Capnography: Helping to save lives and reduce costs

Capnography has long been the American Society of Anesthesiologists' (ASA) standard of care in the operating room to monitor ventilation for patients under general anesthesia. In 2011, the ASA also required capnography in standards for monitoring adequacy of ventilation during moderate and deep sedation.[1] Statements from clinical organizations continue to drive the use of the technology outside the OR and sedation into other applications where the use of capnography has been shown to save lives.[2-5]

A common concern when employing any new technology is the cost. More and more evidence is showing that capnography can not only save lives, it can also reduce costs associated with caring for patients across the care continuum. Adverse events are costly from many perspectives: increased length of stay, transfers to higher levels of care, additional care required, not to mention high medicolegal costs.[2, 6-8] According to the Institute of Medicine, each preventable adverse event costs about $8,750—and this does not take into account potential litigation costs.[10] HealthGrades estimates the attributable charge for postoperative respiratory failure at $53,502 per episode.[8]

Intensive Care Unit

A landmark British study by Cook et al found that the failure to use capnography contributed to 82 percent of airway-related deaths and brain damage in intensive care units (ICUs).[3] The researchers wrote that the single most important change that would save lives is the use of a simple breathing monitor, which would have identified or prevented most of the events that were reported. The physicians involved in the study recommend use of capnography for all patients receiving help with breathing in the ICU. Their research found that current evidence suggests capnography is used for only a quarter of these patients, and they specifically state that "greater use of this device [capnography] will save lives." While the study focused on potential improvements in the ICU, it also noted similar opportunities to improve care in anesthesia (recovery) and the emergency department.

By using capnography to guide ventilator management, one system was able to reduce the number of arterial blood gases required in the ICU. Total blood gases decreased by more than half, as did ABGs per ventilator day.

Cost savings for a four-month period amounted to $947,491. When the cost of the monitors was deducted, annualized cost savings was projected to be more than $2.5 million.[10]

Sedation and Monitored Anesthesia Care

A 2009 analysis of closed claims from the ASA of the use of anesthesia in remote locations put a major emphasis on the use of capnography.[2] The report concluded that 62 percent of claims were preventable by better monitoring. The payments for claims ranged from $460,000 to $7 million.

A 2006 analysis of ASA closed claims in monitored anesthesia care (MAC) reported similar findings:[7] Respiratory depression, after overdose of sedative or opioid drugs, was the most common specific damaging mechanism in MAC claims and nearly half were judged as preventable by better monitoring, including capnography, improved vigilance, or audible alarms. The range of payments (2006 dollars) was $254,000 up to more than $2 million.

Emergency Medical Services[2]

In a modeling of costs among common emergencies treated by Emergency Medical Services (EMS), substantial cost savings were proposed. After factoring in the added costs of the disposable capnography sample lines, cost savings per case were forecasted:

- COPD patient – $31-$97
- Heroin overdose - $52.25
- Myocardial infarction – $8-$18

Postoperative Opioids[6, 14]

In 2004, St. Joseph's/Candler Health System (SJCHS) replaced its existing IV pumps with "smart" IV safety systems, including pulse oximetry and noninvasive capnography modules for monitoring IV opioids.

Over a five-year period, implementation of these smart systems reduced high-risk medication errors and patient controlled analgesia-related undesired outcomes. The systems helped avert at least 471 adverse drug events (ADE), and provided a five-year return investment of $1.87 million. In addition, the authors reported that as a result of the implementation of safety technology, the facility has significantly reduced its health system self-insured liability cost.

The Veterans Health Administration (VHA) performed root cause analyses of infusion device incidents at its facilities. The investigators evaluated 129 incidents related to two types of infusion pumps: 60 incidents on general purpose pumps and 69 incidents on PCA pumps. Based on the root cause analyses, published literature and device evaluations, the VHA's integrated product team recommended PCA pumps with an integrated end-tidal CO_2 monitor as the pump of choice. The integrated product team believes that use of this technology could have prevented more than 60 percent of adverse events related to PCA pumps in VHA.[11]

Additional publications have noted improved outcomes after implementing capnography monitoring of IV opioids (e.g., PCA).

