood oxygen levels and high blood CO_2 levels. Patients with OHS are 10 times more likely to end up in the intensive care unit postoperatively, three times more likely to need a tracheostomy, and have longer hospital stays than patients without OHS (Kaw et al., 2012). Around 10% of patients with OSA will have comorbid OHS. If patients have a BMI > 30 and retain CO_2, they will likely have not only OSA but also OHS (Hart et al., 2014; Manuel, Hart, & Stradling, 2015). Patients with OHS, when given opioids or other sedating medications, are more likely to exhibit OIRD as well as other negative outcomes during the postoperative period. Although nurses can screen for OHS using the STOP-BANG questionnaire and assessing bicarbonate and CO_2 levels on a chemistry profile, this is not common practice.

To date, guidelines published by the professional anesthesia and pain nursing organizations on monitoring for OIRD recommend first screening for OSA using the STOP-BANG questionnaire and then increasing the frequency of nursing assessments and considering electronic monitoring in those patients screened positive. STOP-BANG has been found to be the most feasible and sensitive screen for OSA and OIRD (Chung, Abdullah, & Liao, 2016; Chung, Memtsoudis, et al., 2016; Joshi, Ankichetty, Gan, & Chung, 2012; Nagappa et al., 2015). Although OSA and OHS are highly correlated with OIRD, around 18% of patients without OSA will develop at least mild OIRD during the postoperative period (Chung, Liao, Yang, et al., 2015).

Summary and Critique of Extant Recommendations for Nursing Assessment for OIRD

According to published guidelines, nurses should assess their patients for signs and symptoms of OIRD: (a) before administering an opioid, (b) at peak effect after administration of an opioid, and (c) every 2 hr for the first 24 hr. Nursing assessment should include the following: (a) counting RR for 1 min while assessing depth of breath and presence of snoring or ancillary muscle retraction, (b) intermittent measure of oxygen saturation (pulse oximetry [PO]), and (c) level of sedation using a validated sedation scale (American Society of Anesthesiologists Task Force on Perioperative Management of Patients With Obstructive Sleep Apnea, 2014; Horlocker et al., 2009; Jarzyna et al., 2011; Jungquist et al., 2016). Nurses are to use prescribed thresholds such as SpO_2 < 90% or RR < 8 BPM to determine whether their assessment findings warrant change in the plan of care. The problem with using prescribed thresholds is that the patient's baseline or "normal for that patient" is not taken into consideration. For example, if the patient was admitted to the hospital with an SpO_2 of 99% and was found to have an SpO_2 of 92% after being medicated, the nurse would consider that a normal and tolerable finding as the patient remains above 90% saturated. However, using this threshold may result in missing early signs of patient deterioration. In the review of medical records relating to death secondary to OIRD, it was commonly found that clinicians failed to recognize patient deterioration early in the trajectory of care (Fouladpour et al., 2015).

Evidence, as mentioned earlier, is building in support of using continuous electronic monitoring of all patients during the first 24–48 hr of starting a parenteral opioid.

Worldviews on Evidence-Based Nursing, 2019; 1–9.

There is also evidence that continuous electronic monitoring of all patients on the general care floor can result in alarm fatigue (Poole & Shah, 2018; Wilken et al., 2017). As current screening mechanisms are fallible and continuously monitoring all patients has downfalls, it seems prudent to develop tools that nurses can use to objectively identify patients experiencing OIRD early in the trajectory of their care. This study aims to explore the effectiveness of using PO, capnography, and minute ventilation (MV) data to identify and predict OIRD in patients recovering from anesthesia. Once identified, the postanesthesia care unit (PACU) nurse could use these data to recommend opioid-sparing pain management or more aggressive monitoring strategies that are personalized to each patient.

