Capnography compared to pulse oximetry for early detection of respiratory compromise in non-intubated patients undergoing gastrointestinal endoscopy procedures: a systematic review protocol

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Review question/objective: Does the use of capnography versus pulse oximetry increase the early detection of respiratory compromise and improve safety in non-intubated patients undergoing moderate sedation for gastrointestinal endoscopy procedures?

Respiratory compromise will be detected by alveolar hypoventilation/hyperventilation (EtCO₂ < 35 mmHg/EtCO₂ > 50 mmHg), arterial oxygen desaturation (defined as a pulse oximetry reading of <95% for >5 s), visual assessments of abnormal ventilation including apnea detection and adverse respiratory events that involve the need for bag-mask ventilation.

Keywords Capnography; gastrointestinal endoscopy; non-intubated patients; pulse oximetry; respiratory compromise

Background

Gastrointestinal endoscopy (GIE) procedures are investigative, diagnostic tools employed for the assessment and management of gastrointestinal (GI) aberrations; however, these procedures are invasive and uncomfortable for patients.¹ There is currently an accelerated use of these procedures worldwide,¹ and in 2009, in the United States alone, more than 55 million procedures were performed with GIE devices.²

The focus on excellence and high-quality interventions, as well as the trepidation of patient awareness and the prospect of a painless procedure, has given rise to the use of moderate sedation during GIE procedures.¹ While it is possible for certain patients to undergo such procedures without sedation, the use of sedation is concurrent with a greater level of patient satisfaction and higher quality of care;³ therefore, sedation and analgesia are recounted by numerous gastroenterologists to be a central and fundamental element of the endoscopic study. In the United States, more than 98% of upper and lower endoscopy procedures are carried out with the use of sedation. Numerous choices for methods of sedation exist. In addition, there are four distinct levels of sedation outlined by the American Society of Anesthesiologists (ASA). These levels vary from minimal sedation (anxiolysis) to deep sedation and general anesthesia;³ with the option selected for sedation contingent upon the individual undergoing the procedure, the specific procedure itself and the institution’s capability and scope of practice.¹ Although these different levels of sedation and analgesia exist, the most frequently used sedation for GIE procedures is moderate sedation, which is described by the ASA to be a drug-induced decrease in the level of consciousness, throughout which an individual purposefully responds to verbal commands either with verbal stimulation solely or in conjunction with light tactile stimulation.³ In addition, no interventions are necessary to maintain a patent airway, spontaneous ventilation is sufficient and cardiovascular function is typically conserved.³ Although moderate sedation in GIE procedures reduces a patient’s probability of sustaining physical harm during the procedure and presents medical personnel with a suitable milieu for a comprehensive examination, the application of sedation continues to be associated with risks.⁴ Sedation has been linked to a...
prolonged patient recovery time and length of stay as well as a sizeable amount of side effects, which involve hypotension, hypertension, bradycardia, cardiac arrhythmias, cardiac arrest, aspiration, desaturation, respiratory depression and respiratory arrest.\(^5\) Currently, the primary source of morbidity and mortality related to GIE procedures are cardiorespiratory-related complications.\(^5\) Significant risk factors associated with these complications are related to respiratory issues, including ventilatory depression and oxygen (O\(_2\)) desaturation from the medications used to achieve sedation.\(^6\) Critical to protecting the safety of the patient receiving moderate sedation for GIE procedures is the employment of continuous monitoring.

Currently, the standard of care for detecting insufficient blood oxygenation and irregular respiration during GIE procedures incorporates visual assessment of the patient, as well as the use of pulse oximetry.\(^7\) The American Society for Gastrointestinal Endoscopy, under the guidelines for moderate sedation, lists the standard monitoring of moderately sedated patients undergoing endoscopic procedures to include logging the heart rate, blood pressure, respiratory rate and O\(_2\) saturation (pulse oximetry).\(^8\)

