

Implementation of Continuous Bedside Capnography Monitoring of High Risk Patients Receiving Opioids

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BJC HEALTHCARE

BJC HealthCare is a 15-hospital, 3,275-bed health system that delivers services primarily in the greater St. Louis, southern Illinois and mid-Missouri regions.

One of the largest nonprofit health care organizations in the United States, BJC HealthCare includes two academic adult hospitals, an academic pediatric hospital, and suburban and rural hospitals. Barnes-Jewish Hospital and St. Louis Children's rank among the most highly regarded teaching hospitals in the nation. BJC's community and rural hospitals are also regularly recognized for excellence.

BACKGROUND

Opioid analgesics are the 'gold standard' of care for pain management and commonly administered intravenously, often through patient-controlled analgesia (PCA). These powerful narcotics are widely used, but a patient's physiologic response to opioids is unpredictable and highly variable. Even commonly used dosages can result in oversedation—an adverse drug event (ADE) that can lead to cardiopulmonary arrest, anoxic brain injury and even death.¹ Only one in five patients who suffer cardiopulmonary arrest survive to hospital discharge.² Patients in “unmonitored” beds—currently the majority of postsurgical patients on opioid analgesics—are twice as likely as those in monitored beds to receive delayed treatment of an overdose.³

Early detection of patient deterioration has been identified as the primary determinant of whether emergency medical intervention is successful.⁴ As one researcher noted, “Monitoring systems ... can provide an added layer of care by continually observing hospitalized patients and drawing attention to those who show signs of deterioration.”⁵

Pulse oximetry has long been used to monitor the respiratory status of hospitalized patients. Until recently, capnography, which directly measures ventilation (gas exchange) by quantifying exhaled carbon dioxide, was limited mostly to critical care areas, because its use required the patient to be intubated. The development of non-invasive capnography systems allowed for use of this technology in general care units.

BJC HealthCare has used pulse oximetry for many years. Several factors increased interest in adding continuous capnography to monitor high-risk patients. First, in 2003 the Institute for Safe Medication Practices recommended continuous pulse oximetry and capnography monitoring of patients receiving sedatives.⁶ Next, The Joint Commission, in TJC Sentinel Event 49,⁷ recommends “not to rely on pulse oximetry alone because pulse oximetry can suggest adequate oxygen saturation in patients who are actively experiencing respiratory depression, especially when supplemental oxygen is being used – thus the value of using capnography to monitor ventilation.”⁸ Also, “when either pulse oximetry or capnography is used, it should be used continuously rather than intermittently.”^{3,7-9} By 2011, site visits by BJC staff to seven local hospitals revealed that bedside capnography had become a local best practice, but was limited to patients receiving PCA, however, at BJC only 18% of emergent opioid reversals at our hospitals were associated with PCA. This quality improvement project was undertaken to add continuous capnography monitoring to a broader at-risk population than PCA patients while efficiently balancing resources.

To identify a larger high-risk population beyond PCA that would require continuous capnography monitoring at the bedside, BJC developed innovative approaches to gather and analyze data on Opioid Induced Respiratory Depression (OIRD). Then a unique hypothesis led to the identification of that larger population. In this article, we describe a quality improvement

project including building system consensus using comprehensive and reproducible methods of data collection and analysis, the identification and selection of a high-risk population, and the final case building and system-wide implementation of bedside capnography monitoring across a large and diverse healthcare system. We also evaluated the effectiveness of the implementation on the rate of the most serious OIRD events.

BUILDING CONSENSUS

Going from using traditional capnography in a few small areas of the hospital to system-wide use of bedside capnography is an immense undertaking. At BJC HealthCare, the importance placed on evidence-based care required that any such change be supported by solid data. It was evident that we would need expert opinion, the extent of events occurring at our hospitals, and an evaluation of the potential impact of acquiring and implanting new technology.

Having a way to continually measure the need for and impact of bedside capnography helped build the case for implementation, prioritize the project and gain the support the major stakeholders, including senior leadership and the system patient safety executive council (chief medical officer [CMO], chief nursing officer [CNO], the legal department, and the quality and safety vice-president). A multidisciplinary Pain Safety Team was established (Table 1). The stepwise BJC Improvement Process was used to help build the case, as described below.