METHODS

This study was approved by the Institutional Review Board of the University at Buffalo and the nonprofit healthcare system, Catholic Health. All study team members were trained in ethical research of human subjects, and all research participants signed informed consent. The graduate nurse anesthesia students were all trained in study procedures, standardized procedures with data collection, and equipment prior to participant enrollment. A prospective observational study was performed in the PACU at a community hospital in Buffalo. Graduate nurse anesthesia students, serving as research assistants, recruited 60 patients in the preoperative admissions department. Baseline data were collected from the patients before they received any medications. Data included baseline SpO_2, end-tidal carbon dioxide ($ETCO_2$), MV, and STOP-BANG assessment. Forty-eight of the 60 patients wore three types of electronic monitoring devices while they were recovering from back, neck, hip, or knee surgery in the PACU. Data from three patients were not analyzed; two patients deteriorated quickly ($n = 2$) in the PACU, and one patient was extremely restless and combative and took off the monitoring equipment. The PACU staff usually monitors patients with PO. The patients consented to wear the capnography cannula and MV chest pads in addition to care as usual. The research assistants placed the monitoring devices on the patients as soon as they were settled into the PACU for recovery. The research assistants stood at the foot of the bed and recorded data off the monitoring devices every 2 min throughout their stay in the PACU. The nurses caring for the patients did not interact with the capnography or MV devices, nor did they use the data to influence their care. Other measures recorded during observation were presence and liter of supplemental oxygen, medications name, dose and time of delivery, device alarms, pain level, and body position (degree of head of bed elevation). The devices remained on participants until discharge from the PACU. No participants were monitored after discharge from PACU. Medical records of the postoperative hospital stay were reviewed for evidence of OIRD.

Electronic Monitoring Devices

Pulse oximetry

The oldest and most often used device to monitor oxygen saturation is PO. This device measures the percentage of red blood cells that are saturated with oxygen and has been found to be valid and reliable when measured using a finger probe that rests on the end of a finger (Jensen, Onyskiw, & Prasad, 1998). Normal oxygen saturation levels range from 95% to 100% while awake and >92% when asleep. Elderly patients may exhibit normal awake oxygen levels as low as 91% (Rodriguez-Molinero, Narvaiza, Ruiz, & Galvez-Barron, 2013). In general, an oxygen saturation of <90% for more than 15 s is considered clinically relevant. According to the American Academy of Sleep Medicine (AASM), which provides guidelines for scoring sleep studies to diagnose OSA, a sign of an apneic event is an oxygen desaturation of 3% from baseline for 10 s or more. PO has been found to be a reliable screening procedure for detecting OSA in patients not using supplemental oxygen (Chung et al., 2012). Alarm threshold set for PO is typically < 90%.

Capnography

The measurement of $ETCO_2$ is performed using a capnography device. The capnography device captures the numeric partial pressure of the maximum value of exhaled breath either through the nose or through the mouth over that last 20 s. The $ETCO_2$ numeric value is updated once a second. The patient wears a cannula under the nose, like an oxygen cannula, but it also has a scoop that extends over the top lip that collects data from oral exhalation in patients who breathe through their mouth. Capnography is a validated device that captures respiratory depression earlier than PO, as CO_2 levels increase before oxygen decreases in response to hypoventilation from OIRD (Chhajed et al., 2010; Corbo, Bijur, Lahn, & Gallagher, 2005). Capnography has been validated in the detection of OIRD (Burton, Harrah, Germann, & Dillon, 2006; Cacho et al., 2010; McCarter, Shaik, Scarfo, & Thompson, 2008). Normal $ETCO_2$ levels are in the range of 35–45 mm Hg. Clinically relevant levels that may require intervention are <30 and >50 mm Hg lasting more than 15 s. A clinically relevant level that would define an apneic event is <30 mm Hg with the presence of no breath for 30 s (Ronen, Weissbrod, Overdyk, & Ajizian, 2016). Problems that occur in the clinical setting are mostly related to patient comfort: (a) The cannula interferes with supplemental oxygen delivery and requires a special adaptor; (b) the cannula interferes with the positive airway pressure (PAP) mask, resulting in mask leaks unless the special mask designed to connect through the PAP mask is used (special mask costs between $70 and $100 and are heavy); (c) nurses are

not using the special masks or adaptors for supplemental oxygen, and in most cases, they are putting all three (PAP, oxygen cannula, and capnography cannula) on the face (there are no validation studies to assess whether capnography readings are accurate in this scenario); (d) false alarms happen due to the patient taking off the cannula, as well as alarms when the patient talks or is eating; and (e) taking off the cannula during ambulation or eating can lead to patients returning to bed and not putting the mask back on before they go to sleep. Alarms' threshold defaults for the devices in this study were >50 and <30.

Minute ventilation

Minute ventilation refers to the amount of air, in liters, that a person breathes per min. It is calculated by multiplying RR by tidal volume. Traditionally, this measure was assessed by the anesthesiologist in the operating room. Recently, a portable device was developed that uses two chest leads to detect tidal volume and RR. The only FDA-approved device for this use is Respiratory Motion's ExSpiron 1Xi Minute Ventilation Monitor. This device has been found effective in detecting OIRD (Voscopoulos, MacNabb, et al., 2014). The device uses comparison to predicted minute volume. Predicted minute volume is calculated using sex, height, and weight. There is evidence supporting the determination of OIRD as an MV of less than 40% of predicted level.

