

Patient Safety Tip of the Week

November 21, 2017

OSA, Oxygen, and Alarm Fatigue

We've done numerous columns on the dangers of oxygen supplementation in patients lacking hypoxemia. And we've often commented on the danger that supplemental oxygen may mask incipient respiratory depression in patients on opioids. Now, for the first time, a well-done study has demonstrated that use of supplemental oxygen in patients with OSA (obstructive sleep apnea) indeed may lead to elevated levels of CO₂ postoperatively.

As we've seen so many times, researchers from the University of Toronto led by Frances Chung did this study on OSA patients undergoing surgery ([Liao 2017](#)). They randomized patients with documented OSA (apnea/hypopnea index greater than 5 per hour) to routinely receive supplemental oxygen (3L/minute via nasal prongs) or not. The group receiving supplemental oxygen did have higher average oxygen saturation and a lower average oxygen desaturation index and a decreased AHI when measured on postoperative night #3. However, though the average amount of time spent with pCO₂ greater than 55 mm Hg did not differ between groups, 11.4% of patients receiving supplemental oxygen had CO₂ levels exceeding 55 mm Hg on postoperative nights, most notably on the first postoperative night.

So the Liao study had somewhat mixed results. It clearly showed better oxygenation status and actual improvement in sleep disordered breathing parameters. The paper has a good discussion of the theoretical reasons oxygen would improve the latter. But it also highlights that a substantial minority of patients with OSA do develop some degree of respiratory depression postoperatively when receiving supplemental oxygen. The authors recommend additional monitoring of respiratory rate or pCO₂ measured by transcutaneous CO₂ monitor (Ptc CO₂), especially on postoperative night 1.

Yet another study from the University of Toronto group ([Lam 2017](#)) was a systematic review and meta-analysis of continuous pulse oximetry and continuous capnography monitoring of patients receiving opioids postoperatively. They concluded that use of continuous pulse oximetry on the surgical ward is associated with significant improvement in the detection of oxygen desaturation versus intermittent nursing spot-checks, and that there is a trend toward fewer ICU transfers with continuous pulse oximetry versus standard monitoring. The evidence on whether the detection of oxygen desaturation leads to less rescue team activation and mortality was inconclusive. They also concluded that capnography provides an early warning of postoperative respiratory

depression before oxygen desaturation, especially when supplemental oxygen is administered.

So we have long been advocates of monitoring all patients receiving opioids with continuous pulse oximetry, respiratory rate, and capnography. Of course, the issue of alarm fatigue always rears its ugly head any time we are talking about continuous monitoring. The number of false alarms that may occur can be immense. A very elegant 2-part study done at Virtua Health System (VHS) in New Jersey used an algorithm from combined alarms to result in a significant reduction of alarms without sacrificing patient safety ([Supe 2017](#)). VHS sought to prioritize narcotic safety by implementing noninvasive capnography monitoring in 2013. But since most of their post-op patients on opioids were located on med/surg units, where continuous monitoring equipment was not as ubiquitous as in ICU's, alarm fatigue became a potential barrier. So they first did a pilot study focused on remote monitoring of capnography alarm signals issued through middleware to telemetry technicians within three hospitals in their system. Various alarms were prioritized, based upon clinical importance and degree of urgency, and appeared color-coded on the remote telemetry dashboard. Their initial data collection showed that alarms for respiratory rate, heart rate, pulse oximetry, and end-tidal CO₂ were far too frequent. An overall average across all patients of 182 alarms per hour was determined from the raw counts of the data. In some cases, as many as 427 alarms per hour were issued on a single patient corresponding to threshold breaches (principally) in low respiratory rate and low et CO₂. They especially found that low etCO₂ and both low and high respiratory rate alarm signals dominated. So they used this data to investigate ways in which to reduce alarm signals and provide only **actionable** notifications to appropriate clinical staff.

They also noted that two sensor devices, the end-tidal CO₂ nasal cannula and the pulse oximeter, were very sensitive to patient movement and thus generated many false alarms. Another important observation was that some patients with OSA would not awaken to the audible alarms that occurred in their rooms while they were asleep (those in-room alarms were indeed intended to awaken the patient).

