

Continuous Respiratory Monitoring and a “Smart” Infusion System Improve Safety of Patient-Controlled Analgesia in the Postoperative Period

Ray R. Maddox, PharmD; Harold Oglesby, RRT; Carolyn K. Williams, BPharm;
Marianne Fields, RN, MSN; Sherry Danello, RN, MSN

Abstract

The Anesthesia Patient Safety Foundation has noted an underappreciated risk of serious injury from patient-controlled analgesia (PCA)—including life threatening respiratory depression (RD) in young, healthy patients—and has urged consideration of “smart” PCA pumps and continuous oxygenation and ventilation monitoring of patients receiving PCA therapy. St. Joseph’s/Candler Health System was the first U.S. hospital system to implement such technology. Clinical experience shows that non-invasive capnographic monitoring provides the earliest warning of RD. Use of this technology documented an incidence of PCA-related RD-bradypnea many times higher than previously reported. We describe implementation of “smart” PCA pumps with continuous respiratory monitoring and results achieved in significant programming errors averted and patients protected even when the PCA infusion was correctly programmed. Our experience shows that continuous respiratory monitoring of PCA therapy, especially non-invasive capnography, assists clinicians in early identification of RD and other complications to prevent serious adverse events and the need for costly interventions.

Introduction

Effective pain management is essential to patient satisfaction, quality of care, and institutional compliance with Joint Commission standards.¹ Patient-controlled analgesia (PCA) is a widely used, effective method of opioid administration for postoperative pain management. However, PCA therapy is also associated with serious risks.^{2, 3, 4, 5, 6, 7}

The Anesthesia Patient Safety Foundation notes that the significant, underappreciated risk of serious injury from PCA in the postoperative period includes a low, unpredictable incidence of life threatening, opioid-induced respiratory depression (RD) in young, healthy patients.⁸ A recent study using continuous noninvasive monitoring of both oxygenation and ventilation found that the incidence of RD based on bradypnea was many orders of magnitude greater than the 1 to 2 percent widely reported in the literature.⁹ MEDMARXSM and U.S. Pharmacopeia (USP) data show that when PCA pumps are involved, the chance for patient harm increases more than 3.5 times.¹⁰

The Joint Commission has noted that health care professionals' concern about opioid-related RD is one of the barriers to adequate pain management.¹ Improving the safety of PCA is thus a major factor in improving both medication safety and the quality of postoperative care.

Numerous factors can lead to opioid-related RD: prescribing errors, PCA pump programming errors, "PCA by proxy," improper patient selection, improper patient and clinician education,^{3,4} and the variability of patient response to opioid administration. Accurate dosing and administration of opioids are critical. However, even when correctly programmed, therapeutic doses of opioids can suppress respiration.^{5,6,11} Comorbidities, diagnosed or undiagnosed, also affect how a patient responds to a particular dose of narcotic,^{2,3,4} even one that is within approved administration limits. If a patient requires mechanical ventilation or some other supportive intervention secondary to RD, this can result in increased length of stay, risk of hospital-acquired infections, and associated costs.

If detected early, most cases of opioid-related RD can be treated with naloxone. However, severe cases can be fatal.¹¹ PCA opioid-induced episodes of bradypnea and desaturation can escalate to RD requiring rescue, and in-hospital cardiopulmonary resuscitation is successful in fewer than one in five patients.^{9,12,13} Detection of a patient's declining respiratory status before progression to RD can help avert unwarranted outcomes and the possible need for critical care. Thus, safe, effective use of PCA requires monitoring of both practice (i.e., correct pump programming) and patients (i.e., individual respiratory response to opioids).²

Current protocols for respiratory monitoring of hospital ward patients receiving PCA therapy typically require documentation of the respiratory rate (RR) and less commonly, the oxygen saturation (SpO₂) value, initially at 30-minute intervals but thereafter at intervals as far as 2 to 4 hours apart.⁹ RR is often determined by clinician assessment, even though manual respiration counts may be inaccurate when compared to capnometry.¹⁴ SpO₂ is measured by intermittent or continuous pulse oximetry. Typically, only some high-risk patients are monitored by capnography, a technology that assesses ventilation by measuring RR and the concentration of exhaled carbon dioxide (EtCO₂).

