The case for capnography in patients receiving opioids

Learn why capnography is essential for detecting respiratory depression.

By Heather Carlisle, PhD, DNP, FNP-BC, RN-BC

IT'S YOUR WORST NIGHTMARE: *At 8 A.M., you walk into the room of Laura M, a 35-year-old patient who had surgery yesterday, for your morning assessment. She's unresponsive. The night nurse told you in report that she'd given Laura morphine I.V. every 2 hours for postoperative pain; since then, she said, Laura had been sleeping quietly, waking only during hourly rounds to ask for more pain medication. When the patient-care technician last checked vital signs at 6 A.M., Laura's respiratory rate was 16 breaths/minute and oxygen saturation (SaO_2) 98% on room air.*

Faced with an unresponsive patient, you decide to act on the standing order for naloxone. You call out for someone to get the drug as you assess Laura's pulse and respirations. She still has a pulse but her respiratory rate is just six breaths/minute. Your colleague begins ventilations with a bag-valve mask as you slowly administer naloxone until Laura begins to wake up. When her respiratory rate starts to improve, you heave a huge sigh of relief while your charge nurse arranges for her transfer to the intensive care unit (ICU). Crisis averted.

At the end of your shift, you check on Laura in the ICU. Her nurse tells you Laura has been complaining of poorly controlled pain throughout the day, but the physician is reluctant to order more opioids because of her near-miss this morning.

This scenario strikes fear in the hearts of bedside nurses. Opioid-induced respiratory depression (OIRD) is a life-threatening complication of opioid analgesia. Even the most opioid-tolerant patient isn't immune. Respiratory arrest is a contributing factor in about one-third of the 750,000 cardiopulmonary arrests that occur annually in U.S. hospitals, and about half of these patients had received an opioid. Mortality for in-hospital cardiopulmonary arrest may be as high as 80%, with the worst outcomes occurring on medical-surgical units. Between 2006 and 2009, postoperative respiratory failure was the third most common safety incident in American hospitals, affecting an estimated 600,000 patients yearly at a cost of $1.5 billion.

Professional associations and regulatory agencies have called for action repeatedly to prevent OIRD in the hospital setting. In 2012, The Joint Commission (TJC) issued an alert urging hospitals to take action to increase opioid safety and reduce opioid-related sentinel events. The Anesthesia Patient Safety Foundation (APSF) has called for OIRD to be designated a "never" event. In 2011, the American Society for Pain Management Nursing (ASPMN) issued evidence-based guidelines to help nurses monitor for OIRD in acute-care settings.

Nurses bear the brunt of responsibility for monitoring hospital patients for OIRD, yet we have little control over the medication regimens they're receiving. This is where capnography can play a lifesaving role. This noninvasive technique detects early signs of OIRD by measuring exhaled carbon dioxide (CO_2). Early detection promotes timely rescue, particularly on medsurg units where nurse-to-patient ratios are higher and critical events are less likely to be witnessed. Numerous studies show capnography detects signs of respiratory depression earlier and more effectively than visual respiratory assessments or pulse oximetry. This crucial tool can help you keep patients safe.

CNE
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LEARNING OBJECTIVES

1. Describe opioid-induced respiratory depression (OIRD).
2. Discuss the role of capnography in monitoring patients for OIRD.
3. State how to use capnography for patients at risk for OIRD.

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Understanding OIRD

Defined as a decrease in baseline ventilatory function after opioid administration, OIRD manifests as a respiratory rate between eight and 10 breaths/minute, oxygen saturation as measured by pulse oximetry (SpO_2) below 90%, and end-tidal carbon dioxide ($ETCO_2$) above 50 mm Hg. Severe respiratory depression occurs when the respiratory rate falls below eight

breaths/minute with SpO_2 below 85% for at least 6 minutes.

But these thresholds aren't exact, and OIRD has occurred even when vital signs are outside these parameters. So always treat the patient, not the numbers. Keep in mind that sedation, a common opioid side effect, precedes respiratory depression. Be sure to assess regularly for sedation (along with respirations and pain) and document sedation using a validated scale, such as the Pasero Opioid-Induced Sedation Scale.

