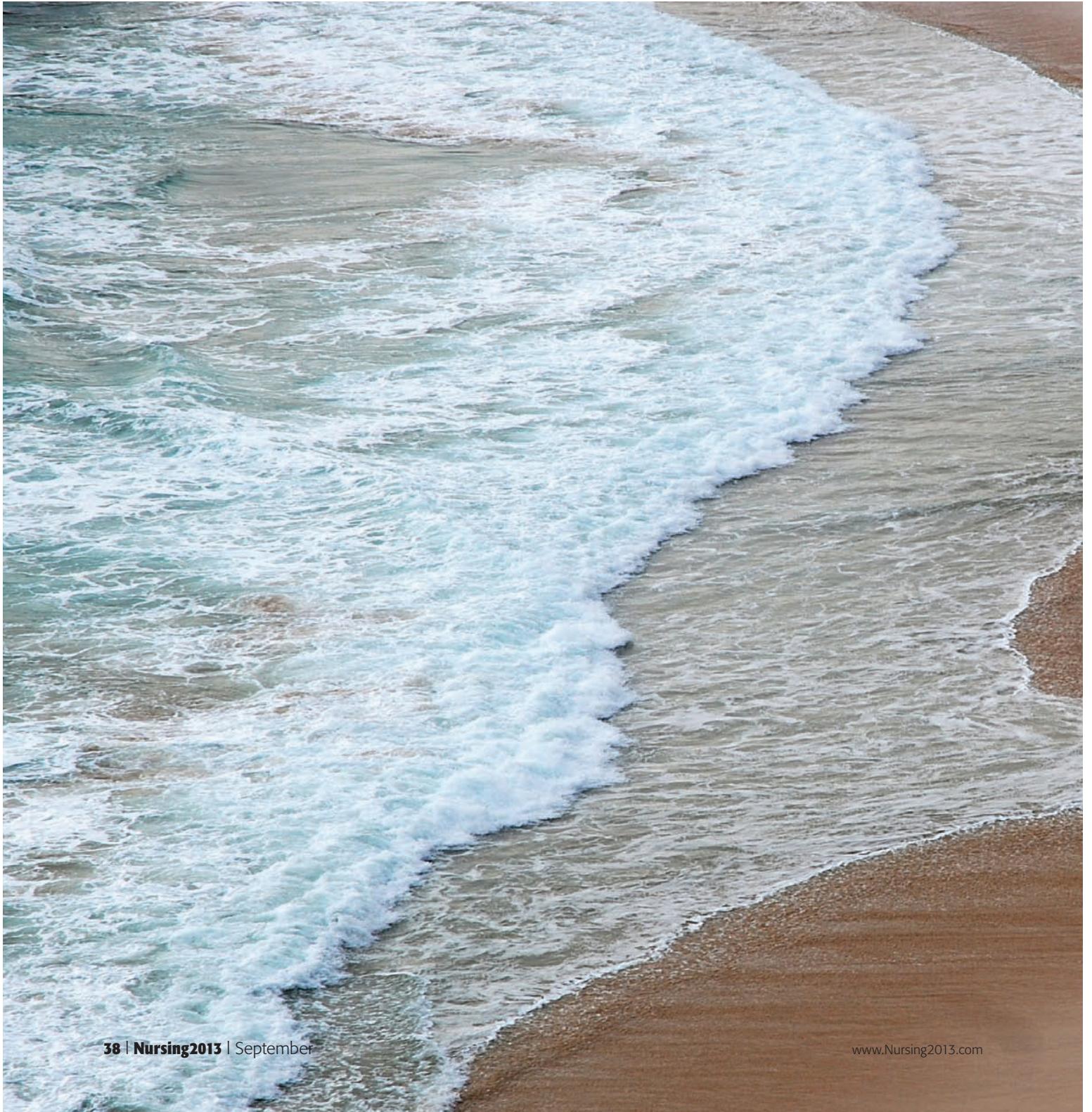


Turning the tide on **respiratory depression**

By Yvonne D'Arcy, MS, CRNP, CNS





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PATIENTS WHO ANTICIPATE surgery expect to receive some type of anesthetic, analgesic, or sedative to keep them relaxed and comfortable. For most patients, the process goes smoothly and they're soon discharged home. However, for others, the procedure may be complicated by oversedation or respiratory depression related to perioperative medications. At particular risk are patients who metabolize drugs slowly and experience sustained drug effects, including sedation, or who have comorbidities such as heart failure, obesity, or chronic obstructive pulmonary disease (COPD) that affect their response to medications. Although all patients should be monitored postoperatively, those with comorbid conditions must be closely assessed for sedation and respiratory depression. The routine use of continuous pulse oximetry is recommended but readings can be skewed when patients are receiving supplemental oxygen.^{1,2} Using tools such as capnography gives the nurse the information needed to evaluate the patient's respiratory status and intervene appropriately.

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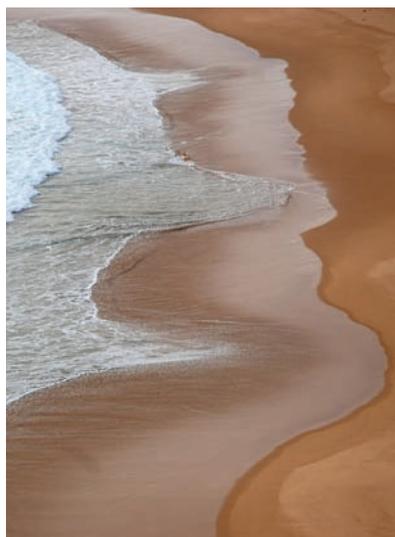
In postoperative patients, pain is a respiratory stimulus. As the pain is controlled with analgesics, patients may become sedated. Sedation monitoring is needed to detect the onset of oversedation, which precedes respiratory depression. Using a sedation scale, such as the Ramsey Sedation Scale, and assessing respiratory rate, depth, pattern, symmetric chest movement, and breath sounds are all essential elements of monitoring patients for changes in respiratory status.

This article describes the issues surrounding the need for respiratory monitoring for postoperative patients using opioids for postoperative pain relief during recovery and explains what national associations recommend for monitoring parameters. A case study will illustrate how effective use of capnography can detect oversedation in a postoperative patient. Start by reviewing how pulse oximetry and capnography differ.

Contrasting pulse oximetry and capnography