The data also noted distinctions between alarms resulting from breaches in thresholds for single alarms versus consecutive alarm breaches, also termed **sustained alarm signals**. The clinical team hypothesized that individual, self-correcting measurements (i.e., those that breached a threshold, then returned to normal range) should not be communicated. Rather, only those instances where measurements continuously trended below/above a specified threshold for a predefined period of time should be communicated. To validate the hypothesis that sustained alarm signal generation would considerably reduce the overall number of alarm signals issued, the data of the initial phase pilot were retrospectively evaluated against sustained delays of 30 seconds. Further clinical discussion and survey of the literature resulted in a decision to consider 30 seconds as the sustained alarm threshold. If measurements in any individual parameter were sustained at or below/above the threshold value for 30 seconds or longer, then an alarm signal would be issued on an individual parameter.

They next took into account how to handle alarms related to technical conditions (eg. nasal prongs off patient) and took the following questions into account as they designed the follow-up study to the original pilot study:

- Is the selected duration of the sustained alarm delay sufficient to reduce alarm signal traffic while not concomitantly introducing a patient safety concern?
- Which alarm signals should be communicated to care providers?
- How long should alarm signals be communicated before escalating?
- Can other measures or combinations of data provide an early indicator of patient respiratory compromise?

This resulted in a clinical trial to evaluate the use of alarm signals generated using **sustained and combinatorial alarm rule conditions** (defined as those for which multiple criteria must be met simultaneously before an alarm condition is signaled) over a period of 4 weeks at one hospital within the health system. 25 patients were enrolled in the study based on existing diagnoses of OSA or meeting the STOP-BANG criteria for OSA.

They found that patients were experiencing extended periods of single-parameter threshold breaches that were continuous or repetitive in nature. In most cases, these single-parameter alarm signals did not signify clinically meaningful events requiring intervention, as verified by research nursing staff. They also found that quantities of combinatorial alarm signals were significantly lower than the single-parameter sustained alarm signals.

As expected in this OSA population cohort, pulse oximetry and pulse rate alarm signals occurred far less often than either respiratory rate or end-tidal CO₂ alarms. In addition, alarms related to low end-tidal CO₂ were far more frequent than those related to high end-tidal CO₂.

The use of **combinational alarm rules** was clearly of benefit, making the quantity of alarm signals much more manageable. One example was that, when SpO₂ was removed from the combinatorial calculations, the number of alarm signals was large (>4,500) until sustained delay of 18 seconds was used, at which point the quantity of alarm signals decreased to 209. Another was that, by using hypopneic hypoventilation combinatorial alarm signals, there was more than a 98% reduction over 30-second sustained middleware-generated respiratory rate and end-tidal CO₂ alarm signals.

During the study, seven patients were identified as requiring some form of intervention, four with true respiratory distress (one requiring administration of naloxone to reverse the effect of the opioid and placement on noninvasive ventilator support). These patients were discovered as a result of the sustained alarms, and combinatorial alarms were triggered for these patients as well.

Analyzing their data over several potential alarm delay periods, they noted a significant reduction in middleware-generated alarm signals occurred when the sustained delay was

increased to 48 seconds, compared to the 30 second delay used clinically in this study. That should be a focus for future studies.

The authors conclude that **combinatorial alarm signals based on multiparameter assessment reduced overall load better than individual-parameter sustained alarm signals** and appeared to be more effective at identifying at-risk patients.

Their work also identified another key need: workflow needs to integrate clinical engineering into the alarm reporting infrastructure, so that technical alarms (e.g., low battery notifications) can be communicated to staff to ensure that technical intervention takes place in a timely manner.

This work is a great contribution to our understanding of both monitoring the post-op patient for opioid-induced respiratory depression and addressing the issue of alarm fatigue proactively. Is it a definitive study? No. The total patient population was small and females may have been overrepresented (17 women and 8 men, which may be somewhat unusual for an OSA population). But it is a great start and this work needs to be replicated in other venues and patient populations. Kudos to the folks at Virtua Health System for this contribution.