The American Society of Anesthesiologists emphasizes that, because ventilation and oxygenation are separate physiologic processes, monitoring oxygenation by pulse oximetry is not a substitute for monitoring ventilatory function by capnography.¹⁵ Oxygen saturation usually is maintained, even at a low respiratory rate, so that pulse oximetry might fail to detect respiratory deterioration, particularly if a patient is receiving supplemental oxygen.⁷ The use of supplemental oxygen does not correct desaturation due to hypoventilation; it simply delays the progression of respiratory failure from bradypnea to apnea. Thus, even continuous monitoring of heart rate and SpO₂ by pulse oximetry is not a substitute for monitoring EtCO₂, respiratory rate, and apneic events by capnography. Capnographic monitoring can anticipate a patient's desaturation by warning of a decrease in RR and rise in EtCO₂.⁸ In a procedural sedation study, pulse oximetry identified only 33 percent of those patients with respiratory distress, while capnography captured 100 percent.¹⁶

Until recently, continuous capnographic monitoring required that a patient be intubated, and its use was limited mostly to patients in critical care areas. Now noninvasive capnography systems with modified cannulae can be used for continuous monitoring of nonintubated patients in

general care nursing areas. By providing clinicians with information on the patient's ventilatory response to PCA therapy, continuous capnographic monitoring helps provide an early warning of potential RD.²

The Anesthesia Patient Safety Foundation urges health care professionals to consider the potential safety value of continuous oxygenation and ventilation monitoring in patients receiving PCA therapy and implementation of "smart" (computerized) PCA pumps containing dose-error reduction software.⁸ The Institute for Safe Medication Practices (ISMP) recommends that technology for PCA be developed that can alert clinicians to unsafe dose settings, programming errors, and RD.³ St. Joseph's/Candler Health System (SJCHS), a 644-bed, tertiary care, "magnet" system, is the first hospital system in the United States to implement such technology.^a The use of "smart" PCA pumps with continuous pulse oximetric and noninvasive capnographic monitoring was made the standard of care at SJCHS in 2004.

In this article, we describe the implementation and use of these technologies, including an automatic PCA "pause" feature, development of a patient selection algorithm, the innovative involvement of respiratory therapists in a multidisciplinary team approach, results achieved in averting significant programming errors that would have likely caused serious negative outcomes, patients protected from adverse physiologic responses to PCA even when infusions were correctly programmed, and improved nursing satisfaction and confidence in their ability to aggressively manage patients' pain. In sharing our experience, results, and lessons learned, we hope this information will be helpful to other health care professionals in their appreciation for the value of implementing PCA monitoring safety systems as they work to improve pain management, medication safety, and quality of care for all patients.

Implementation Methodology

St. Joseph's/Candler Health System

St. Joseph's Hospital and Candler Hospital, the two main facilities of SJCHS, are two of the oldest continuously operating hospitals in the United States. Patient volume is 291,504 discharges annually. Staff includes 517 community-based, private practice physicians, 987 nurses, and 38 pharmacists. SJCHS is an American Society of Health-System Pharmacists-accredited residency site and trains four clinical pharmacy practice residents per year.

In 2002, following an extensive review and systematic evaluation of its nursing practice by the American Nurses Credentialing Center, SJCHS received the designation of "magnet hospital." Interaction among staff and administration is characterized by a high degree of collaboration. Our multidisciplinary Medication Error Team includes pharmacists, respiratory therapists, risk managers, physicians, and others. Experience has taught us that to improve patient safety, the goal must be to improve processes and focus on the issues, not on the individual.

^a The Alaris[®] System with the Guardrails[®] Suite of safety software, Cardinal Health, Inc., San Diego, CA, with Nellcor OxiMax[™] pulse oximetry technology and Oridion's Microstream[®] capnography technology.

IV Safety Systems

In 2000, an ISMP article detailing the hazards associated with PCA¹⁷ prompted our Medication Error Team to focus first on infusion-related errors. In 2001, completion of an ISMP Medication Safety Self-Assessment¹⁸ led to an intense focus on the administration of intravenous (IV) medications. After evaluating various medication safety technologies, the team determined that implementation of a modular, computerized IV infusion safety system with dose error reduction software would provide the greatest “speed to impact” in terms of cost, resources, time, and reduction of harm.¹⁹ In 2002, IV safety systems for large volume infusions were implemented hospitalwide.

Prior to installation of the new systems, safety software embedded in the point-of-care units (the system’s “brains”) was used to create hospital-specific drug libraries with standardized concentrations, maximum and minimum dosing limits, and other infusion parameters for various patient care areas. If nurse programming of the infusion device exceeds the pre-established limits, the system generates an alert that must be addressed before infusion can begin. Software logs record all device programming, alerts, and whether the infusion was reprogrammed or cancelled in response to the alert (i.e., “near misses”). Continuous quality improvement data documented that the IV safety systems helped avert significant IV medication errors with the potential for severe patient harm.¹⁹ Wireless technology was deployed to support ongoing data collection for quality assessment and to facilitate software upgrades.