Comprehensive identification of adverse drug events

The first step was to gather comprehensive, system-wide data on all opioid-related ADEs, using the BJC ADE Surveillance Process (Figure 1). Manual chart sampling was not thought to be sufficiently thorough, nor was it enough to investigate only instances when OIRD already led to

a rapid response team being called, since early detection of deteriorating respiratory status was the ultimate goal. Instead, we developed a unique, independent dual review of every naloxone administration in our hospitals. To start, pharmacists were directed to investigate every time naloxone, an opioid-reversal agent, was removed from an automated dispensing cabinet. An incident was counted as an ADE, only if all three of the following had occurred in this sequence: documentation of ingestion (PO), administration (IV), or application (topical patch) of an opiate; documentation of naloxone administration; and documentation of patient recovery from over-sedation symptoms or, in rare cases, opioid-associated patient fatality.

An incident was not counted as an ADE, if the following had occurred: Administration of small doses of naloxone, as needed, to relieve itching of the skin (pruritus); or administration of naloxone as part of planned sedation-reversal in the operating room or post-procedure.

A Narcotic Event Analysis Tool (NEAT, Table 2) was also developed to enable pharmacist investigators counting ADEs to also identify causative factors, merely by checking a few boxes while documenting an OIRD event.

Once the patient's medical record was complete, a second independent chart review was performed by a trained abstractor, and any disagreements adjudicated by a clinician. This created a comprehensive, reproducible approach that could reliably capture OIRD events and would be accepted as valid by all our hospitals.

The next step was to increase institutional awareness which is crucial to the successful implementation of a new technology. Hospital leaders have many competing priorities, and their strong support is essential to achieve success. Event rates for the entire system, individual hospitals and even nursing units were reported to the system patient safety steering committee, various nursing councils, and key committees. Reports were generated for nurse managers to

convey to their individual nursing units. Results were also posted on the system performance dashboard (Best in Class Scorecard) for hospital executives and quality and safety leaders.

Identifying a High Risk Population

Due to resource constraints, including financial and staff, BJC leadership determined the best approach was to roll-out in a staged process, starting with evaluation of our own OIRD events.

We set out to identify a larger high-risk population that could benefit from continuous capnography monitoring. Recognized risk factors for OIRD include obesity, low body weight, sleep apnea, chronic obstructive pulmonary disease (COPD), asthma, advanced age, and the concurrent use of other medications with sedative effects (e.g., sleeping pills, muscle relaxants, and anti-anxiety medications).¹⁰ But many patients have one or more of those conditions, and no predictive models have been shown to reliably identify which patients are at increased risk for oversedation.¹¹

Therefore, we evaluated the percentage of OIRD events occurring at high-risk times or high-risk populations at BJC. Based on consensus and the availability of electronic data, we evaluated the following groups or time-frames: Procedural sedation, PCA, PCA with supplemental oxygen, Post-operative patients, and Patients on high opioid doses. The BJC Pain Safety Team also tested an additional patient group, based on the following assumption: Patients with COPD, apnea, obesity, and other conditions who were not breathing well would likely be receiving supplemental oxygen. In turn, patients monitored only by pulse oximetry would have a delayed alert response while receiving supplemental oxygen.⁷ We, therefore, simply tested patients receiving supplemental oxygen, with an active parenteral opioid order. More than a year's worth of data were analyzed to determine the percentage of OIRD events related to each of these possibilities.

As in earlier findings, the current community standard of monitoring PCA patients accounted for just 18 percent of OIRD events. However, the population we tested with the highest sensitivity and specificity to predict OIRD had an active order for parenteral opioid (intravenous [IV], intramuscular [IM], epidural, or subcutaneous [SQ]) and were actively receiving supplemental oxygen prior to the OIRD event.

Fifty-two percent of all patients who experienced OIRD

This finding both confirmed that supplemental oxygen administration conferred an increased risk of respiratory depression and presented an elegant solution for identifying patients and initiating monitoring: Nurses could identify a much higher proportion of high-risk patients by considering only two factors: an order for parenteral opioid and the use of supplemental oxygen. Instead of choosing a traditional oxygen cannula, nurses could simply use the capnography cannula both to monitor the patient and to administer oxygen.