Two commonly employed methods of monitoring oxygen saturation levels and end-tidal carbon dioxide (ETCO₂) levels are pulse oximetry and capnography. Increasingly used for surgical procedures and postoperative pain management, these techniques can help clinicians detect impending oversedation, hypoventilation, and respiratory depression. Averting incidents of oversedation that require a higher level of intervention can increase patient safety and improve patient outcomes.

• **Pulse oximetry** noninvasively measures peripheral arterial hemoglobin oxygen saturation (SpO₂) using a small monitoring probe, commonly a clip placed on the patient's finger or earlobe. It reflects hemoglobin saturation that can be negatively affected by the use of supplemental oxygen with oxygen saturation readings higher than the



Using pulse oximetry and capnography can help nurses detect impending oversedation, hypoventilation, and respiratory depression during postoperative pain management.

actual oxygen levels.³ However, an SpO₂ level below 90% is considered to correlate with arterial hypoxemia (a PaO₂ less than 60 mm Hg at a pH of 7.4).⁴ If the patient has poor limb perfusion, the readings can be falsely low.⁴ Patients using supplemental oxygen can have normal or elevated readings despite significantly lower delivery of oxygen to the tissues. Pulse oximetry readings can also be affected when changes in oxygenation lag as a patient's breathing pattern changes. Pulse oximetry doesn't provide immediate detection of hypoventilation, apnea, or airway obstruction.^{4,5}

• **Capnography**, defined as the noninvasive continuous measurement of the partial pressure of carbon dioxide (CO₂) in exhaled breath, measures ETCO₂ using a nasal cannula device for nonintubated patients or a device inserted directly into the airway of intubated patients that can capture real-time readings.⁴ (Intubated patients aren't the focus of this article.) Monitoring ETCO₂ can detect hypoventilation, airway obstruction,

and increasing respiratory depression. According to the Institute for Safe Medication Practices (ISMP) and Anesthesia Patient Safety Foundation, capnography can be used to detect respiratory changes caused by opioids, especially in high-risk patients such as those who are obese or have obstructive sleep apnea (OSA).^{2,6,7}

Other positive outcomes are also associated with the use of capnography. A meta-analysis of eight prospective studies indicates that respiratory depression is 28 times more likely to be detected if patients are monitored by capnography when compared with controls who weren't; ETCO₂ monitoring is an important addition to pulse oximetry.

