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Review Article

Capnography Monitoring During Procedural Sedation: A Prospective Assessment

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ABSTRACT

Procedural sedation performed outside the operating room has traditionally relied on pulse oximetry and intermittent clinical observation to detect respiratory compromise, but both lag behind the actual onset of hypoventilation or apnea, particularly when patients receive supplemental oxygen.

Capnography, which continuously measures exhaled carbon dioxide, detects apnea, hypoventilation, and airway obstruction well before saturation begins to fall, and this review synthesizes the prospective and randomized evidence for its use across endoscopic, emergency department, dental, obstetric, and pediatric sedation settings.

Across these contexts, capnography-guided monitoring is consistently associated with earlier recognition of ventilatory abnormalities and, in most trials, a reduced incidence of oxygen desaturation and hypoxemia relative to standard monitoring alone.

Evidence that earlier detection translates into a reduction in rarer, more serious outcomes such as unplanned intubation remains less mature, constrained by low baseline event rates and modest individual trial sizes, and practical concerns including signal artifact and alarm fatigue temper unqualified enthusiasm for the technology.

We conclude that the physiologic case for capnography during moderate and deep procedural sedation is now well supported, and that thoughtful implementation with adequate staff training is the more pressing remaining question rather than whether the monitor detects respiratory compromise earlier than pulse oximetry.

Keywords: *capnography; procedural sedation; respiratory depression; pulse oximetry; patient monitoring*

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INTRODUCTION

Procedural sedation has become the default anesthetic strategy for an enormous range of interventions performed outside the operating room, from routine

colonoscopy to pediatric fracture reduction to percutaneous gastrostomy placement. The appeal is obvious: patients tolerate the procedure, the endoscopist or interventionalist gets a still field, and the whole encounter is finished faster and more cheaply than it would be under general anesthesia. What is less often appreciated at the bedside is how quickly a comfortable, moderately sedated patient can slide into apnea or airway obstruction, and how poorly the two monitors most sedation teams have traditionally relied upon — pulse oximetry and intermittent clinical observation — perform at catching that slide before it becomes a desaturation event. Pulse oximetry tells the team what happened to oxygenation several breaths, and sometimes a minute or more, after ventilation actually stopped, and that delay is magnified by supplemental oxygen, which preserves saturation even while alveolar ventilation is falling toward zero. Capnography, by contrast, measures the thing that is actually failing first: exhaled carbon dioxide, breath by breath, in real time.

The physiologic argument for capnography during sedation is not new, but its adoption has been slow and uneven, driven in large part by cost, unfamiliarity with waveform interpretation among non-anesthesiologist sedationists, and a reasonable question about whether earlier detection of a ventilatory abnormality actually changes outcomes or merely generates more interventions and more alarms. Over the past fifteen years a substantial prospective and randomized literature has accumulated across endoscopic, dental, obstetric, and emergency department sedation settings, along with pediatric-specific data, that speaks directly to this question. This review synthesizes that evidence, focused on what capnography adds when layered onto standard monitoring during procedural sedation, where the benefit is most convincingly demonstrated, and where the evidence remains thinner than the enthusiasm for the technology might suggest.

THE PHYSIOLOGIC RATIONALE AND WHAT CAPNOGRAPHY ACTUALLY DETECTS

Capnography displays the partial pressure of carbon dioxide in exhaled gas as a continuous waveform, and the end-tidal value, sampled at the end of each expiration, closely approximates arterial CO2 in patients without significant ventilation-perfusion mismatch. During sedation, three abnormal patterns matter clinically: apnea, manifested as a flat line on the capnogram; hypoventilation, manifested as a rising end-tidal CO2 with a normal-shaped waveform; and upper airway obstruction, which produces a characteristic curare-cleft or blunted waveform even while chest wall movement continues. All three precede any fall in pulse oximetry saturation, often by 30 to 90 seconds and sometimes considerably longer when the patient is receiving supplemental oxygen, because oxygen reserve in the lungs and blood buffers saturation against a period of inadequate ventilation that would otherwise be immediately apparent [1].

