Use of Capnography to Optimize Procedural Sedation in the Emergency Department Pediatric Population

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Contribution to Emergency Nursing Practice

- Waveform capnography is a continuous measurement and graphical display of the carbon dioxide (CO_2) levels throughout inspiration and expiration. It varies in accordance with a patient's respiratory rate and tidal volume. During pediatric procedural sedation and analgesia (PSA), waveform capnography can indicate abnormal ventilation before it can be detected through physical assessment of ventilation or by pulse oximetry.
- The weight of a few small, single-center, randomized controlled trials and observational studies suggest a benefit to the use of this technology. However, additional and larger studies are needed to elucidate a more substantial basis to inform best nursing practice.
- Emergency nurses should be engaged in assessing all appropriate sources of data to determine whether use of capnography during PSA improves patient outcomes.

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Introduction

A 10-year-old boy was brought to the emergency department with his left arm in a sling after he was injured during football practice. His left arm had a visible distal deformity, and a weak radial pulse was felt on palpation. The patient received morphine to treat his pain through an IV catheter that was quickly inserted. An x-ray film of the boy's arm showed a displaced radius fracture. His concerned mother provided informed consent for the patient to undergo PSA during which he would be given sedative or dissociative drugs and/or analgesics to facilitate the reduction of the fracture. Cardiopulmonary monitoring and waveform capnography were initiated. Emergency medications and ventilation and suctioning equipment were set up in the room. The end-tidal carbon dioxide ($ETCO_2$) measurement was 40 mm Hg at this time, and oxygen saturation (SpO_2) was 100%. Members of the procedure team conducted a timeout to verify that the closed reduction would be performed on the correct patient, following which the attending physician administered intravenous ketamine, often used for its dissociative, analgesic, and amnestic properties. The patient subsequently became sedated but reactive to voice. While the orthopedist was performing the closed reduction of the fracture, the patient cried out in pain, and the physician administered an additional dose of ketamine. The $ETCO_2$ value was 25 mm Hg at this point, and the patient was reminded to take a deep breath. During the postreduction monitoring, the $ETCO_2$ dropped to 14 mm Hg, and it became necessary to remind the patient to take a deep breath, which the patient was promptly able to do. The capnography reading was in the low 20s, and the SpO_2 displayed 99%, when suddenly an alarm went off. The $ETCO_2$ read zero for a few seconds. The nurse physically stimulated the patient and verbally reminded him to take a deep breath. The attending physician was called to the bedside. The monitor was still displaying an SpO_2 of 99%. The patient subsequently took a deep breath and, immediately after, the $ETCO_2$ alarm stopped beeping as the $ETCO_2$ value rose to 45 mm Hg. The patient continued to

take deep breaths with frequent reminders, and, a few minutes later, the SpO_2 dropped to 89%, then increased immediately to 99% without any additional intervention.

Procedural Sedation and Analgesia

PSA is a technique in which sedative or dissociative drugs and/or analgesics are administered to patients to treat pain and anxiety to facilitate the performance of a diagnostic or therapeutic procedure such as the closed reduction of the fracture in this case study. The types and combinations of the drugs used for PSA are typically commensurate to the patient's needs and induce a state whereby patients can tolerate unpleasant procedures while spontaneously breathing with their protective airway reflexes remaining intact. Ketamine, the drug administered in this case scenario, produces both amnesia and analgesia[1] and has been a popular agent for PSA in the emergency department for nearly 2 decades.[2] There is also strong evidential basis for the safety of administration of ketamine to children for PSA in the emergency department.[3] Studies note that a mean dose of intravenous administration of 1.5 mg/kg is often used to achieve a dissociative state for procedural sedation.[3]

Potential respiratory complications of PSA include drug-induced hypoventilation, respiratory failure, and hypoxic brain injury. Other complications can include nausea and vomiting, hypotension, allergic reactions, emergence reactions, and cardiac arrest. It is important, therefore, to anticipate possible complications of PSA and prepare for necessary resuscitation with suction, oxygen, age-fitting bag-valve mask (BVM) apparatus for positive pressure ventilation, reversal agents for pharmaceuticals used in the procedure, and monitoring equipment as well as an emergency cart with code medications and defibrillator.

PSA requires a minimum of 2 experienced clinicians with advanced life support skills: typically, a medical doctor or an advanced practitioner who oversees the drug administration and performs the procedure and another health care provider who continuously monitors the patient for complications.[1,4] Additional personnel may be present as dictated by hospital policy or procedural needs. PSA has 3 essential components that are performed in sequence: the initial presedation evaluation, sedation during the procedure, and postprocedure recovery. During the presedation evaluation, it is essential to obtain a focused history including allergies, past medical history, medication history, and the timing of the last meal consumed. A presedation risk stratification is important for identifying high-risk cases that should be performed in the more controlled operating-room environment.[5] While the patient is being sedated, the person monitoring the patient must be focused on the patient's cardiopulmonary status. This involves monitoring respiratory function by assessing airway patency, the rate and depth of breathing, SpO_2 monitoring, and monitoring hemodynamic parameters (blood pressure and heart rate).

After the procedure, the patient remains closely monitored to ensure that vital signs are stable and he or she returns to baseline alertness and orientation. Although there are several published sedation scores, the Modified Aldrete Score is most commonly used to monitor patients and assess their readiness to end the period of close monitoring.[6] Components of the scale include measurements of activity level, respiration, circulation, consciousness, and oxygen saturation.

In the pediatric population, PSA is associated with a low incidence of serious adverse events that are potentially life threatening and require the presence of a medical provider for safety.[7,8] These adverse events are most likely to occur during the expected time of the peak effect of the drug.[9] Many of the adverse events occurring during PSA in the pediatric population tend to be brief and self-limiting and can be resolved by simple interventions such as having the patient take a deep breath, as was demonstrated in our case study. However, children may be at greater risk than adults for serious complications from PSA.[10] Compared with adults, children have smaller airways and consequently may be more susceptible to respiratory compromise leading to hypotension and cardiopulmonary arrest.[11] Also, children have a smaller functional residual capacity (FRC), which is the volume of air present in the lungs at the end of passive expiration.[4] FRC is of physiologic importance in keeping the small airways open. Consequently, hypoventilation may lead to more rapid decompensation in the pediatric population than in the adult population.

Capnography

Capnography is a noninvasive method of measuring and monitoring the partial pressure of CO_2 during the respiratory cycle, commonly done through infrared absorption spectroscopy.[12] Carbon dioxide absorbs infrared light at a specific wavelength. When a beam of infrared light is directed onto the exhaled breath, the difference between the infrared light absorbed and amount emitted can be detected on a sensor. The sidestream analyzer system for $ETCO_2$ monitoring is typically used for PSA in the emergency department. In this system, exhaled air is aspirated from the circuit through a sampling line and then delivered to a sensor. The sampling line can be connected to nasal cannulas, nasal oral cannulas, and face masks.[13] Microstream (Medtronic Inc, Langhorne, PA) capnography