When OIRD is detected early, nonpharmacologic interventions may be effective in preventing the condition from worsening. Upright patient positioning, talking to or shaking the patient gently, and encouraging breathing may be enough to arouse the patient and stimulate breathing.

When OIRD isn't detected early, naloxone must be given to reverse opioid respiratory depressant effects. Yet when administered improperly, naloxone reverses opioid analgesic effects, leading to severe pain and distress for your patient. Naloxone acts quickly but doesn't last long, so patients may need multiple doses, depending on duration of the opioids they received. About 0.2% to 0.7% of patients receiving postoperative opioids require naloxone rescue. In the United States, this equates to about 20,000 patients every year.

Although naloxone was once thought to cause only minor side effects (such as nausea and vomiting from increased pain), we now know it's far from benign. It may lead pulmonary edema, arrhythmias, hypertension, and cardiac arrest. (See *Giving naloxone to adults with OIRD.*)

Giving naloxone to adults with OIRD

Naloxone may be administered to reverse opioid-induced respiratory depression (OIRD). In the hospital, it's usually given I.V., although it can also be given intramuscularly, subcutaneously, or even intranasally to patients without I.V. access. It has a rapid onset (2 minutes), reaches peak concentration in 10 minutes, and lasts 1 to 4 hours.

To partially reverse postoperative OIRD, smaller naloxone doses given slowly usually are sufficient and may prevent complete analgesia reversal (which could cause a severe stress response). Dilute 0.2 mg naloxone in 10 mL normal saline solution and titrate the dose 1 to 2 mL at a time until symptoms are reversed. You don't need to give the entire dose if respiratory depression reverses or the patient regains normal alertness. Stimulate the patient to breathe, if necessary, with loud talking, gentle shaking, repositioning, or a sternal rub, and monitor carefully.

If the patient's in respiratory arrest, support respirations with bag-valve-mask ventilation. Administer 0.4 mg naloxone diluted in 10 mL normal saline solution; titrate to effect, as described above. You don't need to give the entire dose. As necessary, repeat the dose at 2- to 3-minute intervals to the desired degree of reversal (adequate ventilation and alertness without significant pain or discomfort). Larger-than-necessary naloxone dosages may cause significant analgesia reversal and increased blood pressure. Too-rapid reversal may induce nausea, vomiting, sweating, or circulatory stress.

Who's at risk for OIRD

All patients are susceptible to OIRD—whether opioid-naïve or tolerant, whether they're receiving an oral-only opioid regimen or an I.V. infusion, whether the nurse administers the opioid or the patient uses a patient-controlled analgesia (PCA) device. But certain factors can raise the risk. ASPMN has identified the following high-risk groups: patients with renal dysfunction, chronic obstructive pulmonary disease, heart failure, obstructive sleep apnea (OSA), or obesity.

In OSA, the upper airway becomes occluded during sleep. The condition increases OIRD risk because opioids may relax pharyngeal tone and worsen airway occlusion. OSA prevalence may be as high as 5%, although only about 15% of sufferers have a confirmed diagnosis. The high rate of undiagnosed OSA means clinicians may not recognize a patient's risk. A body mass index above 30 and a neck circumference of 17.5" or more indirectly indicate OSA and are considered OIRD risk factors. Never ignore loud snoring—an ominous sign of airway obstruction.

Certain iatrogenic factors also increase risk. According to TJC, 11% of opioid-related sentinel events from 2004 to 2011 stemmed from excessive dosing, drug interactions, and adverse effects. Patients receiving both benzodiazapines and opioids or continuous opioid infusions and those within the first 24 hours after surgery involving general anesthesia are at greater risk for OIRD. What's more, OIRD can occur not just with continuous opioid infusions (including continuous infusion mode on PCA) but also with intermittent parenteral opioid injections. One analysis of OIRD cases over a 1-year period found only 20% involved continuous opioid infusions; the rest were linked to intermittent I.V. bolus injections or oral opioids (or concurrent use of both oral and parenteral opioids).

This finding helps us understand where patients at high risk for OIRD tend to be located in hospital settings: Generally, continuous opioid drips are given on critical care units, where continuous monitoring is standard practice. In contrast, RN-administered intermittent parenteral opioids and oral opioids usually are given on med-surg units, where only intermittent bedside monitoring of respiratory status is the norm.