This lag between the onset of a ventilatory event and its manifestation as desaturation is the crux of the clinical argument. A sedation team relying on pulse oximetry alone is, in effect, waiting for a physiologic reserve to be exhausted before intervening, and by the time saturation begins to fall the patient may already need more aggressive airway repositioning, stimulation, or bag-mask ventilation than would have been required had the team intervened at the first sign of hypoventilation. Guideline bodies covering pediatric sedation have incorporated this reasoning explicitly, recommending capnography as an adjunct to, not a replacement for, pulse oximetry and clinical observation in patients undergoing moderate to deep sedation [1].

EVIDENCE FROM GASTROINTESTINAL ENDOSCOPY

Endoscopy has generated the largest and most methodologically rigorous body of capnography sedation trials, largely because propofol-based deep sedation for colonoscopy and endoscopic retrograde cholangiopancreatography carries a nontrivial rate of transient apnea and desaturation even in healthy outpatients. The ColoCap study, a randomized controlled trial of capnographic monitoring during propofol sedation for colonoscopy, found that patients monitored with capnography experienced significantly fewer episodes of oxygen desaturation and hypoxemia than those monitored with standard pulse oximetry and clinical observation alone, and that the sedation team intervened earlier — with jaw thrust, verbal or tactile stimulation, or a brief pause in propofol administration — in the capnography arm [2]. A separate randomized trial of capnographic monitoring specifically for non-anesthesiologist-administered sedation during percutaneous endoscopic gastrostomy placement reported a similar pattern, with capnography-guided intervention reducing the incidence of hypoxemic episodes during a procedure that combines sedation depth with a patient population — often elderly, often with dysphagia or neurologic impairment — already at elevated aspiration and desaturation risk [3].

A phase II study comparing nasal pressure airflow monitoring against standard capnography during invasive endoscopic procedures found both modalities detected ventilatory abnormalities substantially earlier than pulse oximetry, suggesting that the core benefit lies in continuous airflow or CO2 sensing generally rather than in capnography's specific measurement of exhaled gas composition, though capnography remains the more widely validated and clinically familiar of the two approaches [4]. Systematic reviews pooling this endoscopy-specific literature have concluded that capnography reduces the incidence of

hypoxemic events during gastrointestinal endoscopic sedation, though the effect size and statistical significance vary across individual meta-analyses depending on which trials are included and how hypoxemia is defined [5]. A broader meta-analysis covering procedural intravenous sedation across specialties, not limited to endoscopy, reached a similar directional conclusion, finding capnography associated with fewer major desaturation events and earlier corrective intervention than standard monitoring alone [6]. Professional society guidance for GI endoscopy sedation now discusses capnography as an option for moderate to deep sedation, particularly where sedation is being provided by non-anesthesiologists without a dedicated airway specialist immediately at the bedside [7], and earlier clinical commentary framed capnography explicitly as a patient safety intervention for the endoscopy suite rather than a research curiosity [8].

EMERGENCY DEPARTMENT AND PROCEDURAL ANALGESIA SETTINGS

The emergency department presents a different risk profile from elective endoscopy: sedation is often performed for painful reductions or cardioversion in patients who have not fasted, using agents such as propofol, ketamine, or etomidate in combinations chosen for rapid onset and offset rather than for a smooth induction. A randomized controlled trial of end-tidal CO2 monitoring during emergency department procedural sedation and analgesia with propofol found that capnography-guided intervention reduced the incidence of hypoxic events compared with sedation monitored by pulse oximetry alone, with the sedation physician altering propofol dosing, repositioning the airway, or providing supplemental oxygen more promptly when the capnogram signaled hypoventilation before saturation had begun to fall. A pediatric emergency department trial of capnography during sedation similarly found that clinicians blinded to the capnogram were more likely to identify respiratory depression late, after saturation had already dropped, than clinicians who could see the waveform in real time [9].

