

Initiatives *in Safe Patient Care*

Enhancing patient safety through improved surveillance

Medical errors and their impact on patient morbidity, mortality, and the estimated cost of care are receiving increased scrutiny—an area of particular concern for errors caused by increased demands on physicians and nurses, particularly from caring for more, and sicker patients. Although many errors are individualistic, their severity and associated morbidity may be significantly reduced through prompt detection. Compounding this problem, the US is in the midst of a nursing shortage crisis that is expected to worsen with the aging population. Improving patient safety through a combination of monitoring technology, better education of clinicians and refinement of monitoring protocols can help to attain the goal of zero tolerance for serious patient harm. Helping to reach this goal is the purpose of this new serial continuing education program. In each issue of *Initiatives in Safe Patient Care*, we will address topics in patient surveillance in evidence-based articles, symposia, commentaries and case studies and each issue will be accredited for continuing education credits.

In this inaugural issue, Dr. Overdyk addresses the critical problem of unrecognized respiratory depression (RD) in the setting of postoperative opioid therapy as a significant contributor to in-hospital morbidity and mortality. We have convened a multidisciplinary panel of clinicians to give a 'real world' perspective on postoperative respiratory depression (RD) and opioid therapy.

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Postoperative Respiratory Depression and Opioids

Frank J. Overdyk, MSEE, MD

Unrecognized respiratory depression on the general care floor (GCF), culminating in respiratory arrest or "code blue" is a nightly occurrence at hospitals across the United States. A significant portion of these respiratory arrests occur in postoperative patients receiving opioid analgesics and sedatives, which contribute to respiratory depression. Failure to recognize respiratory depression and institute timely resuscitation has led to cardiopulmonary arrest (often referred to as "cardiac arrest"), resulting in anoxic brain injuries and deaths. Herein, we will review the extent of respiratory depression, its pathophysiology, and discuss solutions to the problem, which comes at huge human and economic cost to our medical system.

Background

Respiratory depression is recognized as a serious complication of opioid analgesic therapy. In 2001, the Joint Commission on the Accreditation of Healthcare Organizations (JCAHO) recommended more aggressive pain management in response to scientific data suggesting widespread undertreatment of pain.¹ Not unexpectedly, the incidence of opioid related adverse drug events more than doubled in one study examining the impact of the JCAHO pain therapy standard.²

Although data concerning the incidence of opioid-induced respiratory arrest is limited, patients suffering this condition may indeed constitute a prominent subgroup in the 350,000 to 750,000 patients suffering an in-hospital cardiac arrest annually.³ Outcomes in these events are often catastrophic. Only one in five patients suffering an in-hospital cardiac arrest survives to hospital discharge. Patients in "unmonitored" beds, which include the majority of postsurgical patients on opioid analgesics, are twice as likely to receive delayed defibrillation therapy and by corollary, ventilatory support, than patients in monitored beds. Patients arresting at night, as

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seen in most case reports of opioid induced respiratory arrest, are more likely to be "unmonitored" and have even worse outcomes than patients arresting during the day, with only a 15% change of survival until discharge and a 89% chance of an unfavorable neurologic outcome.⁴ Fragmented evidence of these devastating adverse events prompted the Anesthesia Patient Safety Foundation (APSF) to sponsor a Workshop on the Dangers of Postoperative Opioids in the fall of 2006.⁵

It is important to recognize that there are a number of factors which predispose postoperative patients on the GCF to respiratory depression. Opioid analgesics and sedatives depress respiratory rate. Residual anesthetics blunt airway reflexes, lower airway tone, reduce lung capacities, and disrupt the sleep cycle. Supplemental oxygen may reduce respiratory drive. Yet the majority of patients establish a respiratory equilibrium between factors which depress respiration (opioids, sedatives, pain) and those which stimulate it (pain, hypoxic/hypercarbic drive, pH sensors, airway reflexes) without experienc-

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PANEL DISCUSSION:

Challenges in the Prevention of Postoperative Respiratory Depression and Opioid Therapy

MODERATOR: Frank Overdyk, MD
PANELISTS: Richard Moon, MD;
 Harold Oglesby, RRT;
 Donna Jarzyna, RN, MSN;
 Chris Pasero, MS, RN, FAAN;
 Kathryn Hansen, MPH.

A multidisciplinary panel of clinicians experienced in the respiratory and pharmacologic nuances of postoperative, opioid-inclusive pain management was asked to give a 'real world' perspective on postoperative respiratory depression and the issues presented in this review. In this discussion, they state their views on the pervasiveness of the problem, the challenges of accurate pain and sedation assessment, alternatives to opioids as postoperative analgesics, and the role of monitoring technology and clinician education and awareness in reducing the incidence of respiratory adverse events.

Is it realistic to have a zero tolerance policy for opioid-related respiratory depression given the medical complexity of current in-patients?

Moon: The main problem for in-patient analgesia is that the most effective systemic therapies have a very narrow therapeutic margin, and a risk of respiratory depression. When intermittent intramuscular dosing regimens were replaced by patient controlled analgesia (PCA) over 20 years ago, the hope was that opioid-induced respiratory depression could be avoided entirely. That turned out not to be the case. Furthermore, when patients are weaned from PCA onto oral narcotics, drug absorption and plasma levels are much more variable and unpredictable, and respiratory events continue to occur. Certain comorbidities, particularly obstructive sleep apnea, increase the perioperative risk and specific genotypes also appear to increase the probability of respiratory depression.¹ A zero tolerance policy for respiratory depression is not yet achievable, although it should be our ultimate goal.