Case-Building and System-Wide Adoption

Building the case for the acquisition of capnography technology was an arduous process. System leadership had developed criteria for proposals of this type to include the following domains: Clinical recommendation from stakeholders, review of the community and national standards, a formal decision analysis of available devices (including pilot data), systematic review of the literature, review of the patient population, and analysis of patient population (including number of candidate patients), and costs- including acquisition cost, estimate of cost aversion, current litigation cost. To estimate the number of machines required, we reviewed the number of patients meeting or high-risk definition, and added 15% to the peak usage to account for misplacement and cleaning. Cost aversion was estimated by assuming a 50% reduction of serious events on high risk patients using current adverse drug event costs

found in the literature at the time.¹²To complete the pilot portion, several monitors were evaluated at a BJC best-practice hospital. The hospital CMO, a pulmonologist, appreciated the need for improved monitoring. Nurses, biomedical personnel, respiratory therapists (RTs) and other staff members rigorously evaluated technologies from three different vendors using the following criteria (Table 3) and selected the Medtronic Capnostream 20™ for implementation. Deciding factors included the capability to combine pulse-oximetry and capnography, a unique built-in algorithm to reduce false-positive alarms (Integrated Pulmonary Index: IPI™), and a variety of sampling lines to allow clinicians to select the best line for their area of care (Figures 2-4). Once the evaluation was complete, along with the packet of information addressed above, a recommendation was made to Supply Chain and leadership.

After the larger high-risk population (opioid and oxygen) was identified, the full application was vetted through senior leadership, and our supply chain department had completed contracting, the system-wide implementation of bedside capnography was approved in 2015. In addition to system support teams, a multidisciplinary implementation team was established at each hospital (Table 4), with an implementation leader that coordinated the roll-out at that facility. Leaders were drawn from various departments and included RT managers, nurse educators, quality leaders, and a pharmacist. Since capnography monitoring required a change in nursing practice, it was imperative that a nursing leader be involved in every team. When a hospital met all the criteria on the Capnography Implementation Readiness Checklist (Table 5), implementation could proceed.

Core policy developed

A system Core Policy was developed to set out minimum requirements that could be broadened but not made more restrictive. <NOTE: We can provide the whole policy, including settings, as

a separate document or make it available online.> An important part of the Core Policy was that only an active order for a parenteral opioid was required. This was specified because of the unpredictability of knowing when the first, or next, dose of opiate was going to be needed. It is impossible to predict when a first dose might be administered; therefore, if a parenteral opioid had been ordered and supplemental oxygen was being delivered, the patient needed to be on continuous capnography.

Nursing education

Vendor support teams, often working with local hospital nurse educators, conducted the nursing education. BJC nurse educators prepared custom teaching materials along with materials provided by the vendor. They worked with the vendor and developed hospital-specific education plans and a rigorous training schedule, including short face to face training, on-line modules, and written materials. In addition, algorithms guiding nurses on next-steps after respiratory decline is suspected were developed and handed out. Having a nursing leader helped motivate staff and ensure attendance at scheduled training sessions. Training was begun just prior to go live and vendor and hospital educators were on-site throughout implementation and for days after. Spot rounds were conducted by respiratory therapists and a pharmacist to check compliance and nurse and patient education.

Since most patients were not accustomed to wearing a nasal cannula with a scoop, nurses were trained to convey the importance of this technology to the patient. Nurses were instructed to begin patient education by informing the patient that BJC had invested in this technology for their safety and we will remove the cannula when eating and when they no longer needed oxygen. Patients typically required a cannula for supplemental oxygen anyway, and were

receptive to increased monitoring for their safety. Other BJC hospital teams about to go live also made field trips to the best-practice hospital to help smooth their implementation.

Pre- and post-installation data were collected and will assess the three key aspects of implementation: Does the simple algorithm correctly identify the high-risk population as expected, does bedside capnography, as implemented, reduce the number of events, and are we applying the technology per policy? Answers to each of these questions will generate different mitigation strategies and all three answers are important in meeting the ultimate goal: to improve the safety of patients at BJC HealthCare.

Installation of bedside capnography monitoring systems on all general nursing units was begun on June 10, 2015. The initial roll-out was done at the best practice hospital, where staff was already familiar with the device. Lessons learned during the initial roll-out (Table 6) helped inform the installation process going forward. Installation at 11 of 15 hospitals was complete by February 16, 2015. (A physical rehabilitation facility was not included in the roll-out, and two recently acquired hospitals have begun installation. The BJC academic hospital is testing remote alarm annunciation technology to roll out simultaneously.)

