THE ECONOMIC VALUE OF CAPNOGRAPHY

IMPROVING PATIENT CARE AND REDUCING COSTS

Capnography monitoring — the measurement of end-tidal carbon dioxide in exhaled breath — as a standard of patient care is growing. For decades, anesthesiologists in the OR have routinely used capnography for monitoring patients during general anesthesia. But the benefits of capnography technology are not limited to the OR. The American Society of Anesthesiologists (ASA) is one of many medical societies to update their guidelines to include capnography monitoring during moderate to deep sedation. In fact, a review of the literature finds numerous studies and editorials describing how capnography monitoring can improve patient safety during procedural sedation and anesthesia (PSA). Capnography may also be used for continuous monitoring of patients during EMS transport, in the ICU and the emergency department, during postanesthesia recovery, and on the general care floor. Additionally, the American Heart Association guidelines recommend the use of capnography to verify placement of endotracheal tubes during intubation and to monitor the effectiveness of CPR in patients with cardiac arrest, including using capnography waveforms as an indication of the return of spontaneous circulation.

Yet as use of capnography technology continues to grow and expand into new areas, uncertainty about the cost remains. Do the many benefits outweigh the investment in the equipment and training required to implement capnography monitoring? For many practicing anesthesiologists, there is no question. Capnography monitoring is simply the standard of care they expect in or out of the OR. But paying for new technology can place an economic burden on hospitals, clinics, and other healthcare institutions.

Recent analyses suggest that implementing capnography monitoring will allow both practitioners and financial administrators to meet their shared goals — excellent care and fiscal responsibility. The findings of these studies indicate that the cost savings from increased patient safety can offset the expense of unnecessary complications, adverse events, and potential legal action.

FINDINGS OF THE CADTH HEALTH TECHNOLOGY ASSESSMENT

Although individual researchers have studied the cost versus benefit of capnography, definitive data remain elusive. Recently, Richardson et al of the Canadian Agency for Drugs and Technologies in Health (CADTH) published an extensive Health Technology Assessment of capnography monitoring in hospital and pre-hospital settings. The results of their meta-analysis — comprising more than 200 studies — support the conclusion that capnography does make economic sense as well as offer superior care for patients.

BACKGROUND AND METHODS

The aim of the assessment was to determine whether capnography monitoring is clinically beneficial and cost-effective for patients who:

- Undergo PSA
- Receive CPR
- Are in serious or critical condition (ICU)
- Are in postoperative care with known sleep apnea or taking high doses of opioids

In the analyses, capnography monitoring of etCO₂ was compared with no etCO₂ monitoring, standard monitoring, or other forms of noninvasive respiration and ventilation monitoring. The authors also considered the impact of implementing capnography in terms of access, training, technical support, policy, and procedure.

Reviewers performed a systematic search of literature published between 2005 and 2015, with alerts to update the search through March 2016. They then selected 200 articles for full-text review, from which 23 were included in the clinical review. The analysis was conducted in Canada, and the costs listed were given in Canadian dollars (CD).
SUMMARY OF RESULTS
The meta-analysis showed probabilistic cost-effectiveness results for capnography plus standard monitoring (CapSM) compared with standard monitoring (SM) alone in adult patients. (The authors also analyzed capnography in the pediatric population but data were so limited that results are not included here.)

The total expected cost per adult patient ranged from $61 to $1,019 CD for CapSM and $26 to $954 for SM alone. For adults who received PSA or experienced out-of-hospital cardiac arrest, capnography cost more than standard monitoring, with an incremental cost of $35 and $65 CD, respectively. Capnography monitoring was more effective in both cases, however, with lower respiratory failure rates (0.199 versus 0.283, respectively) in adults undergoing PSA and higher survival rates (0.003 versus 0.005, respectively) in adults receiving CPR. The cost per averted respiratory failure was $413 for adults receiving PSA, and the cost per life saved was $27,269 CD for out-of-hospital cardiac arrest adult patients receiving CPR.10

Clinical evidence suggested that adult patients undergoing PSA had fewer episodes of hypoxemia with the use of capnography. In the economic analysis for PSA, the base-case incremental cost per averted respiratory failure for CapSM, compared with SM alone, was $377 per event avoided.

For adults undergoing CPR, the clinical review found an increased likelihood of return of spontaneous circulation during out-of-hospital cardiac arrest, suggesting that capnography was associated with higher survival rates.

For adults in serious or critical condition, the clinical evidence available for assessment was limited. The exploratory analysis was based on the assumption that treatment effects of capnography compared with standard monitoring for incidence of respiratory failure would be similar to those observed for PSA. The analysis showed that capnography would improve health outcomes at a lower cost than standard monitoring. In fact, the authors also speculated that earlier detection of respiratory compromise would provide even more benefit to critically ill patients than those undergoing PSA, because of their reduced cardiorespiratory reserve.

For adults in postoperative care receiving opioids, again the clinical evidence was limited. Assuming the same treatment effects for incidence of respiratory failure as observed for PSA, compared with standard monitoring, capnography monitoring improved health outcomes at a lower cost.

For these patients, the CADTH analysis showed that capnography was associated with both lower cost and improved efficacy and was deemed the dominant method of monitoring.9

CAPNOGRAPHY IN POSTOPERATIVE CARE
More and more healthcare providers are voicing support for both the safety and economic benefits of capnography monitoring in the ICU and during postoperative care.11,12 Perioperative physicians Gerailemu et al wrote of their concerns regarding respiratory compromise leading to adverse events such as pneumonia, reintubation, and respiratory arrest. They argue that — for the very reasons capnography is used to reduce the risks of procedural sedation — the same caution should be maintained in the postoperative environment, where most patients are still in a sedated state.11

In addition to the impact on mortality and morbidity, the implications of postoperative adverse events for healthcare costs are obvious. In just one example, Zhan et al found that occurrence of respiratory failure (not including pulmonary embolism) added nine days more of hospital length of stay and more than $53,000 US in additional costs.12

WORKING FOR A POSITIVE OUTCOME
Although trying to calculate the worth of a patient’s health versus the expense of technology is uncomfortable, it is a fact of life in our current healthcare system. Being proactive, however, can lead to better outcomes for both patients and the institutions that care for them.