PCA Practice and Patient Monitoring

Recognizing opioids’ potential for harm, the Medication Error Team sought additional technology that would not only help protect against PCA programming errors but also help protect the patient once infusion had begun. Respiratory therapy became an important member of the multidisciplinary team.

“Smart” PCA pump, pulse oximetry, and noninvasive capnography modules were added to the system in 2004. A single safety technology platform with a common user interface for all modules increased ease of use and reduced the time required for staff training. If either pre-established drug or respiratory limits are exceeded (pulse rate <50 beats/min or >120 beats/min; SpO₂ <90 percent; RR <10 breaths per minute; EtCO₂ >60 mmHg; apnea >30 seconds), the system generates alerts. If any of the pre-established parameters noted above are exceeded, a PCA “pause” protocol can automatically halt drug infusion.

The system is designed to supplement, not substitute for, clinician monitoring. Figure 1 illustrates the multipurpose cannula used to collect exhaled CO₂ and to administer O₂ to patients who may require supplemental oxygen. As shown in Figure 2, by providing up to 24 hours of PCA dosing history with corresponding time-based values from pulse oximetry and/or capnography, the system helps clinicians monitor patient response to self-administered opioids. Trend data allow clinicians to better assess a patient’s physiologic response and help provide an early warning of potential RD.

An initial beta test period was begun in June 2004. After 6 months of testing, continuous respiratory monitoring of each PCA patient became the standard of care. Pharmacy and nursing originally planned to purchase a pulse oximetry module for each PCA module and a lesser number of capnography modules for use with high-risk patients. However, beta testing revealed the difficulty of predicting patient response to opioids and showed that capnography, not pulse oximetry, provided the first indication of opioid-related RD. As a result, the original decision was reversed; implementation included a capnography module for each PCA module and a smaller number of pulse oximetry modules for use with selected patients receiving PCA analgesics.

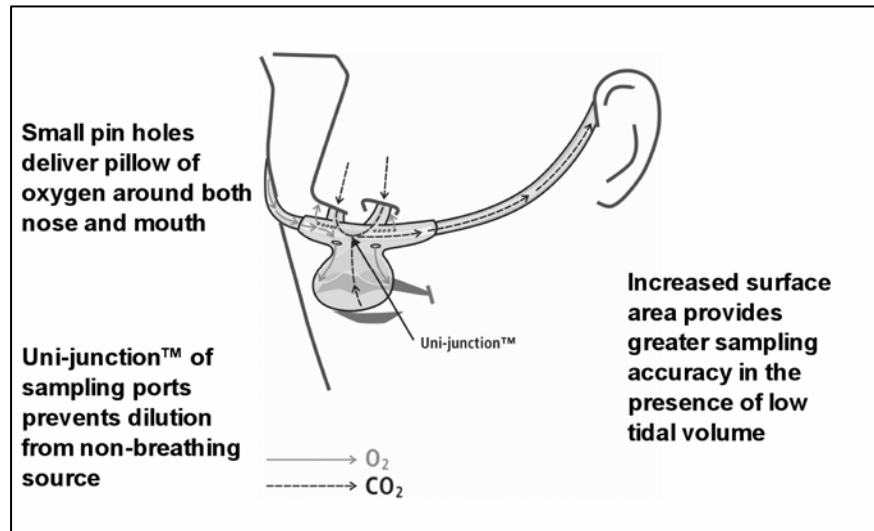


Figure 1. CO₂ sampling/O₂ delivery for nonintubated patients; modified cannula. Source: Oridion Capnography, Inc., Needham, MA. Used with permission.

Patient Selection

As shown in Figure 3, all SJCHS patients who receive PCA therapy have continuous capnographic monitoring and intermittent pulse oximetry monitoring. Continuous capnographic monitoring is used for all patients, while continuous pulse oximetry is used for selected individuals. Patients at high risk for deep vein thrombosis are also at risk for pulmonary embolism. In these cases, continuous pulse oximetry provides a more sensitive assessment of inherent pulmonary pathology, while capnography helps protect against opioid-related RD. Patients with chronic obstructive pulmonary disease who are CO₂ retainers have naturally high levels of EtCO₂ levels and also require continuous pulse oximetry monitoring. The SJCHS oxygenation protocol requires that oxygen saturation be maintained at greater than 92 percent; any patient whose SpO₂ is ≤ 92 percent upon admission is monitored with both pulse oximetry and capnography. If a patient shows signs or symptoms of congestive heart failure, SpO₂ monitoring is required and a nurse is to contact respiratory therapy for assistance. In addition, nursing or respiratory therapy may initiate continuous pulse oximetry monitoring as needed, anytime they deem it necessary.