The literature doesn't support substituting pulse oximetry for capnography to monitor patients for respiratory depression.⁸ In a study of 634 patients using patient-controlled analgesia (PCA) over a 5-month period, 9 patients had significant respiratory depression requiring intervention.⁹ In all cases, capnography triggered an alarm while pulse oximetry did not; all patients were receiving supplemental oxygen, which may have falsely elevated the pulse oximetry readings.

In some instances, pulse oximetry and capnography can complement each other. But in other cases, capnography seems to be more efficient in detecting acute respiratory depression, especially when opioids are involved.

Using the technology

To use capnography for a nonintubated patient, a sidestream ETCO₂ monitoring device is used to aspirate a small sample of respiratory gas via a nasal or nasal-oral cannula.¹⁰ A waveform image is produced for each exhaled breath representing its CO₂ concentration. The numeric values of ETCO₂ are represented as detected from the actual patient airflow. A normal ETCO₂ level is

between 35 and 45 mm Hg for patients without comorbidities such as COPD. Because CO₂ retention is common in patients with COPD, the normal range for ETCO₂ in these patients is higher.^{3,5,11} ETCO₂ values above 45 mm Hg represent hypoventilation and may be a result of opioid-induced respiratory depression, unless the patient has a comorbidity such as COPD in which CO₂ retention occurs as a part of the disease process. (See *Reading a capnography waveform* and *Understanding different types of waveforms*.)

Several types of devices can be used to provide a capnogram or waveform tracing of CO₂ over time, including small hand-held readers, large monitors for ORs or ICUs, and some newer “smart” infusion pumps with modules that can provide numerical ETCO₂ values. Because capnography is noninvasive and is usually portable, it can provide a bedside reading of the patient’s ventilatory status to help the nurse detect increasing respiratory depression. These changes in ETCO₂ can alert the nurse to the need for intervention to avoid a respiratory arrest.

Procedural sedation

Another area where capnography can be helpful is during procedures in which patients receive sedation. Because most patients aren’t known to the hospital staff, they can respond unexpectedly to medications used for procedural sedation or analgesia. The patient may slip into a deeper level of sedation than intended. Monitoring chest movement and pulse oximetry won’t alert the nurse to changes in ventilation (how effectively CO₂ is eliminated by the pulmonary system) or airway obstruction.¹⁰ Capnography can improve patient outcomes during procedural sedation or analgesia by

- decreasing the need for oversedation reversal agents.
- reducing the need for rapid response teams, anesthesia providers,

Reading a capnography waveform

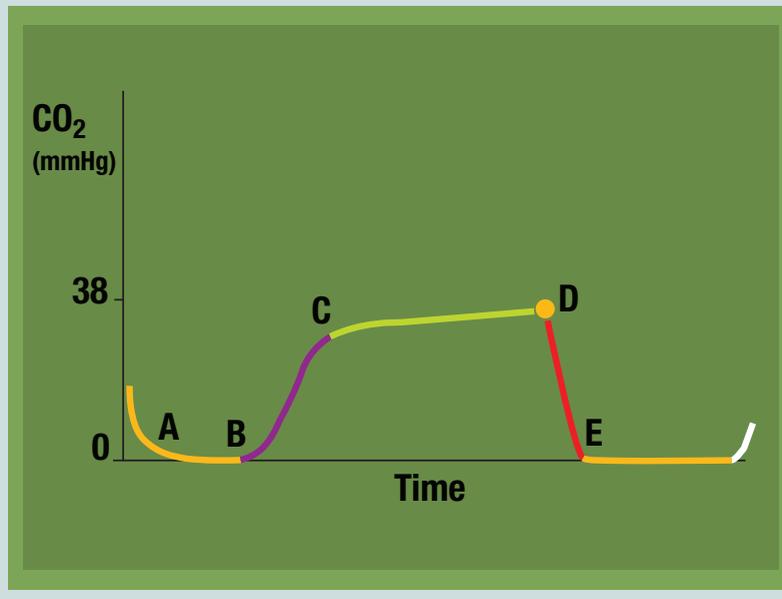
A to B, baseline: end of inspiration, early expiration