Hansen: I believe a zero tolerance policy is possible with education of the care team, and with

The requirements of any monitoring device are simplicity, high alarm sensitivity and specificity, ease of use, and reliability.

- Moon -

increased monitoring that uses centralized clinical trending exported to the nurse when clinical parameters alarm. This is one our top priorities – for many years we have had standing orders for preoperative assessment of patients at risk for sleep apnea or respiratory depression. The health risk status of our patients is increasing, so we have heightened our attention to strategies to reduce the risk. We have also consistently allocated more capital towards monitoring technology and treatment devices over the years. Today we have made a commitment to allocate several million dollars to expanding our monitoring network.

Will a single monitoring technology be able to help us attain a zero tolerance policy, together with proper communication tools?

Moon: The requirements of any monitoring device are simplicity, high alarm sensitivity and specificity, ease of use, and reliability. With these constraints, respiratory monitoring has traditionally been based upon measurements of breathing rate. Despite its apparent simplicity, accurate monitoring of respiratory rate at the bedside has been technically difficult in practice. Expired carbon dioxide, inductance plethysmography and electrical impedance methods all have some drawbacks. New technology uses tracheal sound monitoring to detect breathing, which is an improvement over techniques but does not assess gas movement. Whether the benefits of greater ease of use and reliability will offset its lack of oxygen or carbon dioxide sens-

ing remains to be seen. Such technology must be coupled with algorithms more sophisticated than a simple rate calculator. The wide variation in respiratory rate in normal individuals implies that specific threshold respiratory rate alarms will generate false positives and negatives. Closer to ideal would be a respiratory minute volume monitor, which does not yet exist as a bedside monitor. Hypoxemia can be a late sign of hypoventilation, thus pulse oximetry cannot be relied upon as a single technique. New techniques must therefore be developed, with parameters such as hemoglobin-oxygen saturation, end-tidal PCO₂, respiratory pattern or sleep state, most likely in combination.

Would opioid sparing techniques make this problem sufficiently rare that it would not be an issue anymore? Are opioids avoidable?

Moon: Opioid sparing techniques today include use of regional analgesia and nonopioid medications such as COX inhibitors, acetaminophen, and anticonvulsants such as pregabalin. Along with opioids, the use of such techniques probably reduces the likelihood of respiratory depression, although this is as yet unproven. Moreover, in the United States, many systemic adjunctive agents are only available for enteral use. Ketorolac is the sole exception, but it has side effects which make it less than ideal in many postsurgical patients. There are no parenteral COX-2 inhibitors available in the US, and it is unlikely that there ever will be. Except for dense regional block (which is difficult to implement on a general ward), currently available adjuncts cannot entirely replace opioids for most surgeries. An unacceptable incidence of respiratory depression (i.e. greater than zero) is therefore probably unavoidable with today's drugs and monitoring techniques. With regard to new non-opioid drug development, the greatest promise perhaps lies in pharmacotherapy directed at sites other than the μ -receptor, such as the sodium channel Nav^{1,7,2,3}

Are current time interval standards adequate to allow clinicians to assess postoperative patients on the general care floor?

Jarzyna/Pasero: Monitoring frequency for patients receiving opioids in the early postoperative period needs to be more frequent than "every 4 hours" after early vital sign monitoring

criteria are met. The first postoperative 24 hours seems to be a high-risk period during which more frequent monitoring is indicated. Changes in therapy such as dose escalation to meet pain needs or decreased pain levels without concurrent adjustment of opioid dosing will prolong this risk, making a 72 hour period of systematic monitoring prudent. The establishment of realistic pain goals together with monitoring of sedation and respiratory quality will help prevent situations leading to oversedation and respiratory depression. Despite similarities among high risk patients, risk may be practice specific. Identifying populations at risk is challenging. Facility specific monitoring of naloxone rescue dosing and Rapid Response Team data can be incorporated with the consideration of other known high risk characteristics such as obesity or a history of sleep apnea, pulmonary disease, multiple co-morbidities and the elderly patient. The implementation of risk-reducing interventions and the use of opioid sparing multimodal therapy will ultimately decrease the overall risk for respiratory depression within the institution.

Oglesby: Our monitoring of PCA patients was inadequate prior to our move to continuous respiratory monitoring via EtCO₂. Routine monitoring consisted of vital signs every 30 minutes x 2, every 1 hour x 4, and then every 4 hours. There is ample time between these time frames for patients to deteriorate without recognition. When a patient demonstrated signs of deterioration, the first response would often be to place the patient on O₂ that would tend to mask any underlying hypoventilation. This may have occurred at the time of the fourth “every 1 hour” vital sign check, so when the nurse entered the room to perform the first or second 4-hour interval check, she or he could very well be unable to arouse the patient who by then would be apneic and without a pulse. In an effort to improve patient safety, our facility added respiratory therapists (RTs) to help assess patients’ respiratory status, EtCO₂ trends, and SpO₂. This additional monitoring by both nursing and RTs combined with continuous respiratory monitoring adds another layer of patient safety.