Pulse oximetry’s primary purpose is to deliver a continuous measurement of arterial O\(_2\) saturation, non-invasively.\(^8\) In addition to becoming a defining standard of care, it is useful for the early detection of hypoxemia (pulse oximetry value <90%/desaturation) during sedation for GIE procedures, owing to the evidence that clinical observation alone is inaccurate in the detection of hypoxemia.\(^9\) Hypoxemia typically transpires within 5 min of drug administration or placement of the endoscope.\(^6\) It is essential to regard an O\(_2\) saturation level under 90% as a possible sign of respiratory compromise.\(^8\) Nevertheless, pulse oximetry, as well as the addition of supplemental O\(_2\) to the patient, has not been proven to lessen the frequency of cardiopulmonary complications or the severity of adverse events.\(^8\) Oxygen desaturation is actually a moderately later sign of less-than-desired ventilation.\(^6\) Hence, despite pulse oximetry providing a visual quantification of O\(_2\) saturation, it does not provide a real-time assessment of alveolar ventilation. Through research, it has been conveyed that pulse oximetry is incapable of the detection and prevention of alveolar hypoventilation during moderate-sedation endoscopy procedures. Although pulse oximetry is the current standard of care in this setting and delivers a consistent estimation of oxygenation, pulse oximetry lacks potential to provide an early warning system to detect hypoventilation, apnea or airway obstruction.\(^7\)

Oxygenation involves the inhalation of O\(_2\) into the lungs, diffusing the O\(_2\) via alveoli into the blood and then supplying tissues with the O\(_2\).\(^2\) Ventilation comprises the appropriate exchange of gases inspired and expired from the lungs, involving the exchange of both O\(_2\) and carbon dioxide (CO\(_2\)).\(^2\) Once the vascular system delivers CO\(_2\) to the lungs, CO\(_2\) is then removed through exhalation. In order for expired CO\(_2\) to be sensed, it is essential to have sufficient circulation to facilitate the transport of blood that is saturated with CO\(_2\) from the periphery to the lungs. Further, it is critical to have adequate ventilation in order to transport CO\(_2\) from the lungs to the mouth for exhalation with each breath.\(^7\) Evidence-based literature has found capnography to have a higher sensitivity in the detection of apneic (cessation of breathing) episodes than pulse oximetry or visual assessment.\(^6\)

Capnography presents a non-invasive, real-time quantification of inspiratory and expiratory CO\(_2\) concentration or end tidal carbon dioxide (EtCO\(_2\)). The measurement of EtCO\(_2\) is translated through the capnograph via a measured numeric value, reflected in millimeters of mercury (mmHg), as well as via a graphical waveform tracing of each individual respiratory cycle.\(^7\) Capnography is consequently reflective of a “ventilation vital sign”\(^7\). Therefore, some studies\(^11\) suggest that precise ventilation monitoring during moderate sedation can be achieved through the practice of continuous capnography monitoring in concurrence with pulse oximetry and visual evaluation.

In a prospective, double-blind randomized control trial (RCT) by Lightdale et al., 163 children were monitored with microstream sampling technology during endoscopic procedures undergoing moderate sedation, and EtCO\(_2\) capnography monitoring was simply incorporated into the monitoring practices.\(^10\) The study focused on determining whether interventions based on capnography indications of alveolar hypoventilation would decrease the prevalence of arterial O\(_2\) desaturation in non-intubated children undergoing moderate sedation for non-surgical endoscopy procedures. It was hypothesized that acting on early capnographic indications of ventilator compromise would decrease the incidence of O\(_2\)
desaturation, near misses and other adverse events. Ultimately, the study supports the regular use of microstream capnography to identify alveolar hypoventilation and decrease the incidence of hypoxemia during moderate sedation in children undergoing endoscopy procedures. In this study, microstream capnography is suggested to improve the standard of care for the monitoring of moderately sedated children via permissance of early detection of respiratory compromise and allowance for early intervention to lessen hypoxemia and prevent adverse events. It is suggested from this study that integrating capnography into patient monitoring protocols, in addition to pulse oximetry and visual evaluation, may improve safety of non-intubated patients receiving moderate sedation during pediatric endoscopy procedures. Furthermore, employing capnography in addition to pulse oximetry gives the provider the capability to gauge respiratory regularity and readily detect respiratory depression or adverse respiratory events (apnea, hypopnea and events requiring bag-mask ventilation) in patients earlier than with current standard practices.

Although multiple studies support the routine use of capnography in GIE procedures in both children and adults, some studies find no significance of implementing capnography into routine monitoring of patients undergoing moderate sedation in GIE procedures. The implementation of capnography has not been conclusively shown to optimize patient outcomes during moderate sedation in non-intubated patients undergoing endoscopy procedures.