B to C, rapid rise in CO₂: mixing of alveolar dead space and alveolar gas

C to D, alveolar plateau: alveolar gas exchange

D, end of exhalation: point where ETCO₂ is measured

D to E, inspiration: rapid decrease in CO₂



or respiratory therapists to rescue oversedated patients.

- reducing unplanned hospital admissions for oversedated patients.

Two studies show the advantages of capnography during procedural sedation. In a study of 74 ED patients, 33 patients developed respiratory depression and 11 patients required assisted ventilation. Respiratory depression was detected by pulse oximetry in only 11 of the 33 patients. However, all patients with respiratory depression had an ETCO₂ greater than 55 mm Hg, an absent waveform, or a change in ETCO₂ greater than 10 mm Hg.¹²

Another study involved 132 adults who were sedated with propofol. By adding capnography to standard monitoring, clinicians reduced hypoxemia by 17% and were able to detect hypoventilation and intervene earlier to reduce adverse events (interventions increased by 18%), helping to improve respiratory

status and identifying all episodes of hypoxia in advance.¹³

Following the recommendations

Monitoring with pulse oximetry and capnography is especially important when patients are receiving opioids, which increase the risk of oversedation and respiratory depression. (See *A closer look at opioid use*.) The American Society of Anesthesiologists (ASA) Task Force on Acute Pain Management and its Task Force on Perioperative Management of Patients with Obstructive Sleep Apnea, along with The Joint Commission (TJC) and ISMP, have developed national and international guidelines. They identify the need for consistent monitoring of patients who are in the immediate postoperative period or who are being given postoperative pain medications.^{3,6} Despite these recommendations, many patients continue to experience oversedation and adverse events.

National accrediting bodies such as TJC, national professional organizations such as the ASA, and patient safety organizations such as ISMP have made recommendations to ensure patient safety and avoid

oversedation while providing adequate pain relief in patients using opioids. Because patient response to opioids varies, identifying who's at a higher risk, which procedures present an increased risk for

oversedation, and what conditions increase patient risk are all important factors to explore.

The ASA recommends that the use of neuraxial analgesic techniques such as epidural catheters include monitoring for respiratory depression.¹⁴ This includes patients receiving low-dose epidural opioids via patient-controlled epidural analgesia. It also recommends identifying patients at risk for respiratory depression such as those with OSA or pulmonary disease.

The ASA monitoring recommendations include the following:

- All patients on neuraxial analgesia should be monitored for respiratory adequacy of ventilation, including but not limited to respiratory rate and depth of respiration.
- Monitoring should continue for the entire time the infusion is in use.
- If pulse oximetry is used, it should be continuous rather than intermittent.
- ETCO₂ monitoring is more likely to detect hypercapnia/hypercarbia and respiratory depression than clinical signs.¹⁴