Are reduced monitoring intervals attainable? What are the impediments?

Jarzyna/Pasero: Yes, if systems can be tuned to decrease the nursing time spent in documentation and if monitoring is focused on the high-risk patient. Identification of criteria constituting high risk patients presents numerous challenges and is an ongoing process. Sedation and monitoring can be supplemented with pulse oximetry monitoring in patients not receiving supplemental oxygen and with end tidal carbon dioxide monitoring in those who are receiving supplemental oxygen. This high tech monitoring should occur for patients at high risk for respi-

Advanced monitoring of oxygenation and ventilation is critical, and a centralized station will complement communication of critical events to the bedside nurse.

- Hansen -

ratory depression and for patients whose sedation status deteriorates. The expense of high tech monitoring is an impediment towards wider use as is the training for general care nurses to help them distinguish between oxygenation and ventilation. This must be weighed against the “expense” of unanticipated adverse events such as, cardiac or respiratory arrest.

How can technology help nurses and respiratory therapists to better monitor patients and communicate with clinical staff? Which particular assessments and communications are in most urgent need for improvement?

Jarzyna/Pasero: Nurses must understand how to integrate technological monitoring data with pain intervention to improve care. Among the factors in urgent need of improvement are identifying and communicating respiratory status trends that indicate poor ventilation and poorly controlled pain. Additionally, physician orders to nurses must allow flexibility for the management of pain in acutely ill patients. Patients are frequently oversedated and in pain. When this occurs, the nurse must be able to reduce the opioid dose, adjust or discontinue other sedating medications which cause CNS depression, and implement nonsedating adjunctive pain treatments.

Hansen: Advanced monitoring of oxygenation and ventilation is critical, and a centralized station will complement communication of critical events to the bedside nurse. Ideally, the communication of the critical event is transmitted through a beeper or phone directly to the nurse. Technology with an algorithm to trend clinical changes provides the care team with clinical information that can be used to intervene to prevent an adverse event. Advanced technology provides alarms to protect the patient. Rather

than ignoring the alarm, an educated care team focuses on the clinical assessment required when monitors alarm. We have expanded our monitoring to include capnography and oximetry at a minimum for many of our patients being transferred from the post anesthesia care unit to the GCF. Critical to this is the respiratory therapist who rounds on the patients systematically.

Oglesby: I believe that monitoring patient via a reliable respiratory monitoring device adds an extra layer of patient safety. EtCO₂/SpO₂ in combination provides an excellent manner in which to monitor these patients. With these devices you are able to continuously monitor both oxygenation and ventilation with minimal interference with the patient’s daily hospital routine. With the use of these devices the nurse or respiratory therapist would be able to give the physician detail data of the degree of respiratory depression present. The wise RT would realize the EtCO₂ is not going to be equal to the patient’s paCO₂ and would use the trending of the EtCO₂ to guide their assessment. A trend of an increasing EtCO₂ and stable and decreasing SpO₂ would lead to the skilled RT or nurse to believe that the patient’s respiratory status is worsening and to suggest an action plan. This trending method would be the most important assessment being performed by the nursing and RT, because the EtCO₂ rise will provide an early indication of respiratory depression in this patient population versus other monitoring methods.

To what extent does current monitoring interfere with patient rest, particularly at night? What are the difficulties of assessing pain, sedation levels, and respiratory/cardiovascular vital signs at night?

Jarzyna/Pasero: It is as important for patients to obtain adequate rest and sleep as it is for nurses to insure patient safety. The addition of a noninvasive method of monitoring ventilation is very tempting to avoid awakening the patient at night, however, just as counting the rise and fall of the chest wall does not necessarily indicate adequate respiration, mechanical monitoring has flaws and can lead to a false sense of security. For example, pulse oximetry can suggest adequate oxygen saturation in patients who are actively experiencing respiratory depression. Monitor alarms often awaken patients enough to remind them to take a breath but do not correct the problem of respiratory depression. The use of EtCO₂ monitoring, which determines respiratory rate by registering the exhalation of an adequate volume of carbon dioxide, may be an important option for some patients. Again, the decision to use mechanical monitoring must be individualized according to risk factors. In addition, whether or not mechanical monitoring is used, it is imperative that nurses perform a thorough respiratory assessment that includes determining the depth,

regularity, noisiness, and rate of respiration, and arouse patients with unacceptable respiratory status for further evaluation. The nurse can be empowered to initiate mechanical monitoring for patients whose respiratory status appears to be deteriorating.

Oglesby: EtCO₂ is a wonderful method of monitoring patients on PCA therapy, however, there is the need to deal with alarms and the placing of a nasal cannula to assess EtCO₂ levels. In my experience, patients who are educated about monitoring are very willing to wear the device and tolerate the alarms. Night alarms are associated with periods of apnea or hypoventilation, so they are denoting actual events and are not nuisance alarms. During GCF rounds, it was noted that patients or the families of patients who tolerated their devices could state the reason they were wearing them. Improved alarm systems and “smart alarms” need to be developed in order to ensure patient rest while providing a safe environment. Smart alarms would be able to analyze a series of input data and interpret that data to recognize whether the data is significant enough to warrant an alarm. As for pain assessment—staff must be educated on how to use the appropriate pain and sedation scales. It is important to have a good baseline assessment of the patient’s risk for sleep apnea prior to the use of any opioid PCA therapy.