Effectiveness of Continuous Bedside Capnography Monitoring

If the technology was effective in providing earlier warning of respiratory compromise, BJC expected to see a decrease in severe OIRD events, defined as events that prolonged length of stay, or involved transfer to a higher level of care, intubation, permanent harm, or death. To that end, in the hospitals that implemented capnography, we analyzed all opioid related NCC MERP harm level events F - I before and after implementation in an intent-to-treat review. Events that occurred in ICU settings which already had continuous monitoring were excluded. NCC MERP

is a standard taxonomy of medication errors used in recording and tracking of medication errors. An independent *t* test was conducted to evaluate whether the number of events resulting in harm level F – I reduced after capnography was implemented. The results showed the number of level F – I events was reduced from 21 to 14 events (33%) during the five quarters after capnography implementation compared to the five quarters before (Figure 5). Although the difference in adverse events before and after implementation of capnography is not statistically significant ($t=0.80$, $p = 0.4481$, 95%CI 1.87-5.32 Figure 6), the reduction constitutes a definite downward trend. While these results are promising, these adverse events are infrequent, thus this sample size may be underpowered to detect a significant difference. BJC will continue to evaluate the effectiveness of capnography in improving patient safety.

A “good catch” occurred on the first day of the first installation, as a nurse on the vendor support team was unpacking the first monitor (Sidebar).

[SIDEBAR]

DAY 1 “GOOD CATCH”

During the initial roll-out at the best-practice hospital, a vendor RT was unpacking a monitor in a post-anesthesia care unit (PACU) when she overheard a conversation between two nurses at the next bed. The patient was receiving supplemental oxygen and was recovering from the use of numerous sedating drugs during his surgery. “He just doesn’t look good,” the patient’s nurse said. The other nurse checked the pulse oximetry readings and reported that the oxygen levels and heart rate were good. That prompted the reply, “He looks good on the board, but not in the bed.”

The vendor trainer suggested placing the patient on the just unpacked capnography monitor. In a matter of minutes, the capnography readings showed there must be some kind of obstruction. Even though the patient's chest was moving up and down, oxygen was not getting into his lungs, and he was not exchanging gases. A Code alert was sounded, the patient was immediately intubated, transferred to the ICU, placed on a ventilator, and ultimately recovered from the OIRD event. News of the "good catch" spread rapidly and helped increase nursing acceptance of the new technology. Most importantly, there were no unwarranted outcomes from the OIRD event. As Judith McCallum, RN, a member of the OIRD Task Force, points out. "Sometimes capnography confirms that medication should not be given because of diminished respiratory effort or elevated EtCO₂, despite the patient's requesting pain medication. Also, for patients with a history of sleep apnea, the capnography does provide a bit of comfort, knowing the patient will be awakened by the alarm and aware of the need to deep breathe."

[END SIDEBAR]

Technology Acceptance

We have reviewed physician, nursing, and patient acceptance only subjectively with random hospital walk-throughs conducted by respiratory therapists, pharmacists and nursing personnel. Concerns have been addressed in real-time, and a recent query of Chief Nurse Officers found no issues from nurses, however some patients meeting our monitoring criteria were not being monitored. Reasons for non-compliance were delays in getting monitors, nurse misunderstanding, and lack of an order. A recent hospital walk-through by the system

medication safety pharmacist included conversations with several patients who had been educated about the technology and were satisfied with its use.

Expanded use

The use of capnography monitoring has spread rapidly to other areas of the hospitals such as the emergency departments, PACU, procedural areas, OB, and more. One large community hospital monitors all patients on a parenteral opioid (independent of oxygen) and several have added all patients on basal rate PCA.

Leadership and vendor support

This is a major initiative, and leadership support has been important to obtaining resources for analysis, clinical decision support, and sharing of results. Adding to the complexity, was predicting any new monitoring technology, understanding how the new technology would interact with existing technology, and the ability to annunciate the alarms to the nurses remotely. Also important, was the value of the addition of new alarms to a nursing staff already burdened by current alarms that are often not actionable. We have been monitoring this from the start, and fortunately, our own best-practice hospital has embraced taking a leadership role and is tracking issues that will be shared throughout the system.

Throughout the pilot and system-wide implementation, vendor support was crucial to success. Implementing a new technology in virtually all areas of a hospital was a complex undertaking that involved numerous departments. They worked closely with hospital nurse educators to develop a plan to reach all shifts, even during go-live. Their presence was especially effective during go-live, when they were immediately available to answer questions that the nurses and RTs might have during the earliest stages of roll-out.