A Morphine 1mg/mL 09:00			
2003-06-06	TOTAL DOSE (mg)	SPO2 AVG	PULSE AVG
09:00	2.5	95	90
09:30	3	97	92
10:00	2.5	97	88
10:30	4.5	94	80
11:00	5.5	93	84
11:30	5.5	88	90

A Morphine 1mg/mL 09:00			
2003-06-06	TOTAL DOSE (mg)	ETCO2 AVG	RR AVG
09:00	2.5	44	18
09:30	3	42	22
10:00	2.5	43	20
10:30	4.5	50	14
11:00	5.5	54	9
11:30	5.5	57	7

Figure 2. PCA, SpO₂ and EtCO₂ trending data: Representative examples. Source: Cardinal Health, Dublin OH. Used with permission.

Training

Nurses and respiratory therapists worked together to provide staff training on enhanced pain management, pulse oximetry, and capnography monitoring. Topics included use of technology and appropriate clinical interventions based on patients' physiologic responses to PCA. In particular, training on capnography included patient assessment, evaluation of EtCO₂ wave forms and trend data, recognition of patient-specific normal/abnormal values, appropriate interventions, and collaboration with physicians.

Clinical Practice

During continuous respiratory monitoring, a nurse responds to infrequent EtCO₂ or low RR alarms by stimulating the patient to take some deep breaths. In response to frequent alarms, the nurse arouses and stimulates the patient, verifies that the capnography module is functioning correctly, and if so, contacts respiratory therapy. The respiratory therapist and nurse work together to determine the best course of action—e.g., ordering arterial blood gases to verify the patient's respiratory status or supporting the patient with supplemental oxygen or noninvasive ventilation (C-PAP or Bi-PAP). If they are unable to readily correct the situation and the patient further deteriorates towards respiratory failure, they consult the physician regarding additional treatment and possible transfer to an intensive care unit. In addition, revised hospital PCA policy requires respiratory therapy to round on every PCA patient at least once every 12 hours.

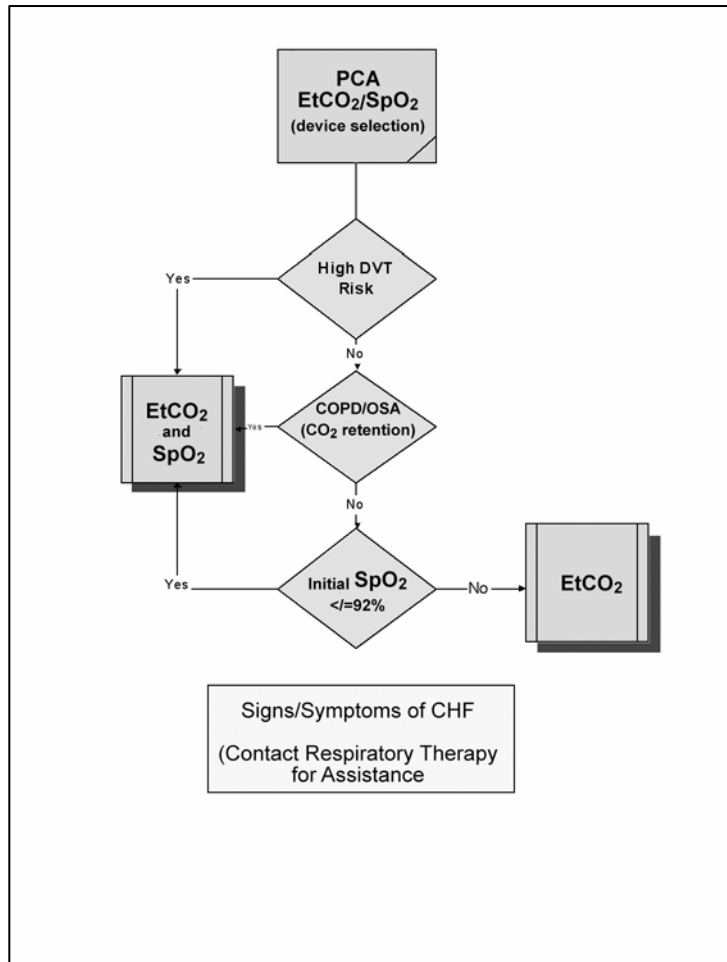


Figure 3. Patient selection algorithm for SpO₂ and EtCO₂ monitoring. (DVT = deep vein thrombosis; COPD = chronic obstructive pulmonary disease; OSA = obstructive sleep apnea; CHF = congestive heart failure)

Results

PCA Infusion Programming: Averted Errors

During the initial 4 months, IV safety systems with PCA modules were used on one unit in each of the two SJCHS hospitals. During this time more than 750 PCA syringes were initiated on the systems for a total of 225 PCA patients. Data collection documented 52 instances when a nurse

received an alert that programming exceeded drug library limits and either reprogrammed or cancelled the infusion—i.e., 52 averted errors.² Representative examples are shown in Table 1.