Summary:

Our panel of experts appear to agree that, while postoperative respiratory depression due to opioids and sedatives cannot be eliminated, a combination of sophisticated monitors, including central surveillance, in addition to better education of clinicians and refinement of monitoring protocols, may attain our goal of zero tolerance for serious patient harm from unrecognized respiratory depression.

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ing sequelae. There are two situations which, when they coexist, transform an effective, uncomplicated, postoperative analgesic procedure into one with a catastrophic outcome: (1) the opioid-treated patient develops *decompensated* respiratory depression, in which the equilibrium described above tilts toward respiratory depression, and (2) the caregiver fails to recognize respiratory arrest in time to prevent the irreversible neurologic and cardiac sequela of prolonged hypoxia. The challenge for clinicians is to identify patients whose respiratory compensatory mechanisms are overwhelmed and respond immediately to a respiratory arrest should the decompensation have gone undetected.

Opioid Pharmacology

The potent analgesic effect of opioids is mediated through the mu (MOR), kappa, and delta opioid receptors, located throughout the brain and spinal cord. The respiratory depressive effect of opioids is also mediated by MOR receptors, primarily located in the brainstem. An elegant set of experiments in mice genetically altered to disable the MOR gene showed how these two effects are intricately linked.⁶ Opioids acted neither as analgesics nor as respiratory depressants in these animals. Humans display a polymorphism of the MOR gene located on chromosome #6 that alters a patient’s sensitivity to analgesia but not respiratory depression.⁷ This may explain a recent study in which some heavily sedated patients in postanesthesia care complained of significant pain.⁸

We have shown that pain scores and plasma opioid levels during patient-controlled analgesia (PCA) are not linearly related, as one would logically assume (i.e. higher plasma levels lead to lower pain scores).⁹ Thus, there is scientific evidence to refute a common misconception in pain management, that is, that a patient who complains of severe pain cannot be at risk of severe respiratory depression, presumably because pain stimulates breathing.

Respiratory depression remains a dangerous side effect of opioids, regardless of dosing route, and that includes some of the newer, more convenient delivery modalities such as transdermal and intranasal opioid therapy.¹⁰ Patients on chronic opioid therapy who have developed pharmacologic tolerance present a very challenging postoperative pain management problem. Equianalgesic opioid dosing can vary 20- to 100-fold in these patients.

Studies suggest that opioid receptors may be acutely sensitized by potent intraoperative opioids such as remifentanyl, leading to opioid-induced hyperalgesia (OIH), a condition similar to opioid tolerance.¹¹ Thus it is clear that relationship between the dose of an opioid and its pharmacologic effects on analgesia and respira-

tory depression is complex, and is subject to differences in genetics, gender, age, comorbidities, comedication, and dosing route, among other factors.

Most clinicians prescribing opioids are unaware of the many nuances in opioid pharmacology, such as women initially requiring more morphine than men to attain adequate pain relief. (This is due to slower equilibration.) Yet morphine is more potent in women than in men, which may make them more vulnerable to severe respiratory depression.¹²

The prevailing postoperative opioid dosing scheme in adults starts with a non-weight-based, “one size fits all” dosing scheme, and a “titrate to effect” order. However, the safety of this procedure is heavily dependent on frequent and responsive patient monitoring on the GCF, if potentially catastrophic events are to be prevented.

Analysis of Opioid-Induced Respiratory Arrest

In a high-risk field such as medicine, a catastrophic event is usually the result of a confluence of smaller missteps that, in aggregate, lead to the event, in this case, a respiratory arrest. Every patient relies on the flawless execution of a series of steps to ensure that their postoperative pain therapy is given safely. Patients may tolerate a mistake in one or two of these steps, but a breakdown in more than these places them at great risk of a catastrophic event, especially with drugs such as opioids, which have a narrow therapeutic index. The various types of errors that occur with opioid administration are well documented in the literature.¹³ Almost half of all deaths attributed to medication errors involve opiates.¹⁴ The following list describes some of the factors in opioid therapy where mistakes can lead to an adverse event. Vignettes from actual cases are included.

Coexisting conditions and medications:

Obstructive Sleep Apnea (OSA): Patients with OSA have an increased risk of postoperative adverse respiratory events.¹⁵ Tools to help identify patients at risk for OSA are being developed.¹⁶

Case event: A patient has a documented history of OSA, confirmed by polysomnography, but is not obese, which is a widely recognized risk factor for OSA. His OSA diagnosis is missed during preoperative evaluation. Patient suffers respiratory arrest at 5:00 AM on the day after surgery.

Difficult pain management: Certain patient populations are likely to have unsatisfactory pain management with standard dosing regimens. These include opioid-tolerant patients, including those who abuse controlled substances.

Case event: Nurses have difficulty controlling pain in a patient on high-dose, preoperative opioids, and receive a late night, verbal order for additional pain medication, outside of clinical guidelines. Code blue called at 6:00 AM.