Multiple factors can influence whether a patient is more or less likely to experience OIRD. Patients who become opioid tolerant from long-term opioid therapy at home for chronic pain may require significantly higher opioid doses for acute pain in the hospital. (See *How opioids ease pain and affect respira-*

How opioids ease pain and affect respirations

Opioids reduce pain by binding with the mu, kappa, and delta opioid-receptor sites that regulate analgesia, sedation, and respiratory depression. Opioid-induced respiratory depression (OIRD) begins with sedation and then affects ventilatory centers in the brainstem that influence respiratory drive and rhythm. Opioids also decrease muscle tone in the throat, making it harder to maintain the airway.

These effects lead to an irregular and decreased respiratory rate, reduce the volume of air moving in and out of the lungs, and ultimately cause carbon dioxide (CO_2) to build up in the lungs. As CO_2 rises, narcosis and respiratory acidosis set in. Ordinarily, chemoreceptors detect increasing CO_2 levels and stimulate breathing. But opioids dampen chemoreceptor sensitivity. Rising CO_2 competes with oxygen for space in the lung alveoli, eventually reducing blood oxygen saturation (O_2 sat).

Because the CO_2 level rises before O_2 sat decreases, capnography detects signs of respiratory depression earlier than pulse oximetry. Patients receiving supplemental oxygen commonly maintain O_2 sat above 90%, masking hypercarbia effects. So capnography is especially important for these patients. Prolonged CO_2 narcosis eventually may progress to respiratory arrest and death.

tion.) Although chronic opioid use at consistent daily doses may provide some protection against OIRD, dose escalation can put the patient at risk. One study showed a higher OIRD incidence among opioid-tolerant patients than opioid-naïve patients. Also, use of illegal opioids, such as heroin, leads to opioid tolerance and creates added challenges for pain control and OIRD risk in hospitals. (See *OIRD risk factors*.)

Comparing capnography and pulse oximetry

Capnography and pulse oximetry measure two different physiologic processes—ventilation and oxygenation, respectively.

- Capnography measures $ETCO_2$, which reflects ventilation—an indicator of how well the patient is managing the mechanics of breathing.
- Pulse oximetry reflects oxygen saturation of the blood—how much oxygen is getting into the blood after passing through the lungs. A low SpO_2 can alert you to a ventilation problem, but only because that problem has caused an oxygenation problem. In other words, low SpO_2 is a relatively late OIRD indicator.

In monitoring patients for OIRD, pulse oximetry is no substitute for capnography—especially in patients receiving supplemental oxygen. Although the additional oxygen boosts SpO_2, it does so artificially, potentially masking compromised ventilation. Relying on pulse oximetry can be misleading and even dangerous, giving a false sense of security that your patient is ventilating well. Studies have validated that capnography is more effective than pulse oximetry in detecting early signs of OIRD in patients receiving supplemental oxygen. (See *Pulse oximetry vs. capnography in OIRD monitoring*.)

Capnography in action

In capnography, a nasal cannula captures exhaled breath and measures $ETCO_2$. Most capnography devices provide both a waveform and a digital reading of $ETCO_2$, usually displayed in mm Hg. The target range is 35 to 45 mm Hg; higher levels indicate worsening ventilation. Capnography also measures apneic events (pauses in breathing lasting more than 10 seconds), as well as respiratory rate.

Placing the capnography cannula on the patient's face is akin to initiating a nasal cannula for supplemental oxygen. Breath samples are obtained through both nostrils, and oxygen may be delivered simultaneously through small pinholes. Some types of tubing have extensions resembling a spoon in front of the mouth, which can be used to obtain readings if the patient breathes through the mouth instead of the nose (as often occurs in patients with sleep apnea).

But don't rely solely on spot checks or short-term continuous $ETCO_2$ readings. Also observe $ETCO_2$ trends over the course of your shift and the previous shift. Say, for instance, your patient's $ETCO_2$ level has been hovering around 45 mm Hg for most of your shift. But if on the night shift he was maintaining 40 mm Hg and yesterday evening he was at 35 mm Hg, this shows an increasing trend that may signify a problem.