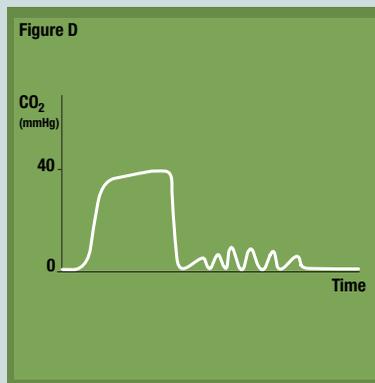
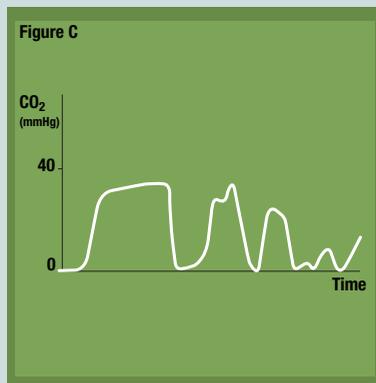
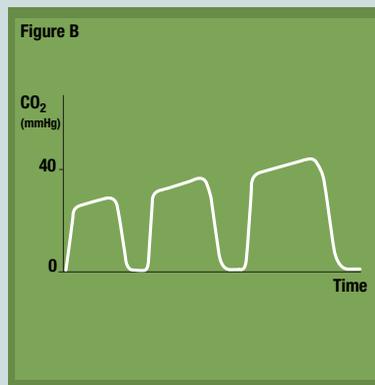
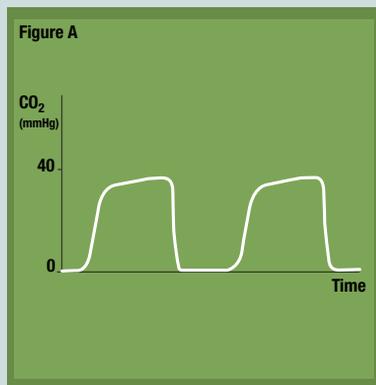
Understanding different types of waveforms

Normal ETCO₂ waveform (35-45 mm Hg); each waveform reflects a breath (see Figure A). Note the alveolar plateau suggesting effective ventilation.

Hypoventilation (decreased respiratory rate and increased ETCO₂) may occur during opioid therapy (see Figure B). Note trends when documenting periodic vital signs. This graph showing hypoventilation depicts exhaled breaths over a few seconds and a steady, rapid increase in ETCO₂. In addition, while the inspiratory time is staying relatively stable in the inspirations shown, each period of exhalation is increasing, which reflects the decrease in the respiratory rate. In an actual case, the trend of increasing ETCO₂, decreasing respiratory rate, and increasing expiratory time would occur over several minutes as respiratory depression develops. In the breath-by-breath graphic such as this example, a more gradual climb in the ETCO₂ is seen.

Partial airway obstruction may be caused by poor head or neck alignment, OSA, or a kinked or occluded oxygen cannula (see Figure C). The first waveform is a normal breath followed by inadequate ventilation caused by partial obstruction or poor airflow.

No breath may be caused by respiratory arrest, total airway obstruction, or a kinked or displaced oxygen cannula (see Figure D). The first waveform is a normal pattern with the following lines showing no ventilation due to obstruction or respiratory arrest.



Minimizing OSA-related risks

OSA is thought to occur in about 5% of the American population, but the incidence may be as high as 9%.¹⁵ Many patients present for surgery with undiagnosed OSA, which increases the risk of oversedation when they receive postoperative opioids.¹⁶ OSA contributes to increased risk for oversedation and respiratory depression because it's accompanied by increased difficulty maintaining upper airway patency. The use of anesthetic agents, analgesics, and sedatives can exacerbate the problem. Patients with OSA are at increased risk for cardiac ischemia, hypoxia, acute hypercapnia, and delirium following surgery.¹⁷ When comparing a group of 101 patients with OSA undergoing knee or hip replacement surgery to a control group, researchers found that complications related to OSA led to unplanned ICU days,

endotracheal reintubations, cardiac events, and longer hospitalizations.¹⁸

TJC and ISMP recommendations for respiratory monitoring focus on patient safety for those patients with respiratory dysfunction, especially OSA. The ASA recommendations, which center on perioperative management, include the following:

- using organizational protocols that include screening surgical patients for OSA¹⁶
- not relying on pulse oximetry readings alone to detect opioid toxicity⁷
- establishing guidelines for appropriate monitoring of patients who require opioids for pain relief that include the quality of the respirations and not just the respiratory rate⁷
- prolonging postoperative monitoring time for patients with OSA.

These patients should be monitored for 3 hours or more longer than patients without OSA, and monitoring should continue for a median of 7 hours after the last episode of airway obstruction¹⁷

- ETCO₂ monitoring should be used during moderate or deep sedation and with analgesia for patients with OSA because of the risk of undetected airway obstruction.¹⁷

All patients who are receiving opioids for postoperative pain management or procedural sedation require careful monitoring to maintain the highest level of patient safety. Nurses caring for these patients should be aware of the increased need for monitoring respiratory status and know their facilities' guidelines and policies.

