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Capnography monitoring in the post Anaesthesia Care Unit (PACU)

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Abstract

Problem identification

Capnography monitoring has been identified as a valuable monitoring tool to assist in the early detection of respiratory adverse events in post-operative patients in the PACU who are receiving supplemental oxygen. This integrated review of literature aims to identify the usefulness of implementing capnography monitoring in the PACU as standard practice to ensure safe patient outcomes.

Literature search

A search was undertaken of Scopus, Cumulative Index Nursing and Allied Health Literature (CINAHL) Complete, Health Source: Nursing and Academic Edition, Clinical Key, PubMed and MEDLINE Complete electronic databases. Articles (n=12) were selected for this review including a randomised control trial (RCT), quality improvement projects, a prospective observation study, a prospective cross-sectional study, an evidence summary and a systematic review and meta-analysis study.

Data evaluation synthesis

The main indicators for the use of capnography in the PACU included patients on assisted oxygen, patients receiving opioid analgesia, patients with obstructive sleep apnoea and paediatric patients. All articles related to capnography presented complimentary findings regarding the usefulness of capnography monitoring and its implementation in the PACU.

Implications for perioperative nursing practice or research

Capnography is effective in identifying compromised ventilation in post-operative patients who are receiving supplemental oxygen in the PACU, compared to the use of pulse oximetry alone. The literature recommends the combined use of pulse oximetry and capnography in the post-operative period to provide clinicians with a complete assessment of a patients ventilatory status. Nursing education is indicated to improve respiratory assessments and monitoring skills of PACU nurses combined with further research to ensure the effective implementation of capnography in the PACU.

Keywords: capnography, end tidal carbon dioxide (ETCO2), hypoxaemia, PACU, paediatrics, respiratory depression, sleep apnoea

Introduction

Capnography is a method for monitoring the partial pressure of carbon dioxide in the blood and end tidal capnography measures the partial pressure of carbon dioxide at the end of an exhaled breath[1], i.e. end tidal carbon dioxide (ETCO2). This observation is non-invasive and occurs through a gas sampling line attached to a mask or nasal prongs in the spontaneously breathing patient[2]. The significance of capnography is its ability to determine the effectiveness of ventilation in patients exposed to supplemental oxygen[3].

Patients in the Post Anaesthesia Care Unit (PACU) are at high risk of adverse respiratory events due the effects of sedation, the use of opioid analgesia and other anaesthetic agents[4]. Respiratory depression, also referred to as hypoventilation, is slow and ineffective breathing which can lead to increasing carbon dioxide levels in the blood (hypercapnia) and low blood oxygen levels (hypoxaemia)[1]. Very early signs of malignant hyperthermia are also heralded by an exponential increase in ETCO2 levels; therefore capnography may assist in faster detection of this life-threatening event[5].

The suite of standard observations in Australian PACUs includes level of consciousness, blood pressure, oxygen saturation, heart rate, respiratory rate, temperature, comfort level, urine output, wound dressing and drain output, Bromage scores, and dermatome levels, if applicable[6]. While currently not mandated, electrocardiogram (ECG) is standard for many PACU units and is growing in popularity[7].

The use of assisted oxygen is known to mask the signs of inadequate or deteriorating respiratory function, and this has resulted in tragic patient outcomes[8]. Oxygen saturation is currently observed using pulse oximetry which is beneficial for identifying hypoxaemia but of limited use when a patient is exposed to supplemental oxygen as pulse oximetry cannot accurately and rapidly detect a patient with compromised ventilation[1].

Capnography can identify variations in ETCO2, respiratory rate, breathing pauses and cessation of breathing (apnoea), providing clinicians with real time information regarding a patient's ventilatory status[1,2]. Capnography has not been broadly adopted as part of standard monitoring practice in PACUs, despite a growing body of research justifying its adoption for post-operative patients on supplemental oxygen[1]. Capnography would be a valuable tool in addition to the existing suite of standard observations to enable early nursing intervention and the prevention of respiratory adverse events[9].

This review has evaluated and synthesised the relevant literature and will discuss capnography use in the PACU, the implications for perioperative nursing and finally the translation of knowledge concerning this valuable monitoring tool.

Problem identification

The use of assisted oxygen may mask a deterioration in respiratory function[8]. While pulse oximetry is a valuable part of observations performed by nurses in the PACU, this tool alone cannot detect compromised ventilation with sufficient accuracy in patients who are receiving supplemental oxygen[1]. Patients recovering on supplemental oxygen may decline rapidly due to ineffective ventilation long before a coincidental drop in blood oxygen saturation is reflected by pulse oximetry[10].

In the operating theatre, the use of capnography has become a standard practice to monitor the continuous ventilation of intubated patients[11,12]. While capnography monitoring has become increasingly used in critical care areas, to assist with the early detection of respiratory events, it has not been broadly implemented as standard practice for monitoring in the PACU[10]. This review aims to identify the usefulness of implementing capnography monitoring in the PACU as standard practice to ensure safer patient outcomes.