Many capnography devices can be integrated with PCA. With these systems, if the respiratory rate drops below the programmed parameter, the PCA shuts down and the patient can't self-administer more opioid medication. This setup

OIRD risk factors

The following factors increase the risk of opioid-induced respiratory depression (OIRD):

- concomitant use of other sedating drugs, such as antihistamines, benzodiazepines, diphenhydramine, sedatives, or other central nervous system depressants
- increased opioid dosage requirement
- longer general anesthesia time during surgery
- morbid obesity with a high risk of sleep apnea
- no recent opioid use
- older age; OIRD risk is 2.8 times higher at ages 61 to 70, 5.4 times higher at ages 71 to 90, and 8.7 times higher after age 80
- opioid habituation
- postoperative status (especially after thoracic or upper abdominal surgery)
- preexisting major organ failure or cardiac or pulmonary disease or dysfunction
- sleep apnea or sleep disorder
- smoking
- snoring
- surgical incisions that may impair breathing.

commonly is used with basal rates (continuous infusions) on PCA pumps, as continuous opioid infusion carries a greater risk. However, even incremental-only PCA regimens carry some risk, especially in the immediate postoperative period.

Typical capnography settings

Anesthesiologists have long relied on capnography in the operating room to monitor lung ventilation and help identify low cardiac output and pulmonary emboli. For many surgical procedures, capnography is mandatory for financial reimbursement. In postanesthesia care units, nurses use capnography to monitor patients during the immediate postoperative period when pain management can be challenging and OIRD risk is high. Nurses on critical care units use capnography to verify endotracheal and nasogastric tube placement, as well as for continuous monitoring of ventilation.

During procedural sedation, physicians, nurse anesthetists, and nurses rely on capnography to monitor ventilatory function. Physicians and nurse practitioners use capnography during cardiopulmonary resuscitation (CPR) to confirm endotracheal tube placement, assess CPR quality, and obtain early indication of return of spontaneous circulation.

Increasingly, nurses are using capnography on general med-surg units to monitor for OIRD, although this is still a novel approach in most hospitals. A national survey of nurses' monitoring practices to prevent OIRD, published by ASPMN in 2013, revealed that pulse oximetry was widely used in the 99 facilities that responded. Only 2.2% used capnography for patients undergoing epidural therapy (but this rose to 6% for high-risk patients) and 1.5% used it for patients with PCA devices. Of the 23 responding facilities that used continuous capnography, 22 found it useful in detecting OIRD. No facilities routinely used capnography based on overall OIRD risk assessment, regardless of opioid administration method. Also, 75% of nurse respondents said they didn't have continuous capnography devices available.

OIRD can arise quickly, and nurses may not always recognize it at an early stage. In critical care units, the higher level of general monitoring and lower nurse-to-patient ratios mean nurses are more likely to detect and recognize OIRD early. But postoperative patients commonly are transferred to general med-surg units, where nurses have more patients to care for and less time to spend with each patient. If OIRD occurs, they're less likely to witness it immediately, so rapid response team activation may be delayed. Continuous monitoring and early detection with capnography makes this method a potentially valuable tool to help nurses ensure patient safety. However, most nurses are less familiar with capnography than pulse oximetry.

Who should be monitored with continuous capnography?

In 2011, APSF recommended continuous electronic monitoring for all postoperative patients receiving opioids. Also in 2011, the ASPMN Expert Consensus Panel published recommendations for nurses on monitoring for opioid-induced sedation and respiratory depression. These included individualizing the frequency, intensity, duration, and nature of monitoring (assessments of sedation levels and respiratory status, plus technology-supported monitoring) based on the type of opioid therapy, patient and iatrogenic risk factors, response to treatment, and facility policies. The panel stated that technology-supported monitoring (such as continuous pulse oximetry and capnography) can be effective for patients at high risk of OIRD based on thorough assessment of the risk factors described above.