Discussion

We demonstrated that with leadership support, adequate case-building, and providing an implementation check-list to each hospital, that capnography can successfully be implemented across a large and diverse healthcare system. Also, it is important to note that we identified an important gap in patient monitoring. All hospitals we were aware of were monitoring only patients on a PCA, however we found they were a small sub-group of patients at risk. Using “oxygen and opioid” as a policy, exposed a new high-risk group to close monitoring. While, preliminary, our data show that a policy of continuous capnography monitoring on patients receiving supplemental oxygen along with an order for a parenteral opioid may reduce the most severe OIRD events.

While we did implement continuous monitoring on a new set of patients across multiple hospitals, as often happens with the implementation of a new technology, especially one that entails a change in practice, initial compliance did not reach the desired level- in some areas, only about half of the patients meeting the criteria were being monitored. This can be explained, in part, by the fact that each hospital was responsible for implementation and, therefore, logistic differences were found in ordering, monitor delivery. Now that the installation is complete at all hospitals, vendor and hospital staff will concentrate on improving compliance. Standard work is being developed, along with a regular monitoring program, with reports to hospital leadership. Staff are analyzing data on adoption/compliance by all nursing units and will conduct repeat education sessions as needed. In addition, while our results are promising and directional, because of the rarity of events, they did not yet reach statistical significance.

Next steps

Work is underway to improve compliance by optimizing alarm settings through the use of sophisticated algorithms to determine whether the current limits are too tight. The Vital Sync™ VPMP software will enable testing of both the feasibility and the functionality of the system. After one month's data has been collected, investigators will analyze the data to determine how broader settings would affect performance. Perhaps more importantly is the need for alarm annunciation or remote monitoring, as currently the alarms are only audible. This pilot will assess that capability also.

Any new process benefits from forced functions. For example, at some hospitals, an order is now automatically generated when the patient meets the core criteria. The prescriber is given the opportunity to cancel the order, but that is rarely done. As the BJC HealthCare system transitions over the next few years to the EPIC system, they are working with program designers to guide the ordering to comply with the Core Policy.

Further investigation also will help determine whether capnography monitoring is meeting the medication safety goals, especially compliance with the core policy. If the evidence shows that capnography monitoring at the bedside is effective (when worn) in reducing OIRD events, then its use will be expanded further. This includes developing nurse-driven protocols that would allow nurses to initiate capnography in the same way as they now initiate pulse-oximetry. Future research will investigate other patient populations that could benefit from continuous bedside capnography monitoring, e.g., patients receiving opioids combined with non-opioid sedatives, and patients receiving oral opioids. At BJC, use has already expanded into areas not mandated by

policy: most emergency departments, post-partum areas, and even to all patients on an opioid, independent of oxygen.

CONCLUSION

Using a systematic plan of building system consensus using comprehensive and reproducible methods of data collection and analysis, the identification and selection of a high-risk population, capnography can be successfully implemented across a diverse and large health-care system. In addition, we show a trend towards reducing the most severe adverse OIRD events when implemented on a high-risk group of patients receiving supplemental oxygen along with a concurrent order for a parenteral opioid. Along with numerous national recommendations, many of which may be found in the AAMI Foundation's Opioid Compendium,¹³ and increasing evidence from similar quality improvement projects from other hospitals¹⁴, health systems may well consider expanding their use of capnography to the bedside, and not only on ventilated patients or those on PCA. For example, monitoring might begin with patients on PCA or those on oxygen and opioids, but its use should be expanded beyond those populations as evidence is available.

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Table 1. Capnography Monitoring Task Force Members

Role (Credentials)	
Sponsor (Chief Nursing Officer)	Pain specialist physician
Champion (Chief Medical Officer)	Pharmacists, including Executive
Clinical Lead (Medication Safety Pharmacist)	Med Surg, PACU, and ICU RNs
Project Manager (Nurse Consultant)	Respiratory Therapist, (including manager)
Data Analyst/ Epidemiologist	Pediatric Nurse Practitioner

Table 2. Narcotic Event Analysis Tool (NEAT)

Causative Factor Choices

SELECT ALL CAUSATIVE FACTORS

- Concurrent administration of more than one opioid
- Concurrent administration of opioid and benzodiazepine
- Surgery back/procedure
- Patient or a visitor misuse (PCA by proxy, patient own med)
- Administrative error
- Renal impairment
- Hepatic impairment
- Opioid naïve
- Dosing not appropriate (other)
- Lapse in monitoring patient status
- History of respiratory disease (obstructive or central sleep apnea, severe COPD)
- Obesity (BMI ≥ 30)
- Concurrent use of PCA plus another opioid
- No causative factor discovered during investigation