STOP-BANG Questionnaire

This questionnaire assesses snoring, tired during day, observed pauses in breathing during sleep, high blood pressure diagnosis, body mass index (>35 kg/m^2), age (>50 years), neck (>17 inches male, 16 inches female), and gender (male). The total score ranges between 0 and 8. A score > 3 identifies intermediate risk of OSA, and >5 is high risk of OSA (Chung, Liao, Farney, 2015).

Definition of OIRD

The main outcome variable in this study was OIRD events. An event was defined as a change in respiratory status within 10 min of administration of an intravenous opioid: (a) SpO_2 dropping below 90% saturation within 10 min of administration of an opioid, (b) $ETCO_2 \geq 50$, or (c) MV <40% of predicted.

Data Management and Analysis

Data were entered into Excel spreadsheets and then transferred into SPSS (IBM Corp., Armonk, NY, USA) for descriptive analysis and R software (R Foundation for Statistical Computing, Vienna, Austria) for time series analysis. Data were cleaned by examining for outliers as well as missing data. Regression analysis was performed using STOP-BANG total score as a predictor of OIRD. Graphs were developed for each patient displaying time series data and a marker representing when a dose of opioid was delivered. Graphs were then reviewed by the research team to identify patients who met the criteria of having an OIRD event as defined previously. Visual examination of each patient's graph, comparing PO, $ETCO_2$, and MV for trends and detection of OIRD events, was performed by the research team. Preprocessing of the data involved fitting piecewise linear models to address the issue of irregularly sampled observations (see Figure 1).

RESULTS

The main outcome variable was an OIRD event. Of the 48 participants who completed all procedures, 26 exhibited OIRD as defined above. Participants not monitored ($n = 14$) either had surgery canceled or were transferred directly to the intensive care unit for recovery. All participants were administered supplemental oxygen via nasal cannula at 2–3 L/min (see Table 1 for sample characteristics). The STOP-BANG questionnaire total score of >5 was not significantly ($p < .05$) associated with evidence of OIRD. Of the 26 subjects that exhibited OIRD, 9 scored > 5 on the STOP-BANG questionnaire. There were no baseline characteristics that significantly ($p < .05$) predicted OIRD.

The preprocessed data were used to train a machine learning model that can predict OIRD (defined as above) several min before it actually happens. The inputs to the model are the PO, MV, and $ETCO_2$ values at a given time instance, as well as an indicator for opioid dosage. The output is 1 if there is an OIRD event after a fixed detection horizon. A support vector machine classifier, a machine learning tool widely used for classification tasks (Cortes & Vapnik, 1995), is trained on these data and then applied to new observations to predict future OIRD events. Results are summarized in Figure 2. The model provides a high detection rate (>0.9) when the detection horizon is short. However, even for longer time horizons (e.g., 10 min before the actual event), the model that uses all three electronic measurements is able to correctly predict nearly 80% of OIRD events. The MV monitor was the single best predictor of the three monitors. MV was able to predict, with >60% accuracy, hypoventilation 5 min before meeting the OIRD threshold.

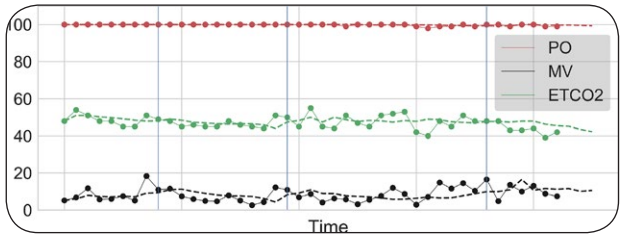

Figure 1. Pulse oximetry (PO), end tidal carbon dioxide ($ETCO_2$), and minute ventilation (MV) data for a single patient. Vertical line is opioid dose.

Worldviews on Evidence-Based Nursing, 2019; 1–9.

Table 1. Subject Characteristics, *n* = 48

	***M* (*SD*)**
Age	58 (10)
BMI	31.5 (6)
STOP-BANG total score	3.8 (2)
Length of surgery (min)	134 (64)
Sex	55% male
Smoker	52%
Type of surgery	
Anterior cervical	13%
Posterior cervical	3%
Lumbar	35%
Knee	8%
Hip	5%
Thoracic	1%

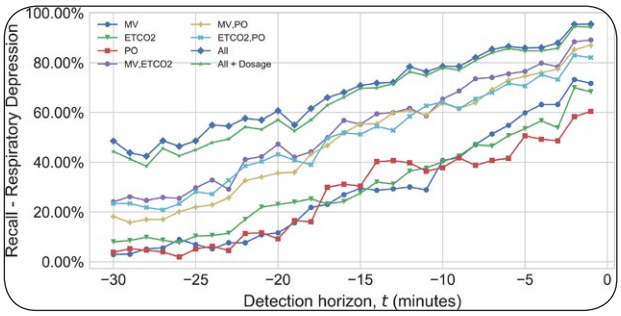

Figure 2. OIRD detection rate for different detection horizons using combinations of electronic measurements.