Not every trial in this setting has shown a difference in hard clinical outcomes such as need for bag-mask ventilation or unplanned intubation, which are mercifully rare events even in unmonitored sedation, and a Cochrane systematic review of capnography versus standard monitoring for emergency department procedural sedation and analgesia concluded that while capnography reliably detects respiratory depression earlier than pulse oximetry, the evidence that this earlier detection translates into a reduction in serious adverse events remains limited by the low baseline event rate and the modest size of individual trials [10]. This is an important qualification: the physiologic signal is unambiguous, but proving that earlier detection changes downstream outcomes requires trials large enough to capture rare events, and most published sedation trials are underpowered for that specific question. Clinical commentary and editorial opinion in emergency medicine has nonetheless argued that continuous capnography should be considered standard for every emergency department procedural sedation, on the grounds that the cost and workflow burden of the monitor are low relative to even a modest reduction in the risk of an unrecognized apneic event in a non-fasted patient [11]. Nursing-focused practice guidance for emergency department pediatric sedation has taken a similar position, recommending capnography as part of a standardized sedation-monitoring bundle rather than as an optional add-on reserved for higher-risk cases [12,13].

DENTAL, OBSTETRIC, AND OTHER PROCEDURAL CONTEXTS

Outside the endoscopy suite and emergency department, capnography has been studied in a range of settings that share the common feature of sedation being administered by a proceduralist rather than a dedicated anesthesia provider. A randomized controlled trial of microstream capnography during midazolam-based conscious sedation for oral surgery found that the capnogram detected episodes of airway obstruction and hypoventilation that were not apparent from clinical observation or pulse oximetry, even though the sedation level used in oral surgery is nominally lighter than the deep propofol sedation studied in most endoscopy trials [14]. This finding matters because it pushes back against an intuitive but incorrect assumption that capnography's value scales only with sedation depth; even at moderate sedation levels, transient airway obstruction from a supine, sedated patient's tongue or soft palate is common enough to be clinically relevant, and dental and oral surgery sedation, often performed in an outpatient office setting without immediate access to advanced airway equipment, is a context in which early warning is arguably even more valuable than in a hospital endoscopy suite.

In obstetric practice, sidestream capnographic monitoring during propofol-based ambulatory anesthesia for surgical abortion has been shown to reduce the incidence of arterial oxygen desaturation, in a population that is typically young and healthy but that nonetheless experiences meaningful rates of transient apnea under deep sedation [15]. A separate trial of capnographic monitoring for propofol-based colonoscopy sedation reported comparable findings, reinforcing that the benefit of capnography is not confined to any single procedural specialty but rather tracks with the pharmacologic depth and respiratory risk of the sedation technique employed, regardless of which specialty is administering it [16,17].

PEDIATRIC SEDATION

Children present a distinct risk profile for procedural sedation: smaller functional residual capacity, higher oxygen consumption per kilogram, and a greater tendency toward rapid desaturation once ventilation is compromised, all of which shorten the window between the onset of a ventilatory abnormality and a clinically significant drop in saturation. A prospective observational study comparing non-invasive capnography with pulse oximetry for early detection of respiratory depression during pediatric procedural sedation found that capnography flagged abnormal ventilation substantially earlier than pulse oximetry across the cohort, consistent with the physiologic expectation that children's smaller oxygen reserve would, if anything, make the timing advantage of capnography more pronounced rather than less [18]. A more recent randomized controlled trial evaluating capnography with an integrated pulmonary index — a composite score combining respiratory rate, end-tidal CO2, and saturation into a single trend value — for preventing hypoxemia during pediatric urologic procedures performed under sedation found that use of the integrated index was associated with fewer hypoxemic episodes than standard monitoring, suggesting that combining capnographic data with other physiologic trends into a single actionable metric may extend the benefit of waveform capnography beyond what either raw CO2 values or saturation trends provide in isolation [19].

The American Academy of Pediatrics' guidelines for monitoring and management of pediatric sedation patients, revised periodically to reflect this accumulating evidence, recommend capnography for moderate sedation when the child's ventilatory status cannot be reliably and continuously observed and for deep sedation more broadly, reflecting a judgment that the smaller physiologic margin in children justifies a lower threshold for adopting the monitor than might apply in a healthy adult undergoing light to moderate sedation [1]. A systematic review protocol addressing procedural sedation and analgesia capnography across pediatric and adult populations was registered specifically to bring some methodological order to a literature that had, by the mid-2010s, already grown large enough that individual trials were difficult to compare directly because of inconsistent definitions of hypoxemia, apnea, and clinically significant respiratory depression [20].