Table 1. Examples of averted programming errors^a

Location	Drug	Variable	Initial	Reprogrammed
Medical-surgical	Hydromorphone	PCA dose	3 mg	Decreased to 1 mg
Medical-surgical	Hydromorphone	Maximum limit	25 mg	Decreased to 10 mg
Medical-surgical	Hydromorphone	Continuous dose	30 mg	Decreased to 1 mg
Medical-surgical	Morphine	Loading dose	10 mg	Decreased to 4 mg
Critical care	Fentanyl	Continuous dose	300 µg	Decreased to 150 µg
Medical-surgical	Hydromorphone	Maximum limit	200 mg	Decreased to 10 mg
Medical-surgical	Fentanyl	PCA dose	1 µg	Increased to 50 µg
Critical care	Morphine	Lockout (time)	30 min	Increased to 15 min
Critical care	Meperidine	Continuous dose	20 mg	Decreased to 10 mg

^a Alerts are not posted until the start key is pressed and programming is completed. All limits are initially set up as "soft" (can be administered as override).

Source: Maddox RR, Williams CK, Oglesby H, et al. Clinical experience with patient-controlled analgesia using continuous respiratory monitoring and a smart infusion system. *Am J Health Syst Pharm* 2006; 63:157-64. Used with permission.

Patient Respiratory Monitoring: Averted Outcomes

During the first months of use, continuous respiratory monitoring helped clinicians identify numerous cases requiring intervention by the respiratory therapist. These included cases in which PCA programming was correct, and opioid dosing was within established limits.

In the 33 months from July 2004 through March 2007, 16 patients with declining physiologic status were identified by continuous respiratory monitoring; unwarranted outcomes and possible transfer to the intensive care unit were avoided. This value is the number of instances for which there are documented case reports. There were other instances in which RR alarms were triggered, interventions made, and unwarranted outcomes averted. However, no case reports were submitted.

The following representative examples illustrate the effectiveness of continuous respiratory monitoring to assess patient response to PCA opioids and, in particular, the effectiveness of noninvasive, continuous capnography in detecting impending RD in nonintubated patients in noncritical care settings.²

Postanesthesia Respiratory Decline

An obese, 71-year-old male with multiple comorbidities, including obstructive sleep apnea, had bilateral total knee arthroplasties. A PCA pump was set up in the postanesthesia care unit and

programmed for patient “demand-only” dosing. A capnography module also was attached. The PCA demand button had not been pressed, and no PCA doses had been administered since pump setup.

Shortly after the patient was transferred to the medical/surgical unit, “EtCO₂ High,” “Low Respiratory Rate,” and periodic “No Breath” alarms were activated, which prompted a STAT call from the nurse to respiratory therapy. Upon entering the room, the respiratory therapist noted that the patient had RD and marked lethargy that required aggressive verbal stimulation for arousal. The patient’s EtCO₂ levels were in the mid-60s mmHg (nl 35 - 45), and RR was 4 to 6 breaths per minute (nl 10 - 14). His SpO₂ level on 2.5 liters per minute (Lpm) of oxygen was 90 to 91 percent (nl >92 percent). The patient was assessed, stimulated, and positioned to optimize patency of his upper airway. A physician was called on consult and an arterial blood gas performed with the patient on oxygen at 2.5 Lpm. The results were pH 7.19 (nl 7.35 - 7.45); PCO₂ 61.2 mmHg (nl 35-45); PaO₂ 78 mmHg (nl 75 - 100); HCO₃ 23.5 mEq/liter (nl 22 - 26); and SaO₂ 91.3 percent (nl >92 percent). The patient was placed on noninvasive ventilation (Bi-PAP) via full face mask.

It was discovered that the patient had received additional narcotic analgesia in the postanesthesia recovery unit (not through PCA). The patient was given naloxone, immediately awakened, and his EtCO₂ level decreased from the 60s to the mid-40s. RR increased from 4 to 6 bpm to 8 to 10 bpm. The SaO₂ increased from the low 90s to the upper 90s. The patient was awake, alert, and responding appropriately. Followup blood gases were pH 7.26; PCO₂ 48.5; PO₂ 93; HCO₃ 22.1; and SaO₂ 95.8.