Clinical implications

In 2010, "The Seventh Annual Healthgrades Patient Safety in American Hospitals Study" reported that the problem of respiratory failure has grown more than was previously suspected. The incidence of postoperative respiratory failure is worsening, up 6.2% from the 2009 study. It's cited as being the third

A closer look at opioid use

Depending on the type of surgery, pain can be intense in the postoperative period. I.V. opioids are regularly used either as intermittent injections or PCA.

The current trend in surgery is to move to outpatient procedures. Surgeries such as a simple laminectomy that required a 2- to 3-day hospital stay 20 years ago are now done as outpatient surgeries without hospital admission. About 70% of all surgeries are performed in outpatient surgery centers.¹¹ In critical care areas and EDs, procedures such as chest tube insertions and central venous access device placements are commonly performed with the use of procedural sedation, which requires monitoring for oversedation. The use of sedatives and anesthetics during surgery compounds the risk of respiratory depression from subsequent opioid use.

Because sedation doesn't provide analgesia, sedatives such as midazolam are combined with analgesics such as opioids to help patients tolerate procedures with minimal pain or discomfort. Because all patients respond differently to opioids and sedatives, monitoring parameters and guidelines must be followed to ensure patient safety. The combination of sedative agents, sleep aids, and other medications such as antiemetics can increase the potential for oversedation when they're used with opioids.

For many inpatients, PCA is used to provide postoperative pain relief. Because the patient administers pain medication when needed, PCA provides a consistent level of pain relief. Once the patient starts oral intake, he or she is usually converted to oral analgesia and PCA is discontinued.

most common of the 16 patient safety indicators.¹⁹

As far as cost to the healthcare system, postoperative respiratory failure is the second most costly patient safety indicator, just after pressure ulcers. Overall, the cost to a healthcare system can total 1.82 million dollars.¹⁹

What makes postoperative opioid use so risky? As indicated previously, the individual response to opioids varies. When patients report more pain after surgery, more pain medication may be prescribed, increasing the risk. Predictive factors for morphine consumption in the postoperative period include:

- emergency surgery
- surgery lasting longer than 100 minutes
- pain score of 2 to 3 on a 5-point pain intensity rating scale
- White patients
- major surgery.^{20,21}

PCAs aren't push-button pain management. Patients like them for the convenience and ease of use, but they present a potential problem for healthcare professionals. For instance, patients' visitors may press

the patient's pump activation button for him or her (PCA by proxy) or patients may slip into undetected oversedation. The real key to success is the monitoring that takes place to ensure that all patients using the devices are doing so safely.

Delivering basal infusions via PCA is no longer recommended for opioid-naïve patients because they add little to analgesia but increase the risk of oversedation.²² (The exception is opioid-tolerant patients, such as those who take daily opioids to control pain related to cancer or chronic pain.) Nurses must recognize a red flag when patients rouse to answer questions but fall right back to sleep. Oversedation is occurring, and the patient will experience respiratory depression if no action is taken. Patients using PCA can become hypoxic even with pulse oximetry readings showing Spo₂ percentages in the low to mid 90s.¹ Patients who are morbidly obese and older than age 65 are at higher risk for respiratory depression and sedation with PCA.²³ Frequent episodes of desaturation and bradypnea, often undetected, can occur

during PCA therapy in the general population unless monitoring is being performed.²³

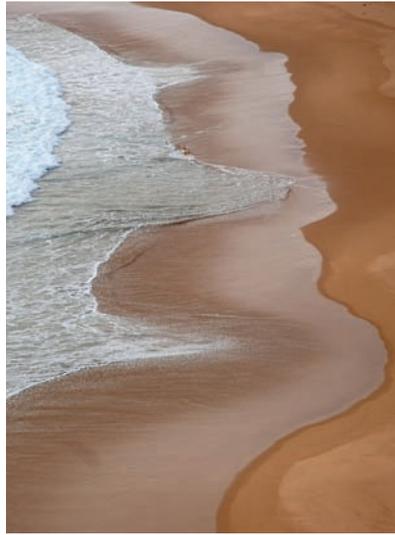
Nurses caring for these patients must adhere to the prescribed monitoring parameters detailed by their healthcare facility. They must also understand how to use newer technologies to monitor the respiratory status of patients receiving opioids.