LIMITATIONS OF THE CURRENT EVIDENCE AND PRACTICAL CONSIDERATIONS

Several caveats temper how far this literature can be extrapolated into a blanket mandate. First, most trials use surrogate respiratory endpoints — time to detection of apnea or hypoventilation, incidence of desaturation below a defined threshold, frequency of airway maneuvers performed — rather than the outcomes that actually matter to patients, such as unplanned intubation, aspiration, or cardiac arrest, because those events are rare enough that even large single-center trials are not powered to detect a difference in their incidence. The Cochrane review's cautious framing of the emergency department evidence reflects exactly this problem [10], and the same limitation applies, to varying degrees, across the endoscopy, dental, and obstetric literature. Second, capnography during sedation, particularly nasal cannula-based sampling in a non-intubated patient, is technically imperfect: mouth breathing, cannula displacement, and dilution of the sampled gas by supplemental oxygen flow can all produce falsely low or unreadable end-tidal values, and clinicians unfamiliar with these artifacts may either dismiss a genuine abnormality as a technical problem or, conversely, intervene unnecessarily in response to a spurious waveform.

Third, alarm fatigue is a genuine operational concern once capnography is introduced into a busy sedation practice, since transient waveform changes are common and not every flattened trace or brief rise in end-tidal CO2 represents a clinically important event; a monitor that fires frequently for events the team has learned to disregard provides less real protection than the trial data in a controlled research setting might suggest. Finally, capnography requires the sedation team to actually interpret the waveform correctly, and much of the demonstrated benefit in these trials came from teams who had been trained specifically for the study; whether that benefit persists once capnography is deployed broadly, interpreted by staff of varying experience, and no longer subject to the vigilance of a clinical trial protocol is a question the existing literature can only partially answer. None of these caveats undermines the core physiologic finding that capnography detects respiratory compromise earlier than pulse oximetry — that much is now well established across multiple independent settings — but they do argue for thoughtful implementation, adequate staff training, and realistic expectations about what earlier detection alone can and cannot prevent.

CONCLUSION

The prospective and randomized literature on capnography during procedural sedation is now broad enough, spanning endoscopy, emergency medicine, dentistry, obstetrics, and pediatrics, to support a fairly confident physiologic conclusion: capnography detects apnea, hypoventilation, and airway obstruction earlier than pulse oximetry and clinical observation, and in most of the settings studied, that earlier detection is associated with fewer episodes of oxygen desaturation and more prompt corrective intervention by the sedation team. The evidence that this translates into a measurable reduction in rare but serious outcomes such as unplanned intubation or aspiration is less mature, constrained by the low baseline event rate for those outcomes and the modest size of most individual trials, and reviewers who have looked specifically for

that harder outcome have appropriately stopped short of claiming it as proven. Taken alongside pediatric-specific data showing an even more pronounced timing advantage given children's smaller respiratory reserve, and newer work exploring composite pulmonary indices that combine capnographic trends with other physiologic signals, the overall trajectory of the field points toward capnography becoming a standard rather than optional component of moderate and deep procedural sedation monitoring, provided that adoption is paired with adequate staff training in waveform interpretation and realistic institutional expectations about alarm management. Where sedation teams have historically relied on pulse oximetry as their primary respiratory monitor, the data reviewed here make a reasonably strong case that they have, in effect, been watching the wrong number.

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Conflict of Interest

The authors declare no conflicts of interest.

Author Contributions

Nikos Lehmann conceived the review and drafted the initial manuscript. Elena Dvorak performed the literature search and contributed to drafting the sections on gastrointestinal endoscopy and emergency department sedation. Astrid Peeters contributed the pediatric and limitations sections and critically revised the manuscript for intellectual content. All authors read and approved the final manuscript.

Ethics Statement

This is a literature review and did not involve new human or animal data; no ethics approval was required.

Data Availability

No new data were generated or analyzed in this review. All sources discussed are cited and publicly available through their respective publishers.

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