Case event: A patient with a known history of substance abuse receives a fentanyl patch post-

operatively. He suffers a respiratory arrest in the early morning hours. There is suspicion that he tampered with the time controlled drug release mechanisms of the patches.

The elderly: The elderly have been documented to be more prone to respiratory depression, largely due to pharmacokinetic and pharmacodynamic variability of opioids.

Drug interactions: Many physicians are not aware of drug interactions that increase the risk of respiratory depression, such as opioids given with sedatives or certain antibiotics.

System and Communication deficiencies:

Drug ordering: The drug ordering and administration protocols in many hospitals are still paper-based and involve multiple data transfers between multiple individuals. Handwritten orders are prone to misinterpretation. Many of the names of the drugs are similar.

Case event: “Discontinue PCA” written at 9:00 AM. Oral (p.o.) opioids ordered. Unit clerk processes orders at noon, but mistakenly forgets to remove PCA order from medicine administration record. Nursing aide administers p.o. opioids while PCA is still in place. Respiratory arrest at 6:00 PM.

Case event: Verbal order for morphine is mistakenly written as “hydromorphone,” a drug 8 times more potent than morphine. Respiratory arrest follows.

Human and Technical Factors:

Technical: Programming sequence of PCA pumps has potential for dosing errors due to confusion with drug nomenclature or dosing units. Pumps rely on unobstructed flow. Manufacturers have improved pump user interfaces and mechanics since many of these problems came to light.

Case event: Patient on fluid restriction suffers respiratory arrest after concentration of opioid is increased 10-fold to minimize fluid administration, without decreasing infusion rate by 10-fold.

Case event: Patient’s IV tube is clamped, yet patient continues to press button and doses accumulate in tubing. Bolus of opioid is released upon unclamping.

Human Factors: PCA relies on the patient to press the pump button and self administer pain medication. Other family members, nurses, and strangers have been known to push the PCA button.

Case event: Mother presses pain button after troublesome early recovery to ensure “a good night’s sleep.” Son suffers respiratory arrest two hours later.

Monitoring:

Current GCF monitoring standards call for vital signs to be recorded as infrequently as once per hour on the day of surgery and once every 4 hours on the second postoperative night. Manually recorded respiratory rates are notori-

ously inaccurate.¹⁷ Assessing the level of sedation, a vital component of opioid monitoring, is difficult at times, especially at night. Differentiating a patient who is sleeping comfortably from a patient who is narcotized with respiratory depression and at risk of an imminent respiratory arrest can be challenging.

Case event: A patient’s wife goes to the nursing desk at 4:00 AM to alert the nurses that “something is wrong” with her husband. She tells them he never sleeps on his back and his snoring is “different.” The nurse checks on the patient and states he “is resting comfortably and needs quiet.” He suffers a respiratory arrest shortly thereafter.

Are Opioids Avoidable?

Given the inherent risk of a serious respiratory complication with opioids, one approach is to minimize the use and/or dosage of opioids. Effective strategies include minimally invasive surgery with local anesthesia, regional anesthetic blocks, and non-opioid analgesics, such as non-steroidal anti-inflammatory drugs (NSAIDs) and COX inhibitors. Unfortunately, the effect on platelet function makes many surgeons wary of using NSAIDs and COX inhibitors postoperatively. Drugs that block the N-methyl-D-aspartate (NMDA) receptor, such as ketamine, dextromethorphan, or gabapentin look promising in blocking OHI. However, it is unlikely in the near term that opioids will be replaced as the mainstay of in-hospital, postoperative pain therapy, and therefore, severe respiratory depression will remain a risk. As of 2006, there were over 10 million inpatient surgeries performed in U.S. hospitals.¹⁸ It can reasonably be expected that a significant proportion of these procedures will require parenteral opioids for at least the first 24 hours postoperatively.

Monitoring

Given the unpredictability of a patient’s response to a given opioid regimen, and the inherent human factor and design shortcomings of our drug administration process, careful monitoring of patients postoperatively on the GCF is the best approach to prevent catastrophic adverse respiratory events. In a small but significant sample of such cases in the American Society of Anesthesiologists Closed Claims database, at least half of the events would have been preventable with better monitoring.¹⁹

Extremely effective monitoring solutions have been developed for the operating room, such as oximetry and capnography, and they have greatly reduced the morbidity and mortality of anesthesia. Unfortunately, monitoring on the GCF is not as straightforward as in the operating room (OR), where patients are anesthetized, immobile, under controlled ventilation, and continually monitored by a dedicated and highly trained anesthesia providers. High-risk patients on the GCF are often monitored with

an intermittent or continuous monitoring bedside pulse oximeter, set to emit an audible alarm triggered by a threshold value, such as a respiratory rate less than 8 bpm. Although the monitor may be identical to that used in the OR, its efficacy in this setting is much reduced. With five or more patients to monitor in different locations, a GCF nurse may note the SpO₂ at most a couple of times per hour and only intervene when the audible alarm goes off. A written value may be charted only every 4 hours. Barring an acute inciting event such as a pulmonary embolus, respiratory depression that culminates in respiratory arrest is an insidious, gradual event, which will escape the notice of the casual observer of intermittent vital signs.