As a result of clinical interventions prompted by continuous respiratory monitoring data, a possible adverse outcome was avoided. This case suggests that the postoperative period can be one of the most critical times when respiratory monitoring is required, with or without PCA.

Obstructive Sleep Apnea Without Obesity

PCA therapy was initiated postoperatively for a normal-weight, 44-year-old female with no known risk factors for PCA therapy.² Initial dosing was continuous PCA infusion of 1 mg/hr morphine and 1 mg every 6 minutes PCA doses, with a 4-hour maximum limit of 35 mg. When the patient arrived in the nursing unit, her oxygen saturations were in the high 80s. After applying 2 liters of supplemental oxygen via nasal cannula, a nurse decreased the basal PCA infusion from 1 mg to 0.5 mg. The patient’s O₂ saturation increased to the high 90s.

Several hours after beginning PCA the patient was put on continuous capnography. Initial EtCO₂ readings ranged from the high 50s to low 60s. Respiratory rate was 6 to 12 bpm, with periods of apnea when the patient fell asleep. While the patient was sleeping, the EtCO₂ module indicated frequent low respiratory rate alarms. A nurse determined that respiratory rate by manual count was 4 effective breaths/min. The nurse discontinued PCA therapy, began oral oxycodone hydrochloride 5 mg/acetaminophen 325 mg (Percocet[®]) therapy, and continued the monitoring. The patient’s respiratory status improved, as indicated by oxygen saturations in the low to mid-90s, EtCO₂ in the mid-40s, and a respiratory rate of 12 to 14 breaths per minute. This case illustrates that a patient can be at risk for respiratory depression even with no known risk factors and when opioid administration is within established dosing limits. For this patient with no

known risk factors for PCA therapy, continuous respiratory monitoring helped clinicians identify opioid-associated respiratory depression and prevent a potential adverse drug event.

Bilateral Pneumonia

Following orthopedic surgery, PCA therapy was initiated for a 56-year-old, 75-kg, Caucasian, female patient with a history of lung cancer and a lower lobe partial lobectomy.² Patient monitoring included continuous pulse oximetry and capnography. Trend data from the monitoring modules documented that her SpO₂ levels decreased from the mid-90s to the low 80s. EtCO₂ decreased from 36 to 32 mmHg; respiratory rate increased from 20 to 24 bpm. After respiratory therapy staff increased the patient's supplemental oxygen from 2 to 10 liters, the patient's SpO₂ increased to the low 90s. Two hours later the SpO₂ module generated alarms for SpO₂ levels in the 70s, RR in the 30s, and an EtCO₂ of 31 mmHg. The patient was quickly transferred to intensive care. Pulmonary embolus was ruled out with appropriate radiographic and laboratory tests. Chest x-ray revealed bilateral pneumonia. In this case, continuous respiratory monitoring, particularly pulse oximetry, alerted clinicians to the acute development of serious bilateral pneumonia.

Study Results: Greater Incidence of RD

As reported elsewhere,⁹ the pulse oximetry and continuous capnography monitoring modules were used in an observational study of 178 patients receiving PCA therapy at SJCHS. Findings showed an incidence of RD based on desaturation consistent with previous estimates. However, we found the incidence of RD based on bradypnea was many orders of magnitude greater than the 1 to 2 percent widely reported in the literature.⁹ Defined by traditional "threshold criteria" (at least one 2 minute or longer low-RR event), the incidence of RD was 58 percent. Defined conservatively (at least one \geq 3-minute low-RR event, RR <10 bpm), the incidence of RD was 41 percent.⁹

Nursing Satisfaction

Nursing staff indicate that the availability of dose error protection and continuous respiratory monitoring trend data allows nurses to feel more comfortable in administering PCA therapy and in giving additional medication so they can manage patients' pain aggressively. Knowing that patients will be more comfortable, nurses are more satisfied. Nurses are also alerted early to potentially life threatening events, such as RD during recovery, so they can intervene faster. A common user interface for PCA and monitoring modules increase ease of use and reduce possibilities for error.²

Discussion

More than 3 years' clinical experience with an IV safety system that combines PCA pump, pulse oximetry, and continuous, noninvasive capnography modules on a single platform has taught us the importance of the following issues regarding the management of postoperative pain.

Multidisciplinary Team Approach

A highly collaborative approach is essential to effective pain management and to the selection, implementation, and use of this technology. Physicians, nurses, pharmacists, and respiratory therapists must work together as a team to maximize its benefits. Respiratory therapists play a vital role in nursing education, patient assessment, and the development of a patient selection protocol and algorithm. During continuous respiratory monitoring, respiratory therapists may need to help interpret the data. Noncritical care nurses and physicians initially may be unfamiliar with the information provided by these devices and have problems applying the data to patient care. Unfamiliarity may make nurses reluctant to call a physician when the system alarms. In these situations respiratory therapists provide valuable assistance.