A preliminary search of the literature yielded two RCTs, two prospective studies, one retrospective study and one relevant article presenting evidence from the opinion of authority. After conducting a search on October 1, 2015 within the JBI Database of Systematic Reviews and Implementation Reports and the Cochrane Database of Systematic Reviews using the same keywords listed for the search strategy, no systematic reviews were located for the proposed topic. Although the majority of these findings reflect a movement for the utilization of capnography in the suggested demographic, in order to achieve higher quality of care and a lower incidence of respiratory complications, rather than the use of pulse oximetry and visual assessment alone, there is insufficient evidence in the preliminary literature search to validate capnography’s use in GIE procedures. Consequently, a systematic review is proposed to collect all existing evidence in order to elucidate and evaluate the current knowledge concerning the efficacy of capnography versus pulse oximetry in the prevention and early detection of respiratory compromise and in the prevention of adverse respiratory events in non-intubated patients receiving moderate sedation undergoing GIE procedures (throughout the procedure).

**Inclusion criteria**

**Types of participants**
The current review will consider studies that include non-intubated pediatric and adult patients for GIE procedures undergoing moderate sedation. The ASA describes moderate sedation as a drug-induced decrease in consciousness which still allows the individual undergoing sedation to respond to verbal commands and/or light tactile stimulation. Participants will be patients greater than one month of age who are classified by the ASA as class one or two.

**Types of intervention(s)**
The current review will consider studies that evaluate patient monitoring for respiratory compromise with capnography compared to pulse oximetry.

**Outcomes**
Differing outcomes within this review will include an absence of respiratory compromise and an incidence of adverse respiratory events or compromise that may lead to cardiac arrhythmias, cardiovascular collapse or death. Adverse respiratory events and respiratory compromise include incidence of dyspnea, alveolar hypventilation ($ETCO_2 <35$ mmHg), alveolar hyperventilation ($ETCO_2 >50$ mmHg), apnea (visually noted or by absence of a capnogram when measuring capnography), hypoxemia (pulse oximetry level $<90\%$) and events that involve the need for an intervention/bag-mask ventilation (pneumothorax, atelectasis, airway obstruction and respiratory arrest). Capnography maintains the ability to measure respirations as they occur while simultaneously measuring $ETCO_2$; however, it does not measure any form of oxygenation. Conversely, pulse oximetry measures arterial $O_2$ saturation non-invasively, but is unable to measure alveolar hypoxemia or hyperventilation. An instance of a direct arterial blood gas measurement is a rare exception and
typically reserved for patients who are extremely ill and have multiple comorbidities that lead to extreme hemodynamic compromise. This review will only consider plausible, non-invasive measures as found with capnography and pulse oximetry. Current standards deem that pulse oximetry is sufficient for patients being monitored and undergoing moderate sedation.

Types of studies
The current review will consider any existing evidence generated by study designs of RCT and quasi-RCTs. In the absence of RCTs and quasi-RCTs, observational studies, cohort designs, case-controlled designs and evidence from the opinion of authority will be included.

Search strategy
The search strategy targets both published and unpublished studies in the English language and other languages that have been translated into English. Studies in a foreign language that have not been translated into English will be excluded. In order to reflect the latest evidence-based practice, only studies between 2005 and the present date will be considered. A three-step search strategy will be employed in this review. An initial limited search of MEDLINE (PubMed) and CINAHL will be executed, followed by evaluation of the text words contained in the title and abstract and of the index terms used to portray the article. A second search applying all acknowledged keywords and index terms will then be performed across all designated databases. Once these two steps are completed, the final step will include the reference lists of all identified reports and articles being examined for additional studies.

The databases to be searched include:
- CINAHL
- Embase
- MEDLINE (PubMed)
- Nursing@OVID
- Cochrane Central Trials Register
- Clinical Trials Registry
- Web of Science
- ProQuest Central

The search for unpublished studies will include:
- New York Academy of Medicine Gray Literature
- MEDNAR

Initial keywords to be used will be: Capnography AND Pulse Oximetry AND Moderate Sedation AND Endoscopy OR Gastrointestinal Endoscopy OR Colonoscopy OR Esophagogastrroduodenoscopy

Assessment of methodological quality
Papers selected for retrieval will be assessed by two independent reviewers for methodological validity prior to inclusion in the review using standardized critical appraisal instruments from the Joanna Briggs Institute Meta-Analysis of Statistics Assessment and Review Instrument (JBI-MAStARI) (Appendix I). Any disagreements that arise between the reviewers will be resolved through discussion or with a third reviewer.