DISCUSSION

In this study, it was apparent that using PO to assess for respiratory compromise in patients recovering from anesthesia was ineffective, whereas capnography and MV were much more effective in detecting OIRD. Using machine learning prediction analysis on the combination of PO, capnography, and MV, we were able to predict an OIRD event 10 min before the event occurred, with 80% accuracy. Of note, the STOP-BANG questionnaire total score was not significantly predictive of OIRD.

There are several findings from this study that could be applied to clinical practice: (a) The recommended use of the STOP-BANG questionnaire to screen for patients at risk of OIRD may not exhibit high enough sensitivity and specificity; (b) the use of supplemental oxygen may mask respiratory insufficiency as measured by PO; (c) the use of capnography or MV may be more sensitive for the detection of OIRD and identifying a patient at high risk of OIRD; (d) combining respiratory parameters such as PO, $ETCO_2$, and MV may be more sensitive than using only one parameter; and (e) considering a paradigm shift from using electronic monitoring data for detection of respiratory insufficiency to the use of predicting respiratory insufficiency, thus identifying the patient at risk of an adverse event. In addition, these pilot data can be used to develop algorithms that will better predict respiratory events up to 10 min before they occur, allowing for adaptations in clinical care to avoid patient harm. Considerable development and testing of algorithms to identify early deterioration is required before application to clinical care. As this development is in process, nurses can develop advanced skills in interpretation of electronic monitoring data.

Paradigm Shift

Electronic monitoring systems have for years been used to "monitor" patients. It is time for a paradigm shift in nursing practice. With the increased use of technology and electronic data, nurses can utilize these data in a more clinically productive manner. Using electronic data to aid in the identification of the patient at risk for respiratory compromise will allow for earlier intervention and changes in the plan of care to prevent adverse events and thus improve patient safety.

Trend monitoring procedures that include comparing the patients' current readings with previous (before drug) readings will allow nurses to use personalized interpretation of patient data. Once an at-risk patient is identified, providers should be notified and changes in plan of care should occur. At the same time, patients should be educated on their risk and how the risk was determined. It is important that more research is needed to determine clinically relevant changes from baseline. For now, nurses can use the Academy of Sleep Medicine definition of clinically relevant change of 3% (e.g., oxygen saturation decreases from 96% to 93%, sustained through peak effect of drug).

Using PO to Identify High-Risk Patient

The use of PO in the PACU is the standard of care at this time despite evidence that supplemental oxygen can mask the detection of respiratory compromise when using PO monitoring (Fu, Downs, Schweiger, Miguel, & Smith, 2004; Gan et al., 2014; Lam et al., 2017; Magboul, Odugbesan, el Dawlatly, & al Saud, 1998; Rozario, Sloper, & Sheridan, 2008; Volk, Peters, & Sessler, 2017). There is evidence supporting the addition of $ETCO_2$ or MV to current monitoring practices to better detect respiratory compromise in the postoperative setting (Ebert, Middleton, & Makhija, 2017; Heines, Strauch, Roekaerts, Winkens, & Bergmans, 2013; Kim, Choi, Bang, & Lee, 2016; Mehta, Cattano, Brayanov, & George, 2017; Voscopoulos, Ladd, Campana, & George, 2014; Voscopoulos, MacNabb, et al., 2014). On the general care floor, most facilities are using intermittent PO during the postoperative period.

The use of intermittent PO is troublesome and less sensitive for detecting respiratory compromise during states of sedation and sleep due to nonstandardized and not evidence-based nurse procedures. For example, when the nurse walks up to the bed, the patient wakes and takes a deeper breath. The PO device is then put on the finger, resulting in a reading that is reflected by the nurse causing an arousal and deeper breath. Thus, intermittent PO will miss measuring respiratory status at its most vulnerable time, during sleep or when sedated. For this reason, continuous PO is recommended in patients that are not receiving supplemental oxygen therapy during the first 2 hr after surgery.