So how do we implement these recommendations in day-to-day practice, especially on general med-surg units where seemingly every patient has some combination of known risk factors? Assessing individual risk for each patient receiving opioids is an unreliable, inconsistent way to predict OIRD. Yet electronic monitoring for every hospital patient receiving opioids isn't feasible. What's more, technology used for continuous capnography isn't perfect; condensation in the tubing can cause false alarms, contributing to alarm fatigue for patients and nurses. As a result, nurses may lower preset thresholds or patients may refuse to wear the cannula. Until the technology is

Pulse oximetry vs. capnography in OIRD monitoring

This table compares capnography and pulse oximetry in monitoring patients for opioid-induced respiratory depression (OIRD).

Pulse oximetry	Capnography
Measures oxygen saturation in arterial blood	Measures exhaled carbon dioxide
Reflects oxygenation status	Reflects ventilation status
Altered by supplemental oxygen	Not altered by supplemental oxygen
Measures pulse but not respiratory rate	Measures respiratory rate
Sensor located on skin (such as fingertip)	Sensor located at nose, mouth, or both
May be intermittent or continuous	May be intermittent or continuous
May be initiated by RN	May be initiated by RN

perfected, we must do the best we can to apply the monitoring to patients who need it most.

Capnography can be lifesaving for patients who clearly are at higher OIRD risk, such as:

- those who are within 24 hours postoperative, regardless of the amount of opioids they're receiving and by what route
- those with confirmed or suspected OSA
- those on continuous opioid infusions
- opioid-naïve patients during their first 24 hours on opioids
- opioid-tolerant patients who've had a dose escalation in the previous 24 hours.

Also, patients receiving supplemental oxygen should be monitored with capnography whenever possible, because administered oxygen can mask hypoventilation.

For high-risk patients, continuous capnography monitoring is better than intermittent monitoring. Even if nurses conduct respiratory assessments every hour for a full 5 minutes, that leaves patients unmonitored 92% of the time. And studies show nurses and patient-care technicians don't consistently conduct and document respiratory assessments. Although technological monitoring is no substitute for frequent face-to-face bedside assessment by a nurse, it can be a valuable supplement.

A shared responsibility

All hospital staff share the responsibility of keeping patients safe. OIRD is a problem of both overprescribing and undermonitoring. Nurses must advocate for sensible multimodal pain medications from the provider, whether that provider is a physician, physician's assistant, or nurse practitioner.

Some prescribers may underdose opioids for fear of causing OIRD. But undertreated pain leads to poorer recovery, longer hospital stays, and low patient satisfaction—and jeopardizes the patient's trust in the nurse. Availability of continuous capnography reassures clinicians that an extra layer of monitoring is in place to detect early signs of OIRD.

With proper education, patients and family members also can watch for signs and symptoms of respiratory depression, and many are savvy to capnography's benefits.

At the other end of the spectrum, prescribers may rely too heavily on high-dose opioid-only therapy and thus neglect to order nonopioids, adjuvant medications, or both. Range orders for opioids (for example, 2 to 4 mg morphine q 4 hours p.r.n. for moderate to severe pain) allow nurses to start low and go slow, which helps prevent OIRD. Capnography provides added security.

With proper education, patients and family members also can watch for signs and symptoms of respiratory depression, and many are savvy to capnography's benefits. Public awareness and interest in capnography is growing. The "Promise to Amanda" website (www.promisetoamanda.org), set up by parents of a teenager who died of OIRD while in the hospital for a minor infection, is devoted to promoting capnography for all patients using PCA. The Physician-Patient Alliance for Health and Safety advocates spreading capnography use among physicians and the public.

Patient education

Another key component of OIRD prevention is patient education regarding the goals of pain management and the need to balance comfort with safety. The goal is to make patients comfortable enough to perform the functions necessary for recovery but not necessarily for completely eradicating pain, which might require high doses that could harm them. Patients benefit from information about expectations of pain control in the context of personal safety; this needn't negatively impact patient satisfaction surveys. When patients believe hospital staff have done their best to address their pain even if they can't eliminate it entirely, they report satisfaction with the care they received.