Spot checks of ventilatory parameters such as respiratory rate, SpO₂, or ETCO₂ may

miss the gradual deterioration of ventilatory efficiency. The reason why the incidence of respiratory depression has been underestimated in the literature is because many of the studies rely on intermittent monitoring.²⁰ Continuous monitoring, combined with trend analysis and interpretation, will likely detect a patient about to cross the threshold from stable respiratory depression to respiratory decompensation and arrest. Furthermore, the GCF patient's wide range in level of consciousness and mobility present a new set of challenges that preclude simply installing operating room monitors on the GCF. Patients sleep, eat, talk, and go to the bathroom. Is the drop in oxygen saturation due to hypoventilation or an artifact from repetitive motion? Is the drop in end tidal carbon dioxide due to airway obstruction or due to the patient coughing? Is

the patient asleep or are they so heavily narcotized from their elevated PaCO₂ that they may arrest at any moment? Why does the respiration rate alarm sound every 5 minutes and then silence itself, or was there even someone there to hear it? These questions suggest that simply monitoring a single physiologic parameter and setting an alarm when it reaches a particular threshold may not be sufficiently specific or sensitive to detect decompensated respiratory depression on the GCF. In other words, there may be too many false positives or false negatives with single parameter monitoring.

It is more likely a combination of technologies will be needed for the GCF. Existing, non-invasive monitoring technologies such as capnography, oximetry, and transcutaneous CO₂, are being refined and improved to address the challenges of the GCF. The capnograph detects and quantifies exhaled CO₂ (ETCO₂), and can measure respiration rate. Although ETCO₂ can vary greatly and is subject to artifacts in non-intubated patients, we have shown that trend analysis of the respiration rate and ETCO₂ using heuristic algorithms can identify the insidious onset of opioid-induced respiratory depression over many hours.²¹ (Figure 1). Smart algorithms are being developed which reduce the number of false positive alarms. In selected GCF patients, we were able to identify transient airway obstruction, manifested by snoring, and correlate the capnograph with different levels of consciousness.²² (Figure 2). Moon and colleagues have used the breath-to-breath intervals of the capnograph to quantify ventilation stability.²³ There is evidence that high resolution pulse oximetry can detect patterns consistent with transient airway obstruction in patients with OSA, and may provide an early warning of patients at risk for respiratory decompensation.²⁴ Transcutaneous CO₂ (PtcCO₂) monitors have also been successfully applied to postoperative patients receiving opioids.²⁵ Bioacoustic technology, which uses a microphone to record airway sounds consistent with breathing, has been used to measure respiration rate during conscious sedation, and may have application on the GCF.²⁶ A neurologic monitor that can help assess level of consciousness may be a useful adjunct for nurses at times when the patient needs to be assessed without being disturbed. Processed electroencephalographs, used in the operating room to monitor depth of anesthesia, have been evaluated in their ability to differentiate stages of natural sleep, with equivocal results.²⁷

However, each of these technologies have shortcomings at this time that make them less than ideal for the GCF patient. The most encumbering of these is that these instruments still require tethering of the transducer attached to the patient to the bedside monitor by means of a cable or cannula. This limits patient mobility, satisfaction, and compliance, especially if multiple monitors are used. Miniaturization of devices will likely improve this problem.²⁸ False posi-

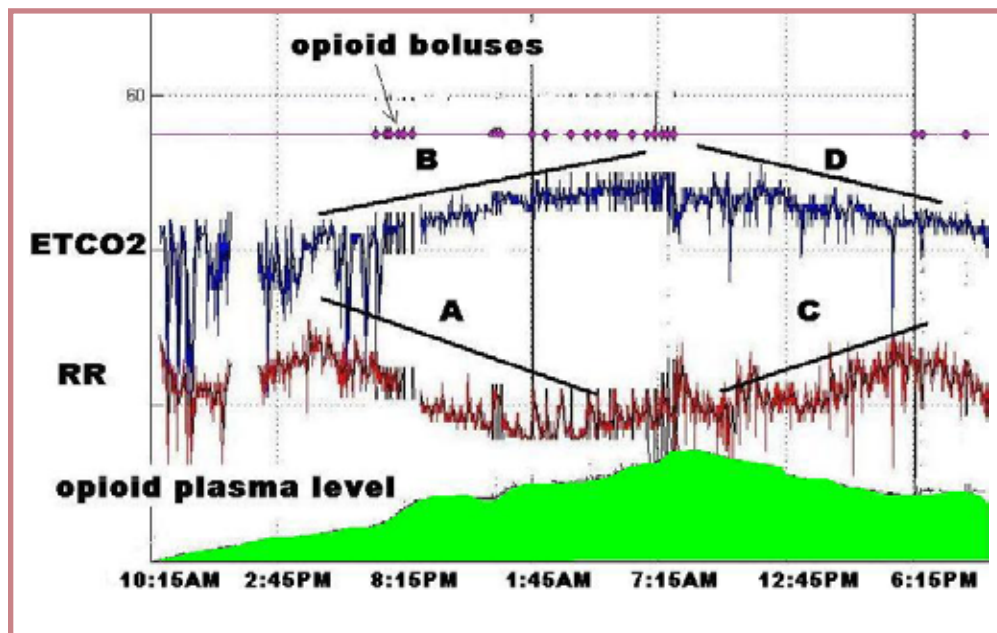


Figure 1. Continuous capnography tracing of patient receiving morphine via patient controlled analgesia (PCA). (A) Gradual decrease in RR after bolus doses of morphine. Pharmacokinetic model shows concentration of morphine at effect site (brain) increasing. ETCO₂ increases as RR falls (B). After opioid level peaks, RR increases gradually (C) while ETCO₂ levels fall (D).