Since we are talking about OSA, it is worth mentioning two other recent studies contributing to the OSA literature. One was yet another meta-analysis done by the University of Toronto group evaluating postoperative complications associated with OSA patients undergoing cardiac surgery ([Nagappa 2017](#)). They found that, after cardiac surgery, MACCE's (major adverse cardiac or cerebrovascular events) and newly documented POAF (postoperative atrial fibrillation) had 33.3% and 18.1% higher odds in OSA versus non-OSA patients, respectively. The majority of OSA patients were not treated with continuous positive airway pressure therapy.

Meanwhile, a nice review on maternal obstructive sleep apnea and sleep disordered breathing (SDB) during pregnancy was also recently published ([Pamidi 2017](#)). It notes that prospective observational studies in which the investigators ascertained SDB by using complete polysomnography have shown a prevalence ranging from approximately 17% to 45% in the third trimester. Observational studies indicate that maternal SDB may be linked with the development of adverse pregnancy outcomes, such as gestational hypertension and gestational diabetes mellitus and possibly delivery of infants who are small for gestational age. However, the review notes that indications for screening for SDB during routine obstetric prenatal visits are still unclear, and little currently is known about whether treatment of SDB during pregnancy improves clinical outcomes for the mother and/or baby. Nice review, but lots of questions remain unanswered.

Other Patient Safety Tips of the Week pertaining to opioid-induced respiratory depression and PCA safety:

- January 4, 2011 [“Safer Use of PCA”](#)
- July 13, 2010 [“Postoperative Opioid-Induced Respiratory Depression”](#)
- May 12, 2009 [“Errors With PCA Pumps”](#)
- September 21, 2010 [“Dilaudid Dangers”](#)
- November 2010 [“More on Preoperative Screening for Obstructive Sleep Apnea”](#)
- February 22, 2011 [“Rethinking Alarms”](#)
- May 17, 2011 [“Opioid-Induced Respiratory Depression – Again!”](#)
- September 6, 2011 [“More Tips on PCA Safety”](#)
- December 6, 2011 [“Why You Need to Beware of Oxygen Therapy”](#)
- February 21, 2012 [“Improving PCA Safety with Capnography”](#)
- September 2012 [“Joint Commission Sentinel Event Alert on Opioids”](#)
- September 2012 [“FDA Warning on Codeine Use in Children Following Tonsillectomy”](#)
- July 3, 2012 [“Recycling an Old Column: Dilaudid Dangers”](#)
- February 12, 2013 [“CDPH: Lessons Learned from PCA Incident”](#)
- February 19, 2013 [“Practical Postoperative Pain Management”](#)
- May 6, 2014 [“Monitoring for Opioid-induced Sedation and Respiratory Depression”](#)
- March 3, 2015 [“Factors Related to Postoperative Respiratory Depression”](#)
- June 2, 2015 [“Reminders of Dilaudid Dangers”](#)
- August 11, 2015 [“New Oxygen Guidelines: Thoracic Society of Australia and NZ”](#)
- August 18, 2015 [“Missing Obstructive Sleep Apnea”](#)
- December 2015 [“Opioid Alert Fatigue”](#)
- March 2016 [“Guideline for Management of Postoperative Pain”](#)
- June 14, 2016 [“Nursing Monitoring of Patients on Opioids”](#)
- October 11, 2016 [“New Guideline on Preop Screening and Assessment for OSA”](#)
- December 6, 2016 [“Postoperative Pulmonary Complications”](#)
- May 2017 [“Another Twist in Opioid-Induced Respiratory Depression”](#)
- June 2017 [“Masterpiece: Monitoring for Opioid-Induced Respiratory Depression”](#)
- June 20, 2017 [“Dilaudid Dangers #4”](#)
- October 3, 2017 [“Respiratory Compromise: One Size Does Not Fit All”](#)
- November 2017 [“Bad Combination: Gabapentin and Opioids”](#)
- Tools: [PCA Pump Audit Tool](#) and the [PCA Pump Criteria](#)