Case study

To put this information into practice, consider a typical patient. Mr. P, 68, is admitted for bilateral total knee replacement. He's been having pain in his knees for several years and the intensity of the pain has become very limiting, rated as an 8/0-10 on some days. He can no longer golf or take walks with his wife. He'd like to have the surgery to help restore a higher level of functioning. He's been taking non-steroidal anti-inflammatory drugs (NSAIDs) to help control his pain, but he hasn't taken any opioids prior to his surgery. He had to stop his NSAIDs 2 weeks before surgery to reduce perioperative bleeding risk. He has a history of asthma that's currently controlled with a rapid-acting beta₂-agonist and a leukotriene receptor antagonist.

After his surgery, Mr. P manages pain with hydromorphone via PCA.²² Because Mr. P is so sleepy after his surgery, his wife occasionally presses the PCA pump activation button for him, hoping to help control his pain.

At midnight (0000 hours), Mr. P wakes up for his assessment but immediately falls back to sleep. At 0030, the nurse can't rouse him with verbal stimuli. Assessment findings include slow and shallow respirations. Breath sounds are clear but decreased bilaterally. His SpO₂ is 90% on supplemental oxygen via nasal cannula at 4 L/minute. Arterial blood gas analysis demonstrates a PaCO₂ of 55 mm Hg (normal, 35 to 45 mm Hg), indicating that



Capnography can be used to detect respiratory changes caused by opioids, especially in high-risk patients who are obese or have OSA.

he is most likely oversedated as the result of opioid use.

What happened to Mr. P could happen to any patient. He was opioid naive, meaning he hadn't taken any opioids for at least 7 days before his surgery.¹¹ When his wife continued to press the PCA pump activation button for him, she was providing a type of continuous medication administration leading to oversedation.

Taking the "patient" out of "patient-controlled analgesia" can have serious consequences. A very important safety feature of PCA is that patients who are oversedated from having received too much opiate won't be able to press the button to obtain additional doses of the drug. This safety feature is overridden if someone else pushes the button for them.²⁴

If Mr. P couldn't activate the PCA button independently, intermittent I.V. analgesia would have been a better way to deliver additional pain medication, if needed. With that method, the nurse could have assessed Mr. P with each dose to determine his level of sedation and respiratory status.

When the nurse discovered Mr. P, if his respiratory rate had been less than 10 breaths per minute, he would have needed naloxone to restore normal respiratory rate.⁷ Naloxone is an opioid antagonist used as a reversal agent; it causes the opioids to release from the mu binding sites. Because the half-life of naloxone is very short, patients receiving it need careful monitoring; if their respiratory status deteriorates again, they'll need additional doses of naloxone.¹¹ If Mr. P had been monitored with capnography, his hypoventilation and increasing sedation would have been detected sooner.

One way to avoid PCA by proxy is through patient and family education. Nurses need to explain how giving patients unneeded opioids can result in dangerous and possibly fatal outcomes. Most family members believe they're helping by giving doses of medication when the patient is "asleep." Explaining the concept of PCA and how the patient is really the only one who knows when medication is needed can help optimize patient safety.

Summing up the pros and cons

All patients using opioids for postoperative pain relief or undergoing procedural sedation/analgesia like Mr. P need to be closely monitored. Currently, the use of pulse oximetry is less effective when it's used alone. Adding capnography can improve patient safety and patient outcomes.

Nurses caring for these patients need to be aware that hypoventilation can be difficult to detect using standard assessment practices. Using all the technology available, including capnography, is always best practice. ■

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Yvonne D'Arcy is a pain management and palliative care nurse practitioner at Suburban Hospital—Johns Hopkins Medicine in Bethesda, Md. Ms. D'Arcy is also a member of the *Nursing2013* editorial board.

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Turning the tide on respiratory depression

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