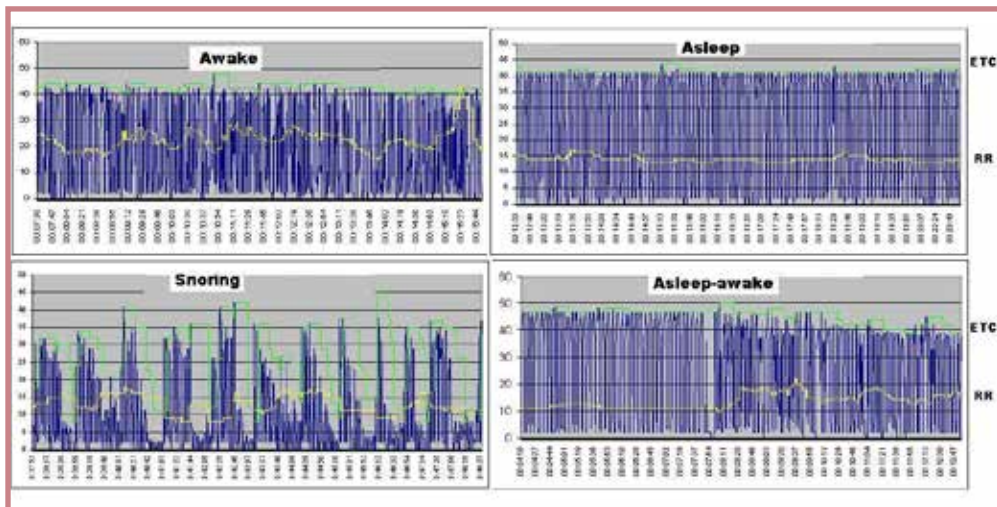


Figure 2 Continuous, condensed capnograph from a patient demonstrating differing CO₂ patterns when snoring (partial airway obstruction), when sleeping without snoring, and when awake, and while awakening.

tive alarms, more common when monitoring an awake, moving patient, are also a significant problem with current monitors.²⁹ Unlike the situation in the OR, where a dedicated provider immediately assesses the alarm and silences it if deemed to be a false positive, bedside audible alarms are a nuisance to the patient and may fail to alert a provider who is not in the room. Patients, family members, and at times nurses, disable the alarm for this reason.

Application of wireless technology to enable instant, remote notification of care providers, or centralized respiratory monitoring on the GCF are excellent solutions. As in centralized cardiac telemetry, centralized respiratory monitoring would provide surveillance by an individual specifically trained in detecting respiratory depression and interpreting the more sophisticated algorithms in future respiratory monitors. It would also relieve nurses from having to silence bedside alarms that are clearly an artifact. Commercially available central monitoring applications for oximetry which use the paging system for notification of adverse events are Oxinet[®], (figure 1) and Patient SafetyNet. (masimo.com) One pain pump manufacturer has logically incorporated oxygenation and ventilation monitoring into their pump platform, allowing for an immediate halt to the infusion should monitoring data suggest respiratory insufficiency. (cardinalhealth.com) Lastly, the adoption of a medical device “plug and play” (MDPnP) standard by medical equipment manufacturers will allow monitoring data to be disseminated more readily, and help reduce communication mishaps with critical data, which are common during respiratory adverse events. (mdpnp.org)

Summary

Unrecognized, decompensated, respiratory depression in the setting of postoperative opioid therapy is a significant contributor to in-hospital morbidity and mortality. The consensus statement from the APSF Workshop on the prevention of postoperative respiratory complications called for “zero tolerance” to patient harm due to postoperative opioids. Respiratory complications due to opioids are deemed preventable with better monitoring and awareness by clinicians.



Figure 1. Oxinet[®] (Covidien/Nellcor)

cians.

A commitment to reduce and eventually eradicate this complication will require capital equipment expenditures, clinician education, and further research. Some healthcare administrators and clinicians view this investment as one that may benefit only a few patients, and favor limiting continuous respiratory monitoring to patients identified as being at high risk by pre-operative screening. Since catastrophic events happen to patients not regarded as high-risk, the APSF statement concludes that this approach is misguided and inconsistent with a “zero tolerance” policy.

In the near future, areas that should receive immediate attention are physician and nursing education programs on opioid pharmacology and side effects, as well as more frequent and inquisitive bedside patient evaluation. In spite of their limitations, many available bedside apnea monitors, oximeters, and capnometers are effective in identifying prolonged cessation of ventilation or respiratory arrest, as long as monitoring is continuous and clinicians can respond immediately to their alarms. This is vital to reduce the delay in recognizing respiratory arrest, if not in reducing its incidence. Delayed resuscitation is the major contributor to poor outcomes in these patients. Longer term, clinician awareness and advanced monitoring and communication techniques may lead us toward our goal of “zero tolerance” for patient harm due to postoperative opioids.