Revisiting the scenario

If Laura had been monitored with capnography, both you and she would have been alerted that her exhaled CO_2 levels were climbing and her respiratory rate was slowing. The alarm might have triggered Laura to take deeper breaths, while alerting you to adjust her morphine dose. You would have requested orders for nonopioid pain medication and adjuvant medications for multimodal pain management. As a result, the prescriber wouldn't have withheld Laura's pain medications as a knee-jerk reaction, and Laura wouldn't have suffered poor pain control all day. Her transfer to the ICU wouldn't have been needed, and most likely she would have been discharged home within a day or two. ✯

Visit www.AmericanNurseToday.com/Archives/spx for a list of selected references.

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Purpose/goal

To provide nurses with information on how to use capnography to help detect and prevent serious complications of opioid-induced respiratory depression.

Learning Objectives

1. Describe opioid-induced respiratory depression (OIRD).
2. Discuss the role of capnography in monitoring patients for OIRD.
3. State how to use capnography for patients at risk for OIRD.

Please mark the correct answer online.

1. Which of the following suggests your patient is experiencing opioid-induced respiratory depression (OIRD)?

a. Respiratory rate of 11 breaths/minute
b. Pulse oximetry (SpO_2) value of 92%
c. Oxygen saturation value of 95%
d. End-tidal carbon dioxide ($ETCO_2$) value of 26 mm Hg

2. Your patient is experiencing postoperative OIRD. To reverse symptoms, you should dilute 0.2 mg naloxone in 10 mL normal saline solution and titrate the dose to:

a. 1 to 2 mL.
b. 2 to 3 mL.
c. 3 to 4 mL.
d. 4 to 5 mL.

3. The appropriate dilution of naloxone for a patient in respiratory arrest from OIRD is:

a. 0.1 mg naloxone in 10 mL normal saline solution.
b. 0.2 mg naloxone in 10 mL normal saline solution.
c. 0.3 mg naloxone in 10 mL normal saline solution.
d. 0.4 mg naloxone in 10 mL normal saline solution.

4. Which patient is *not* at high risk for OIRD?

a. A 76-year-old man with heart failure
b. A 62-year-old woman who is 5' tall and weighs 250 lb (113 kg)
c. A 44-year-old woman with chronic obstructive pulmonary disease
d. A 36-year-old man who is 6' tall and weighs 180 lb (81kg)

5. Which of the following suggests your patient has obstructive sleep apnea?

a. Body mass index of 22
b. Body mass index of 28
c. Neck circumference of 18.5"
d. Neck circumference of 13.5"

6. Which statement about the effect of opioids on respirations is correct?

a. They can decrease respirations, leading to a rise in the Co_2 level, followed by a decrease in oxygen saturation.
b. They can decrease respirations, leading to a rise in oxygen saturation, followed by a decrease in the Co_2 level.
c. Hypercarbia leads to respiratory alkalosis.
d. Hypercarbia leads to increased muscle tone in the throat.

7. Which statement about factors that influence OIRD risk is correct?

a. OIRD occurs only with continuous infusion of opioids.
b. Patients who are opioid tolerant have a higher risk for OIRD.
c. Opioid-naïve patients have a lower risk for OIRD than opioid-tolerant patients.
d. Patients receiving both benzodiazepines and opioids are at lower risk for OIRD.

8. Which statement comparing pulse oximetry and capnography is correct?

a. Capnography reflects oxygenation status.
b. Capnography reflects ventilation status.
c. Pulse oximetry measures respiratory rate.
d. Pulse oximetry is not altered by supplemental oxygen therapy.

9. When using capnography, the nurse should keep in mind that the target range for $ETCO_2$ is:

a. 35 to 45 mm Hg.
b. 40 to 55 mm Hg.
c. 50 to 55 mm Hg.
d. 55 to 65 mm Hg.

10. Which statement about the use of capnography monitoring is correct?

a. Condensation in the tubing won't cause false alarms.
b. Capnography is recommended for opioid-naïve patients who've been receiving opioids for 8 hours.
c. Intermittent monitoring is preferred to continuous monitoring.
d. Capnography is not recommended for patients on continuous opioid infusions.

11. When setting up the capnography equipment, the nurse should:

a. put the spoon extension in front of the patient's eyes.
b. put the device on the patient's finger.
c. put the cannula in the patient's nostrils.
d. put the mask over the patient's face.