Data extraction
Data will be extracted from papers included in the review using the standardized data extraction tool from JBI-MAStARI (Appendix II). The data extracted will include specific details about the interventions, populations, study methods and outcomes of significance to the review question and specific objectives. For data or information that is missing, authors will be contacted.

Data synthesis
Quantitative data will, where achievable, be pooled in statistical meta-analysis using JBI-MAStARI. All results will be subject to double data entry. Effect sizes will be quantified by measuring the number of adverse events that occur when patients are monitored with pulse oximetry in comparison to when patients are monitored by capnography. Adverse events include hypoxia, apnea, dyspnea or abnormal cardiac events such as a potentially fatal rhythm or cardiac arrest. Heterogeneity will be assessed statistically using the standard chi-square and through visual inspection of the Forrest Plot while variations in treatment effect will be explored using subgroup analyses based on the different study designs included in this review, such as studies that include only children or only adults. Where statistical pooling is not possible, the findings will be presented in narrative form including tables and figures to aid in data presentation where appropriate.
Acknowledgements

The current systematic review will contribute to the primary and secondary reviewer’s degree in Doctor of Nursing Practice (DNP) at Texas Christian University (TCU), Fort Worth, Texas, USA.

References

Appendix I: MAStARI appraisal instrument

**JBI Critical Appraisal Checklist for Randomised Control / Pseudo-randomised Trial**

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Overall appraisal: Include [ ] Exclude [ ] Seek further info. [ ]

Comments (Including reason for exclusion)

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# JBI Critical Appraisal Checklist for Descriptive / Case Series

Reviewer: 
Date: 

Author: 
Year: 
Record Number: 

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Overall appraisal: Include □ Exclude □ Seek further info □

Comments (including reason for exclusion)

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JBI Critical Appraisal Checklist for Comparable Cohort/Case Control

Reviewer ___________________________ Date ___________________________

Author ___________________________ Year __________ Record Number ________

1. Is sample representative of patients in the population as a whole? Yes ☐ No ☐ Unclear ☐ Not Applicable ☐
2. Are the patients at a similar point in the course of their condition/illness? Yes ☐ No ☐ Unclear ☐ Not Applicable ☐
3. Has bias been minimised in relation to selection of cases and of controls? Yes ☐ No ☐ Unclear ☐ Not Applicable ☐
4. Are confounding factors identified and strategies to deal with them stated? Yes ☐ No ☐ Unclear ☐ Not Applicable ☐
5. Are outcomes assessed using objective criteria? Yes ☐ No ☐ Unclear ☐ Not Applicable ☐
6. Was follow up carried out over a sufficient time period? Yes ☐ No ☐ Unclear ☐ Not Applicable ☐
7. Were the outcomes of people who withdrew described and included in the analysis? Yes ☐ No ☐ Unclear ☐ Not Applicable ☐
8. Were outcomes measured in a reliable way? Yes ☐ No ☐ Unclear ☐ Not Applicable ☐
9. Was appropriate statistical analysis used? Yes ☐ No ☐ Unclear ☐ Not Applicable ☐

Overall appraisal: Include ☐ Exclude ☐ Seek further info. ☐

Comments (Including reason for exclusion)

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Appendix II: MASTARI data extraction instrument

**JBI Data Extraction Form for Experimental / Observational Studies**

Reviewer: __________________________ Date: __________________________

Author: __________________________ Year: __________________________

Journal: __________________________ Record Number: __________________________

**Study Method**

- [ ] RCT
- [ ] Quasi-RCT
- [ ] Longitudinal
- [ ] Retrospective
- [ ] Observational
- [ ] Other

**Participants**

Setting: __________________________

Population: __________________________

**Sample size**

Group A: __________________________ Group B: __________________________

**Interventions**

Intervention A: __________________________

Intervention B: __________________________

**Authors Conclusions:**

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**Reviewers Conclusions:**

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**Dichotomous data**

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