Our prior columns on obstructive sleep apnea in the perioperative period:

- June 10, 2008 [“Monitoring the Postoperative COPD Patient”](#)

August 18, 2009	“Obstructive Sleep Apnea in the Perioperative Period”
August 17, 2010	“Preoperative Consultation – Time to Change”
July 2010	“Obstructive Sleep Apnea in the General Inpatient Population”
July 13, 2010	“Postoperative Opioid-Induced Respiratory Depression”
November 2010	“More on Preoperative Screening for Obstructive Sleep Apnea”
February 22, 2011	“Rethinking Alarms”
November 22, 2011	“Perioperative Management of Sleep Apnea Disappointing”
March 2012	“Postoperative Complications with Obstructive Sleep Apnea”
May 22, 2012	“Update on Preoperative Screening for Sleep Apnea”
February 12, 2013	“CDPH: Lessons Learned from PCA Incident”
February 19, 2013	“Practical Postoperative Pain Management”
March 26, 2013	“Failure to Recognize Sleep Apnea Before Surgery”
June 2013	“Anesthesia Choice for TJR in Sleep Apnea Patients”
September 24, 2013	“Perioperative Use of CPAP in OSA”
May 13, 2014	“Perioperative Sleep Apnea: Human and Financial Impact”
March 3, 2015	“Factors Related to Postoperative Respiratory Depression”
August 18, 2015	“Missing Obstructive Sleep Apnea”
June 7, 2016	“CPAP for Hospitalized Patients at High Risk for OSA”
October 11, 2016	“New Guideline on Preop Screening and Assessment for OSA”
November 21, 2017	“OSA, Oxygen, and Alarm Fatigue”

Prior Patient Safety Tips of the Week pertaining to alarm-related issues:

- March 5, 2007 [“Disabled Alarms”](#)
- March 26, 2007 [“Alarms Should Point to the Problem”](#)
- April 2, 2007 [“More Alarm Issues”](#)
- June 19, 2007 [“Unintended Consequences of Technological Solutions”](#)
- April 1, 2008 [“Pennsylvania PSA’s FMEA on Telemetry Alarm Interventions”](#)
- February 23, 2010 [“Alarm Issues in the News Again”](#)
- March 2, 2010 [“Alarm Sensitivity: Early Detection vs. Alarm Fatigue”](#)
- March 16, 2010 [“A Patient Safety Scavenger Hunt”](#)
- November 2010 [“Alarms in the Operating Room”](#)
- February 22, 2011 [“Rethinking Alarms”](#)
- February 2013 [“Joint Commission Proposes New 2014 National Patient Safety Goal”](#)
- May 2013 [“Joint Commission Sentinel Event Alert: Alarm Safety”](#)
- July 2, 2013 [“Issues in Alarm Management”](#)
- August 2013 [“Joint Commission Formalizes 2014 NPSG on Alarm Management”](#)
- February 4, 2014 [“But What If the Battery Runs Low?”](#)
- October 2014 [“Alarm Fatigue: Reducing Unnecessary Telemetry Monitoring”](#)
- December 15, 2015 [“Vital Sign Monitoring at Night”](#)
- February 9, 2016 [“It was just a matter of time...”](#)
- August 16, 2016 [“How Is Your Alarm Management Initiative Going?”](#)

- February 21, 2017 “[Alarm Fatigue in the ED](#)”
- April 18, 2017 “[Alarm Response and Nurse Shift Duration](#)”
- April 25, 2017 “[Dialysis and Alarm Fatigue](#)”
- October 17, 2017 “[Progress on Alarm Management](#)”

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Lam T, Nagappa M, Wong J, et al. Continuous Pulse Oximetry and Capnography Monitoring for Postoperative Respiratory Depression and Adverse Events: A Systematic Review and Meta-analysis. *Anesthesia & Analgesia* 2017; Article Published Ahead of Print Post Author Corrections: October 19, 2017

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