Highlights of some studies include:

- Pohlenz et al reported a 40 percent reduction in reversal of PCA narcotics and a 100 percent reduction in transfers to higher level of care for respiratory suppression after implementing capnography for PCA patients.[15]
- Fox et al reported a decline in severity of adverse drug events (ADEs) and the percentage of moderate/severe ADEs that progressed to code blue. In 2007, prior to implementing a postoperative program that incorporated capnography monitoring, 19.6 percent of ADEs were rated as severe and 16.7 percent of moderate/severe ADEs progressed to code blue. In January to June 2011, after full implementation of the program, only 2 percent of ADEs were categorized as severe and 0 percent of moderate/severe ADEs progressed to code blue.[16]
- Weber et al reported that after a patient death from oversedation, a postoperative management program including $etCO_2$ monitoring was implemented. Since implementing, they reported a reduction in naloxone (Narcan) reversals and more than 600 days without a serious safety respiratory event.[17]
- Kjorven et al reported a 70 percent reduction in operating costs on the surgical unit after implementing capnography monitoring.[18]

At the 2009 annual ASA conference, a mathematical model was presented to help institutions calculate potential cost savings by avoiding additional length of stay associated with postoperative events.[19] The model used data derived from published sources, but enables the institution to input its own data.

Using this model, Hansen reported savings would amount to nearly $400,000 based on 10,000 patients (see table).[20]

Preventable Costs Associated with Postoperative Respiratory Failure[20]

Surgical Patients	10,000
Postoperative Respiratory Failure Rate	17 per 1,000
Respiratory Failure Events	170
Increased LOS per Event	9.08 days
Total Increased Hospital Days	1,544
Cost per Hospital Day	$1,237
Preventable Costs	$1,909,433

Hospital-Specific Data

Candidates for Monitoring a Year (M)	10,000
Increased Disposable Cost per Procedure (IC)	$15
Hospitalization Costs per Day (HC)	$1,500
Success of End-Tidal CO_2 Monitoring (S)	30%
Number of Capnography Machines Necessary (N)	170

Peer Reviewed Journal Data

Postoperative Respiratory Failure Rate per 1,000 (FR)	17
Additional Length of Stay (LOS)	9.08

Financial Calculations

Regulatory Failure Events Prevented with Oridion (F)	51 M *(FR/1000*S)
Initial Capital Expenditure (CC)	$765,000 (N * 4500)
Increased Disposable Costs per Year (DC)	$150,000 (M * IC)
Respiratory Failure Cost Avoidance (CA)	$694,620 (HC*F*LOS)

Financial Returns

Total Annual Costs Savings	$391,620 (CA - [DC + CC/5])
Cost on each Payback Period	17 months

1. Healthgrades - The Fifth Annual HealthGrades Patient Safety in American Hospitals Study.
2. Zhan C, Miller MR. Excess length of stay, charges, and mortality attributable to medical injuries during hospitalization. *JAMA*. 2003;290(14);1868-1874.
3. Assumes five-year straight line depreciation schedule.

In a review of legal literature for liability cases involving obstructive sleep apnea during the perioperative period, researchers reported that 92 percent of cases were associated with death and anoxic brain injury and the majority (54 percent) were judged to be due to "failure to monitor the patient." Average financial penalty was $2.5 million (up to $7.7 million).[21]

After implementing capnography monitoring, SJCHS clinicians are convinced that the solution has made a significant difference in patient care. Dr. Ray Maddox, co-author of several papers describing SJCHS results, states, *"Over the course of five years, we've had an internal rate of return of 83%, with a cost savings of $1.8 million over and above the cost of the technology. More than that, I know we have not only saved money, we've saved lives."*[14]