Monitoring

Practice monitoring. Misprogramming IV infusion pumps can result in serious, potentially life threatening adverse events.²⁰ Opioid analgesics are associated with a high risk of harm. Implementation of “smart” IV safety systems with dosing parameters for each narcotic is essential to help avert errors in PCA infusion programming.

Patient monitoring. Due to the variability of patient response to opioid analgesics, even when correctly programmed, therapeutic doses can result in an adverse drug event.² While some patient populations are at higher risk of an opioid-related event, clinical experience has shown that it is not possible to prospectively identify all patients who may be at increased risk.⁸ This fact underscores the need for continuous respiratory monitoring that provides trend data to the nurse at the bedside on a patient’s physiologic response to PCA and helps prevent oversedation and undesirable outcomes. Use of this technology may also allow clinicians to identify undiagnosed clinical conditions that predispose patients to respiratory complications from IV opioids.

Capnography

SpO₂, EtCO₂, and RR are all important clinical parameters that should be used in conjunction with each other. SpO₂ reflects oxygenation, while EtCO₂ and RR reflect ventilation; one may be normal while the others demonstrate an abnormal respiratory status. Capnography provides the earliest indication of opioid-induced RD. It is important to monitor changes from a baseline EtCO₂ level. As the EtCO₂ level starts to increase, early intervention and changes in medication can be made. Capnography monitoring should be used for all patients receiving PCA, not only for those at heightened risk of toxicity.

Need for Greater Care

Clinical experience and study findings suggest that greater care might be needed with PCA therapy. The incidence of secondary RD may be greater than previously thought.⁹ Patients can progress to RD even when correctly programmed doses are within the dose range of the safety software data set.² In particular, the belief that most preventable episodes of RD are caused by programming errors²¹ might not be correct.

Improved Pain Management and Efficiency

Pain management. Continuous pulse oximetry and capnography monitoring during PCA therapy allows improved opioid delivery. By monitoring both pulse oximetry and capnography, medication doses can be adjusted more safely to prevent over- and undermedication and to keep patients comfortable. Patients whose pain is unrelieved from initial PCA therapy are at high risk for oversedation and respiratory depression from increased doses. The use of continuous pulse oximetry and capnography reduces this risk.

Efficiency. In addition to providing early identification of impending RD in patients receiving PCA therapy, this technology also allows respiratory therapists to care for patients more efficiently, so that existing staff can oversee more patients. Earlier identification of respiratory distress allows respiratory therapists to intervene before a patient's condition becomes serious, which saves time and helps increase the likelihood of a positive outcome.

Reduced Likelihood of Critical Events

As a result of training and working with respiratory therapists, nurses can increase their ability to interpret trend data from capnography and pulse oximetry. The availability of these data enhance clinician assessments and their ability to intervene earlier, thereby reducing the likelihood of critical events.

Additional Applications

SJCHS clinicians have used the respiratory monitoring modules with non-PCA patients, such as those receiving epidural infusions, moderate sedation, or procedural sedation. Respiratory therapists have used the capnography modules to monitor patients in respiratory failure on hypoxic drive, for whom increasing oxygen administration by only 0.25 Lpm can have adverse effects. Compared with current monitoring by blood gas analysis, the use of capnography can allow clinicians to titrate supplemental oxygen administration much more efficiently.

Capnography can also help early detection of severely asthmatic patients who are beginning to "fatigue out" and go into RD, so that aggressive treatment might prevent ventilation and intubation.

Conclusion

Data indicate that the use of "smart" PCA infusion devices with dose error-reduction systems helps avert significant patient harm from inadvertent misprogramming of PCA therapy by nurses. In addition, capnography and pulse oximetry are valuable tools that help clinicians with early identification of PCA-related RD and other complications to prevent serious adverse events and the need for costly interventions. The availability of combined dosing and respiratory trend data greatly enhances clinical assessments of patients receiving PCA therapy. Nurses are more satisfied using these technologies, patients' pain is better controlled, safety is improved, and costly adverse events are avoided.

Capnographic monitoring to measure ventilation (RR and EtCO₂) is particularly important because it can provide an earlier warning of respiratory depression compared to pulse oximetry (SpO₂) in some patient populations. Thus, the combination of IV safety system components allows monitoring of both practice (PCA programming) and patients (individual respiratory response to opioids). Implementation of “smart” PCA pumps combined with continuous respiratory monitoring is in keeping with professional practice recommendations and can help hospitals comply with Joint Commission standards for effective pain management, while improving medication safety and quality of care.