In general, an oxygen saturation of <90% for more than 15 s is considered clinically relevant. According to the AASM (Berry et al., 2015), which provides guidelines for scoring sleep studies to diagnose OSA, a sign of an apneic event is an oxygen desaturation of 3% from baseline for 10 s or more. PO has been found to be a reliable screening procedure for detecting OSA in patients not wearing supplemental oxygen (Chung et al., 2012). Alarm threshold set for SpO_2 is typically <90%. There is evidence that setting the alarm threshold at 88% decreases the rate of false alarms without increasing sentinel OIRD events (Taenzer, Pyke, Herrick, Dodds, & McGrath, 2014; Taenzer, Pyke, McGrath, & Blike, 2010).

Using PO to Identify High-Risk Patients

Although the use of capnography in the PACU is increasing, nurses on the general care floors are often not familiar with the device and the interpretation of the $ETCO_2$ levels, thus leaving nurses, at times, with only interpreting the RR. Capnography is well validated in the measurement of $ETCO_2$, but it is a new technology and will require considerable nursing education and experience to adapt to the standard of care. In addition, as mentioned earlier, there are considerable patient-related issues such as discomfort and taking the mask off frequently for nursing care, eating, and talking to visitors. These issues must be considered closely, as compliance with leaving the mask in place is important to adequate data acquisition and interpretation. Current thresholds for abnormal findings that represent hypoventilation are sustained $ETCO_2$ levels >50 or repeated and intermittent $ETCO_2$ levels <30 representing lack of breath. Capnography devices currently in clinical practice are developed for threshold monitoring. Considerable development will need to occur before the devices will be prepared with algorithms that will alert nurses using prediction models.

Using MV to Identify High-Risk Patients

There is only one device currently on the market for clinical use that captures MV. This device has been validated in the operating room on ventilated patients and has undergone clinical trials in the PACU. It has recently received approval for use in the pediatric population. This device is easily accepted by patients, and the problem of removing the leads or disconnecting the device only occurs during ambulation. In the future, perhaps Bluetooth technology will be available, or a smaller device that is more mobile for ambulation.

This MV device is the only electronic monitoring device that has alarm threshold determined according to the patient's normal. The predicted MV is calculated by the devices after the nurse enters the patient's sex, height, and weight. The device then sets an alarm threshold of <40% of the predicted MV, thus personalizing the detection of hypoventilation. There have been some concerns that excessive body fat impairs the device sensitivity, as does improper placement of the leads. This device is more sensitive to body movement, which can allow for overestimating MV. Of significance, this body movement sensitivity does not cause excessive alarming. More studies are needed in the clinical application of the device.

Limitations

This study occurred in a select group of orthopedic patients at one hospital. None of the patients actually experienced a critical or reportable opioid-induced respiratory depressive adverse event during their hospitalization. The data were observational as opposed to recorded electronic data directly off the device. Observationally deriving the data could be considered biased by the research assistant and could lend to recording errors. The PACU nurses were providing direct stimulation of the patient during the recovery period and thus likely intervened before a respiratory depressive event could occur. Furthermore, this study was a pilot observational study, which does not meet the higher level of evidence such as case-controlled or randomized clinical trials. Higher level designs are unlikely to ever occur in this setting as it is unethical to ask PACU nurses to put patients in danger by delaying care for an experiment.

SUMMARY

Nurses have the responsibility to provide safe and effective pain management in the postoperative setting. Providing sensitive and specific tools for nurses to improve patient safety is essential. The standard of care to use PO in the patient using supplemental oxygen has been found less sensitive than using capnography or MV. Although capnography is more sensitive in the detection of respiratory insufficiency, MV is as sensitive to detect hypoventilation and is more comfortable for the patient. Best practice, although probably not feasible, would be the use of all three types of devices. This paradigm shift will require hospitals to purchase electronic devices and train nurses on interpretation of the electronic data. Considerable education of nurses will need to occur to adapt more sensitive monitoring practices and to institute a paradigm shift from threshold monitoring

Worldviews on Evidence-Based Nursing, 2019; 1–9.

to using electronic monitoring devices for identification of high-risk patients and prediction of OIRD. In addition, more empirical support is needed in the application of devices and the use of electronic data in nursing care of the hospitalized patients. **WVN**

LINKING EVIDENCE TO ACTION

- Capnography and MV are more effective in detecting respiratory compromise in patients on supplemental oxygen.
- Nurses can use electronic monitoring data to identify patients experiencing OIRD in the postoperative care unit to influence opioid-sparing pain management.
- Postoperative care unit nurses are in the prime position to identify the patient at risk for OIRD after being transferred to the general care floor.
- MV devices are the only device that uses a personalized approach (i.e., compares current reading to what is normal for the patient) to identify hypoventilation.

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