Table 3. Objectives Evaluated During Capnography Pilot

Reliable method to start new patient at Baseline Settings
Display Clinical Trends Accurately for Only Current Patient
Cannula accurately collects nasal & oral breaths without extensive adjustment
Display Clinical Trends Easily for Current Patient - Ease
Display Clinical Trends Easily for Current Patient - Memory Capacity
Prevent Further Dosing of Sedative
Minimize False Positives
Easy to Transport - Size & Weight
Alert for Clinical Intervention - Effective
Allow Patients to Self-Correct
Identify Patient Respiratory Status Accurately
Support from vendor adequate for roll-out
Acceptance of Device by Patient, RN, MD
Battery Life - Hours Run Time
Battery Life - Charged Battery Shelf life
Data Extraction/Push - Future Wireless transfer (Existing Thumb Drive)
Adequately Serves All Patient Types
Consistent & Repeatable Processes to reduce confusion
Same Vendor/Technology Platform Solution enables future compatibility & enhancements
Cost of Equipment (Over Life Cycle...Year of Service, etc.)
Cost of Disposables
Durability of Equipment
Performance History of Equipment (no recalls, etc.)
Upfront investment (additional costs over capnography unit)
Reliable method to start new patient at Baseline Settings
Display Clinical Trends Accurately for Only Current Patient
Cannula accurately collects nasal & oral breaths without extensive adjustment
Display Clinical Trends Easily for Current Patient - Ease
Display Clinical Trends Easily for Current Patient - Memory Capacity
Prevent Further Dosing of Sedative
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Easy to Transport - Size & Weight
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Cost of Equipment (Over Life Cycle...Year of Service, etc.)
Cost of Disposables
Durability of Equipment
Performance History of Equipment (no recalls, etc.)
Upfront investment (additional costs over capnography unit)

Table 4. Hospital Capnography Implementation Team

Since local implementation will be managed by the hospital, a diverse team should be established that includes at least the following specialties:

- Respiratory Therapy
- Biomedicine or Clinical Engineering
- Nurses from PACU, Surgery, ICU, and Medicine (other areas, as needed)
- Clinical Nurse Specialists
- Materials Management
- Information Technology
- Professional Development and Nurse Educators
- Local Vendor Representative
- Nursing or Medical leadership representative

Table 5. Capnography Implementation Readiness Checklist

Installation of bedside capnography will be driven by hospital readiness and vendor resources, once all of the following criteria have been met:

- Hospital Capnography Implementation Team formed with all key stakeholders represented
- Electronic Health Record solution in place for ordering and charting
- Education plan in place for nurses
- Education plan in place for prescribers
- Vendor is engaged and education schedule in place
- Adequate number of devices on site, checked, and barcoded
- Clinical engineering or department that manages equipment engaged
- Bedside Capnography Core Policy edited and adopted