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1. Factors which predispose postoperative patients to respiratory depression include all of the following except:
 - a. opioids
 - b. sedatives
 - c. sleep deprivation
 - d. presence of family members
2. Only 20% of all patients suffering an in-hospital cardiac arrest survive to hospital discharge.
 - a. True
 - b. False
3. Which of the following statements is TRUE
 - a. Transdermal opioids do not cause respiratory depression.
 - b. Identical opioid doses should provide the same amount of pain relief between patients.
 - c. Analgesia and respiratory depression are both mediated by the Mu (MOR) opioid receptor.
 - d. A patients suffering a high level of pain cannot have respiratory depression.
4. Which is the most likely cause of a catastrophic outcome in a patient suffering decompensated respiratory depression.
 - a. Failure to use continuous pulse oximetry.
 - b. Failure to recognize and treat decompensated respiratory depression in a timely manner.
 - c. Failure to administer naloxone.
 - d. Failure to identify patient as 'high risk' preoperatively.
5. Risk factors for postoperative respiratory depression on the general care floor include all of the following except:
 - a. gender
 - b. age
 - c. Obstructive sleep apnea (OSA)
 - d. Difficult pain management
6. Documented reasons why patients have received too much opioid postoperatively include all of the following except:
 - a. Misprogramming of the Patient Controlled Analgesia (PCA) pump.
 - b. Mistake or misinterpretation of a physician order.
 - c. Individuals other than the patient press the PCA bolus button.
 - d. Patients with a high pain threshold.
7. Sedation invariably accompanies respiratory depression.
 - a. True
 - b. False
8. Which of the following is not consistent with the development of opioid induced respiratory depression?
 - a. The slowing of respiratory rate is gradual, not acute.
 - b. Patients complain of dyspnea (difficulty breathing).
 - c. Patients may snore or make gasping sounds.
 - b. Patients are difficult to arouse.
9. Effective strategies that may prevent/detect decompensated respiratory depression include all of the following except:
 - a. Keep patients awake or stimulated.
 - b. Monitor patient vital signs, quality of respiration, sedation, and pain levels frequently.
 - c. Awareness of other drugs, such as muscle relaxants and sedatives, which cause drowsiness and potentiate respiratory depression.
 - d. Continuous monitoring of oxygen saturation and/or exhaled carbon dioxide.
10. Strategies to minimize the dose of postoperative opioids include
 - a. Addition of nonsteroidal anti-inflammatory drugs (NSAID's), anticonvulsants, acetaminophen, and COX inhibitors.
 - b. Regional anesthesia blocks (with or without indwelling catheters).
 - c. Minimally invasive surgery.
 - d. All of the above.
11. The Panel members favor more frequent patient monitoring intervals on the general care floor than current standards dictate.
 - a. True
 - b. False
12. Electronic monitoring elements that will greatly enhance patient safety on the general care floor include:
 - a. Central surveillance station.
 - b. Continuous patient monitoring.
 - c. Sophisticated alarm algorithms that reduce false positive alarms.
 - d. all of the above.

Participant's Evaluation

Answers

This program has been approved for 2.0 contact hours of continuing education (CRCE) by the American Association for Respiratory Care (AARC). AARC is accredited as an approver of continuing education in respiratory care.

Provider approved by The California Board of Registered Nursing. Provider # CEP 14477

To earn credit, do the following:

1. Read the educational offering (both articles).
2. Complete the post-test for the educational offering online at www.saxetesting.com/cf. The questions are the same as above
3. Complete the learner evaluation.
4. To earn 2.0 contact hours of continuing education, you must achieve a score of 75% or more. If you do not pass the test, you may take it again one more time. You will not be charged to take the test a second time.
5. Upon completion, you may print out your certificate immediately. If you are an AARC member, your results are automatically forwarded to the AARC.
6. Accreditation expires May 15, 2018 (RTs) June 24, 2018 (Nurses).

The goal of this program is to educate healthcare professionals on the management of OSA

1. What is the highest degree you have earned? Circle one. 1. Diploma 2. Associate 3. Bachelor 4. Masters 5. Doctorate
2. Indicate to what degree the program met the objectives:
 1. List four risk factors for postoperative respiratory depression.

Strongly Agree	Strongly Disagree
1 2 3	4 5 6
 2. Identify common errors in the process from physician pain order to patient administration that may contribute to opioid induced respiratory arrest.

Strongly Agree	Strongly Disagree
1 2 3	4 5 6
 3. Describe three strategies to minimize postoperative opioid doses.

Strongly Agree	Strongly Disagree
1 2 3	4 5 6
 4. List four features of an electronic monitoring system that can improve monitoring safety.

Strongly Agree	Strongly Disagree
1 2 3	4 5 6

	A	B	C	D		A	B	C	D
1	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	9	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
	A	B	C	D		A	B	C	D
2	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	10	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
	A	B	C	D		A	B	C	D
3	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	11	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
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6	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	14	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
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7	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	15	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
	A	B	C	D		A	B	C	D
8	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	16	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>

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