Author Affiliations

St. Joseph’s/Candler Health System, Inc., Savannah, GA.

Address correspondence to: Ray R. Maddox, PharmD, St. Joseph’s/Candler Health System, Inc., 5353 Reynolds Street, Savannah, GA 31405; e-mail: maddoxr@sjchs.org.

References

1. Pain management. Tools for implementing JCAHO’s new standards. Available at: <http://mkeamy.typepad.com/anesthesiacaucus/2007/08/pain-the-sixth.html>. Accessed June 18, 2008.
2. Maddox RR, Williams CK, Oglesby H, et al. Clinical experience with patient-controlled analgesia using continuous respiratory monitoring and a smart infusion system. *Am J Health Syst Pharm* 2006; 63: 157-164.
3. Safety issues with patient-controlled analgesia. Part II: How to prevent errors. ISMP Medication Safety Alert; 2003 July 24.
4. Safety issues with patient-controlled analgesia. Part I: How errors occur. ISMP medication safety alert; 2003 July 10. Available at: www.ismp.org/Newsletters/acutecare/articles/20030710.asp. Accessed April 13, 2008.
5. Frequent problems with medication systems noted during ISMP hospital evaluations. Part 2. ISMP Medication Safety Alert 1998 June 17. Available at: www.ismp.org/Newsletters/acutecare/articles/19980617.asp. Accessed April 13, 2008.
6. More on avoiding opiate toxicity with PCA by proxy. ISMP medication safety alert; 2002 May 29. Available at: www.ismp.org/Newsletters/acutecare/articles/20020529.asp. Accessed April 13, 2008.
7. Overdyk FJ. PCA presents serious risks. [letter] *APSF Newsletter* 2005; 20: 33.
8. Weinger MB. Dangers of postoperative opioids. *Anesthesia Patient Safety Foundation newsletter* 2006-2007; 21: 61-88. Available at: www.apsf.org/assets/Documents/winter2007.pdf. Accessed April 13, 2008.
9. Overdyk F, Carter R, Maddox R, et al. Continuous oximetry/capnometry monitoring reveals frequent desaturation and bradypnea during patient controlled analgesia. *Anesth Analg* 2007; 105: 412-418.
10. Patient-controlled analgesia pumps. *USP Qual Rev* 2004 Sep; 81. Available at: www.usp.org/pdf/EN/patientSafety/qr812004-09-01.pdf. Accessed April 13, 2008.
11. Etches RC. Respiratory depression associated with patient-controlled analgesia: A review of eight cases. *Can J Anaesth* 1994; 41: 125-132.
12. Schneider AP II, Nelson DJ, Brown DD. In-hospital cardiopulmonary resuscitation: A 30-year review. *J Am Board Fam Pract* 1993; 6: 91-101.
13. Davis TA, Mathewson HS. Opioids and respiratory depression. *Resp Care* 1999; 44: 78-80.
14. Overdyk FJ. Respiratory depression in PCA patients: What continuous respiratory monitoring has revealed. Presented at the 6th annual conference – Pain Management and Patient-Controlled Analgesia: Improving Safety and Quality of Care. San Diego, CA; 2005 Nov.

15. Practice guidelines for sedation and analgesia by non-anesthesiologists. American Society of Anesthesiologists Task Force on Sedation and Analgesia by Non-Anesthesiologists. *Anesthesiology* 2002; 96: 1004-1017. Available at: www.asahq.org/publicationsAndServices/sedation1017.pdf. Accessed April 13, 2008.
16. Miner JR, Heegaard W, Plummer D. End-tidal carbon dioxide monitoring during procedural sedation. *Acad Emerg Med* 2002; 9: 275-280.
17. Design flaw predisposes Abbott Lifecare PCA Plus II pump to dangerous medication errors. ISMP safety alert; 2000 May 31. Available at: www.ismp.org/Newsletters/acutecare/archives/May00.asp. Accessed April 13, 2008.
18. Smetzer JL, Vaida AJ, Cohen MR, et al. Findings from the ISMP Medication Safety Self-Assessment® for Hospitals. *Jt Comm J Qual Safety* 2003; 29: 586-597.
19. Williams C, Maddox RR. Implementation of an IV medication safety system. *Am J Health Syst Pharm* 2005; 62: 530-536.
20. Williams CK, Maddox RR, Heape E, et al. Application of the IV Medication Harm Index to assess the nature of harm averted by “smart” infusion safety systems. *J Patient Saf* 2006; 2: 132-139.
21. Carpenter RL. Optimizing postoperative pain management. *Am Fam Physician* 1997; 56: 835-44, 847-50.