Table 6. Lessons Learned from Initial Rollout

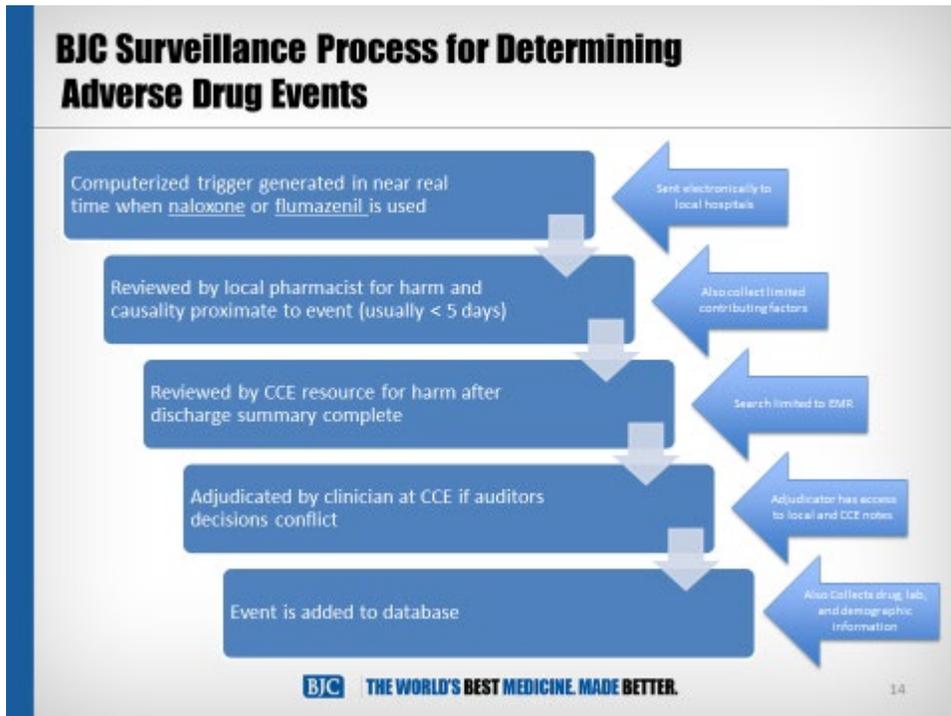
PEOPLE

- Involve leadership role on implementation team
- Engage all stakeholders as early as possible
- Have nurse manager introduce vendor educators to help improve staff engagement
- Vendor support has been strong, though repeat education needed in some area

POLICY

- Application of policy in ICU settings may not be of benefit
- Hospitals are modifying policy to allow nurses to begin capnography at their own discretion
- Capnography usage quickly spread to other areas in hospitals, including the emergency department, PACU and obstetrics
- One large community hospital monitors all patients on a parenteral opioid independent of oxygen) and several have added all patients on basal-rate PCAs
- Modification of alarm settings has a big impact on nurse and patient satisfaction without compromising safety

Figure 1.



The Center for Clinical Excellence (CCE) was represented by the Senior Pharmacist safety officer for the first year, then a trained nurse, and now a trained abstractor and occasionally a trained advanced pharmacy student.

Figure 2. Medtronic™ Microstream™ oral-nasal sampling line, designed for longer-term use (procedural sedation, monitored anesthesia care [MAC], or emergency services) in non-intubated patients.

[Photo in separate file.]

Figure 3. Microstream™ Uni-junction™ sampling line, designed to simultaneously capture exhaled CO₂ from both nostrils and the mouth, while delivering O₂ to both nostrils and the mouth.

[Illustration in separate file.]

Legend: This more complex design can monitor carbon dioxide levels while the patient receives supplemental oxygen and can monitor oral and/or nasal breathing to provide better sampling, especially in mouth-breathing patients.

Figure 4. Microstream™ nasal-only FilterLine®, designed to deliver O₂ to and sample CO₂ from both nares with an additional drying filter to extract humidity from a higher-humidity environment, for longer-term use in non-intubated patients.

[Photo in separate file.]

Figure 5. Effectiveness of Continuous Capnography Monitoring at BJC Facilities That Implemented Capnography

OIRD Events (NCC MERP Harm Level F, G, H, & I), 2Q2014 – 1Q2017

(N= Quarters)