References

1. ASA Standards for Basic Anesthetic Monitoring. Committee of Origin: Standards and Practice Parameters. (Approved by the ASA House of Delegates on October 21, 1986, and last amended on October 20, 2010 with an effective date of July 1, 2011).
2. Metzner J, Posner KL, Domino KB. The risk and safety of anesthesia at remote locations: the US closed claims analysis. *Curr Opin Anaesthesiol*. 2009;22(4):502-508.
3. Cook TM, Woodall N, Harper J, Benger J; Fourth National Audit Project. Major complications of airway management in the UK: results of the Fourth National Audit Project of the Royal College of Anaesthetists and the Difficult Airway Society. Part 2: intensive care and emergency departments. *Br J Anaesth*. 2011;106(5):632-642.
4. Patail B. Veterans Health Administration – Infusing Patients Safely. AAMI/FDA Infusion Device Summit. October 5, 2010:12.
5. Thomas McCarter T, Shaik Z, Scarfo K, Thompson LJ. Capnography monitoring enhances safety of postoperative patient-controlled analgesia. *American Health and Drug Benefits*. 2008;1(5):28-35.
6. Danello SH, Maddox R, Schaack GJ. Intravenous infusion safety technology: return on investment. *Hospital Pharmacy*. 2009:(44)8
7. Bhananker SM, Posner KL, Cheney FW, Caplan RA, Lee LA, Domino KB. Injury and liability associated with monitored anesthesia care: a closed claims analysis. *Anesthesiology*. 2006;104(2):228-234.
8. HealthGrades Patient Safety in American Hospitals Study. March 2011. Available at: http://www.healthgrades.com/business/img/HealthGradesPatientSafetyInAmerican-HospitalsStudy2011.pdf.
9. Institute of Medicine. Preventing Medication Errors: Quality Chasm Series. .Available at: http://www.iom.edu/Reports/2006/Preventing-Medication-Errors-Quality-Chasm-Series.aspx.
10. Rowan C, Ahmed S, Hedlund T, Speicher R. Continuous capnography decreases the utilization of blood gases. *Critical Care Med*. 2011;39(12):91.
11. Association of the Advancement of Medical Instrumentation. Infusing patients safely. Priority Issues from the AAMI/FDA Infusion Device Summit. October 2010.
12. Brandt P. Positive justification. JEMS Supplement. December, 2010:10-13.
13. Maddox R, Williams C, Oglesby H, Butler B, Colclasure B. Clinical experience with patient-controlled analgesia using continuous respiratory monitoring and a smart infusion system. *Am J Health-System Pharmacists*. January 15, 2006;63.
14. Maddox R. Personal interview. www.smartcapnography.net.
15. Pohlenz, P, Woodward K, Rosacker L Nickel B. Capnography monitoring for patient controlled analgesia. *Respir Care*. 2011; 56:1660.
16. Fox D, Wencel M. Integral role of respiratory therapists in a comprehensive pain management program using end tidal CO_2 monitoring. *Respir Care*. 2011; 56 (12):1706.
17. Weber P. High risk patient protocol preventing respiratory complications. *Respir Care*. 2011; 56:1636.
18. Kjorven M, Dunton D, Milo R, Gerein L. Bedside capnography: Better management of surgical patients with obstructive sleep apnea. *Canadian Nursing*. 2011; 107:24-26.
19. Boyd PE. Return-on-investment (ROI) analysis of capnography monitoring in post-operative care. Presented at American Society for Anesthesiologists. 2009. A1391.
20. Hansen K. Implementation of monitoring to prevent respiratory complications with sedation. *RT Magazine*. July 2011. Available at: http://www.rtmagazine.com/issues/articles/2011-07_03.asp.
21. Fouladpour N, Jesudoss R, Bolden N, Auckley D. Perioperative complications in OSA patients undergoing surgery: a review of legal litigation. Society of Anesthesia and Sleep Medicine. 2012. Abstract 035.

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