In 2016, St. Joseph’s/Candler Health System (SJ/CHS) in Savannah, Georgia, celebrated 12 years without opioid-related adverse events. Since implementation of the pilot program in 2004, continuous capnography monitoring for all patients receiving IV opioid therapy has been required.

The SJ/CHS team replaced its existing IV pumps with “smart” IV-safety systems that included both pulse oximetry and noninvasive capnography modules for monitoring administration of IV opioids. Over a five-year period, these expanded IV-safety systems helped avert 450 highest-risk medication errors, and respiratory monitoring helped avert at least 35 undesirable outcomes related to patient-controlled analgesia, for a total of at least 471 preventable adverse drug events. The decision of SJ/CHS to replace existing IV pumps and incur the incremental cost for safety systems using capnography resulted in financial benefits, improved safety, improved quality of care, and a five-year return on investment of $1.87 million. In addition, as a result of the implementation of safety technology, the facility reported significantly reduced health system self-insured liability cost.13,14
AVOIDING COMPLICATIONS AND FATAL EVENTS

Others have documented the benefits of capnography — and the potential cost savings it can provide. McCarter et al published a case series providing evidence that continuous capnographic monitoring offered more reliable and earlier indications of changes in patient status compared to pulse oximetry. They found that the automatic pausing of patient-controlled analgesia, combined with prompt intervention, helped prevent potentially fatal complications and avoided increased length of stay and costs.\(^{15}\)

In a landmark British study, Cook et al found that the failure to use capnography likely contributed to more than 70% of ICU-related deaths, and they recommended the use of capnography for all patients receiving help with breathing in the ICU. The authors also stated that “capnography would have prevented half of the deaths in the emergency department.”\(^{16}\)

CAPNOGRAPHY IN PROCEDURAL SEDATION

Despite concerns about cost, capnography monitoring of patients receiving PSA has become increasingly popular, especially for gastrointestinal and endoscopic applications. Several recent publications outline the benefits as well as the cost implications.

Saunders et al [2016] developed a comprehensive model of PSA during endoscopy to analyze the impact of adverse events, interventions needed, patient outcomes, and costs incurred. They observed a 27.2% and 18.0% reduction in adverse events experienced during deep and moderate PSA, respectively. This reduction resulted in savings that helped offset the expenses for initial purchase of the capnography equipment, and it lowered the estimated cost per procedure by $85 and $35 USD, respectively. They concluded that capnography is cost-effective and may play an important part in safely providing PSA.\(^{17}\)

In 2017, Saunders et al also published a meta-analysis providing clear evidence of a decrease in respiratory compromise with use of capnography during PSA.\(^{5}\)

Jopling et al presented a model demonstrating the cost-effectiveness of routine capnography monitoring for gastrointestinal procedures. They took the costs associated with adverse events and complications from peer-reviewed literature and assumed capnography costs at $3,000 per device and $12 per single-use sensor. After running 10,000 simulations, they calculated the median annual cost avoidance with routine capnography as $304,234 USD.\(^{8}\)

CAPNOGRAPHY IN EMERGENCY CARE

Healthcare organizations such as the American Society of Anesthesiologists\(^{2}\) have instituted standards of care that require capnography monitoring to measure the adequacy of ventilation during intubation.

The 2015 American Heart Association Guidelines for Cardiopulmonary Resuscitation and Emergency Cardiovascular Care contain a Class I recommendation for continuous capnography to confirm endotracheal tube placement and to detect dislodged tubes.\(^{4}\) The AHA also recommends capnography to monitor the effectiveness of CPR during cardiac arrest. Capnography can also be effective to detect return of spontaneous circulation, as well as hypo- and hyperventilation.

In an article in the Journal of Emergency Medical Services, Brandt et al wrote that unrecognized esophageal intubation leads to one of the most frequent and costly EMS lawsuits. If an improperly inserted endotracheal tube is not detected and corrected quickly, the resulting hypoxia can cause severe brain injury and, ultimately, death. They state that settlements for injury and wrongful death resulting from undetected misplaced endotracheal tubes are often in the multimillion-dollar range.\(^{18}\)

NEWER TECHNOLOGY FOR BETTER OUTCOMES

Given the nature of the study subjects, it is not feasible to conduct large randomized, controlled trials to investigate the direct relationship between the use of capnography and the cost of care. Without that hard data, however, it may seem more difficult for institutions to justify the expenditure for new technology. It can also be hard to change behavior, even in the face of new observational evidence.

Yet the analyses in the current literature seem to point to the same conclusion reached by Thomas Ahrens in his editorial of 2008.\(^{19}\) Citing the common concern about cost, he points out what studies show consistently: because capnography technology helps avoid complications, it is cost-effective — unlike traditional vital signs and assessments. He goes further to warn that traditional assessments may lead clinicians to believe patients are safe when they may not be, or in danger when they are not.

Keeping patients safe is the real objective of capnography monitoring. Keeping costs down is the fortunate by-product of a growing and lifesaving technology. Investing in capnography is investing in value — in both economic terms and for the long-term benefit of improved patient outcomes.

2. 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).


10. Table B. Richardson et al.