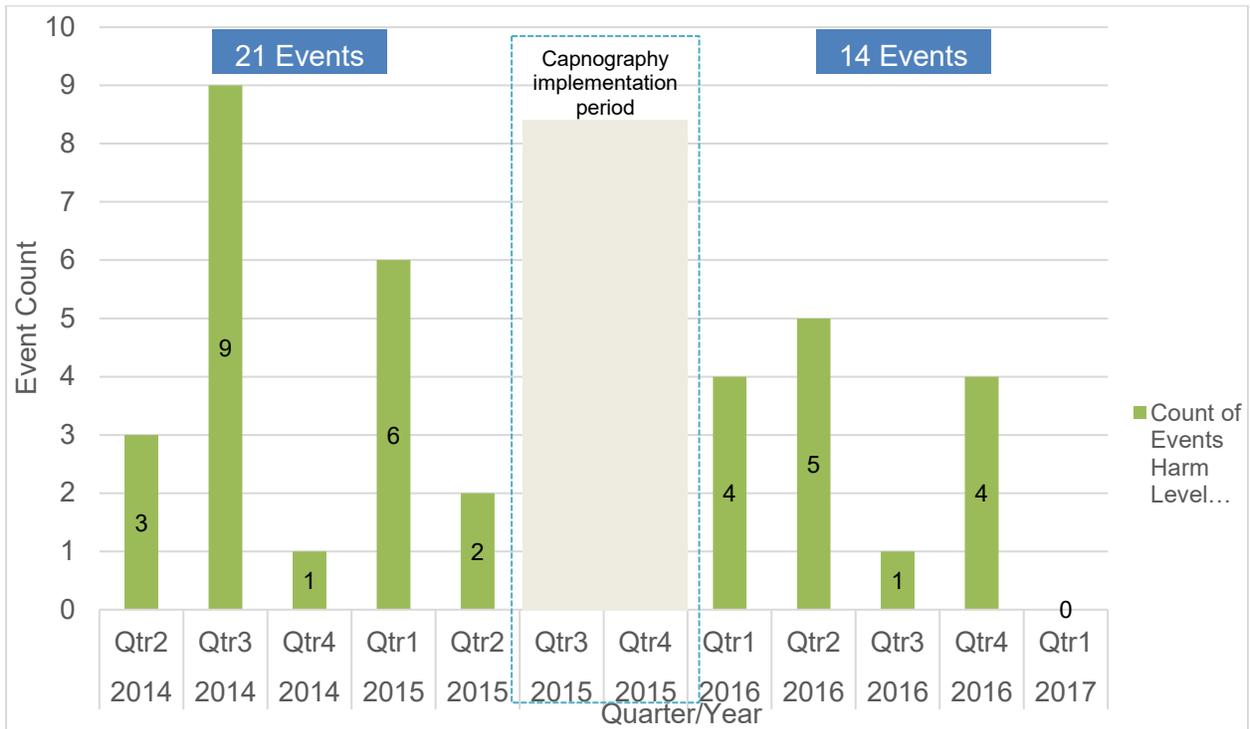
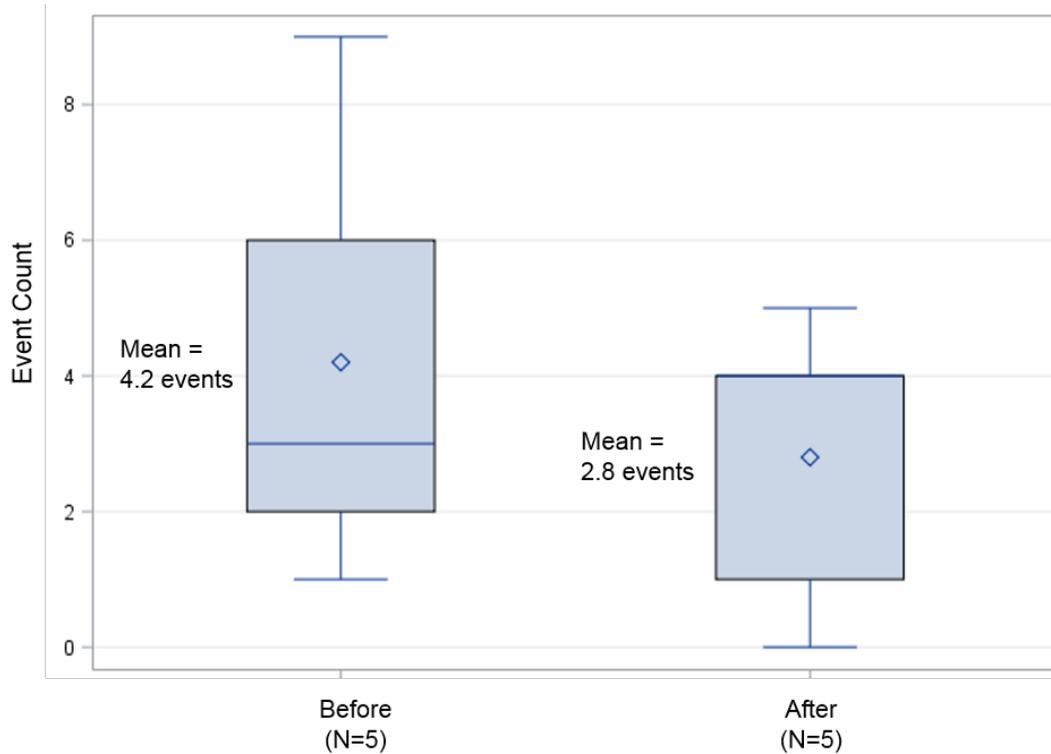


Figure 6. Effectiveness of Continuous Capnography Monitoring at BJC Facilities That Implemented Capnography

Severe OIRD Events (NCC MERP Harm Level F, G, H, & I), 2Q2014 – 1Q2017

(N= Quarters)



($t = 0.80$, $p = 0.4481$). The 95% confidence interval for the mean event count difference between the before and after groups was between 1.8743 and 5.3160.