Literature search

Design

This review adopts the method outlined by Whittemore and Knafl for conducting an integrative review[13]. This method includes five stages – problem identification, literature search, data evaluation, data analysis and presentation – providing an exhaustive review of the literature for inclusion in this review[13].

Literature search methods

A search of the literature was undertaken electronically using databases including EBSCOhost (including Cumulative Index Nursing and Allied Health Literature (CINAHL) Complete), Health Source: Nursing and Academic Edition, Clinical Key, PubMed and MEDLINE Complete. Medical subject headings (MeSH) terms, parentheses, truncation and Boolean operators were used included Capnography" OR "End tidal carbon dioxide" OR "ETCO2" OR "Capnometry" AND "Monitoring" AND "Post Anaesthesia Care Unit" OR "PACU" OR "Recovery" OR "Postoperative.

Delimiters regarding peer-reviewed articles only and year of publication were set, with articles accepted

from 2015 to 2020, in order to ensure only relevant, timely and quality articles were used in this literature review. Articles were excluded if the full-text was not written in English, due to language constraints of the authors. Primary sources of literature were prioritised for the purpose of allowing direct interpretation of results. Editorials, conference abstracts and opinion papers were excluded due to inability to directly analyse the quality of the research included.

This search criteria identified 25 articles excluding duplicates, which were reviewed against the inclusion and exclusion criteria to determine applicability. Initially 12 articles were selected including a randomised control trial (RCT), quality improvement projects, a prospective observation study, a prospective cross-sectional study, an evidence summary and a systematic review and meta-analysis study.

A review of the reference lists was also completed in search of other relevant articles for inclusion in the review. Four additional pieces of literature were included in this paper, one provided information on writing an integrated review, two provided further background information on monitoring, and one explored the risks of assisted oxygen.

Data evaluation and synthesis

The final 16 articles were read and examined to identify background information and indications for the use of capnography. Indications included patients on assisted oxygen, patients receiving opioid analgesia, patients with obstructive sleep apnoea (OSA) and paediatric patients. These four indications have been used as subthemes to facilitate this review.

Results: Studying the performance of capnography in the PACU

The Australian and New Zealand College of Anaesthetists (ANZCA) PS04 Statement on the Post Anaesthesia Care Unit states that capnography monitoring must be applied to patients with an endotracheal tube and must be available if a patient is intubated or requires intubation in the PACU[6]. There are currently no recommendations for the use of capnography as standard monitoring in the PACU although respiratory events are frequent and capnography would be beneficial to ensure the safety of post-operative patients[2].

Three studies analysed the use and effectiveness of capnography monitoring in the PACU environment. A prospective observational study was conducted by Chung et al. to determine the usefulness of capnography in the PACU for early detection and intervention in comparison to the standard PACU monitoring[2]. PACU nurses adopted standard monitoring while capnography monitoring was undertaken by researchers[2]. The capnography detected respiratory adverse events 8.3 to 11 minutes earlier than standard monitoring in 75 per cent of cases[2]. Chung et al. concluded that the addition of capnography to standard PACU monitoring would be valuable in the early detection of respiratory adverse events[2]. A systematic review and meta-analysis conducted by Lam et al. identified an increase in ETCO2 to be a valuable indicator and early warning sign for respiratory depression[1]. Data revealed that a group monitored with continuous capnography identified 8.6 per cent more episodes of post-operative respiratory depression than those observed in the group with pulse oximetry (11.5% compared to 2.8%; P<.00001)[1]. Lam et al. also found capnography provided an accuracy six times greater than pulse oximetry alone in the detection of respiratory depression (P<.00001)[1]. Similarly, a quality improvement project conducted by Latham et al. in a large hospital PACU identified that the early detection of respiratory complications was 28 times more likely with capnography than pulse oximetry[4].

Capnography can also provide early identification of patients at risk of respiratory events prior to discharge from the PACU, allowing for transfer to an area of higher-level care or for increased supervision on lower acuity units[2]. A prospective cross-sectional study was conducted by Zito et al. to determine if the confidence of nurses was increased with the use of ETCO2 in the discharge of patients from the PACU[14]. The confidence of nurses regarding patient readiness for discharge differed before and after the assessment of ETCO2, suggesting ETCO2 has an important role as a monitoring tool to ensure safe discharge from the PACU to lower acuity nursing areas, such as the surgical wards[14].

The apparent opportunity to improve the safety of post-operative patients in relation to respiratory events using capnography is well documented[2]. The four main areas of focus for the use of capnography in the PACU identified in the literature include patients receiving assisted oxygen, patients receiving opioid analgesia, patients with OSA and paediatric patients. It is well accepted that patients in these categories are at heightened risk of compromised ventilation while recovering from general anaesthetic.

The ability of supplemental oxygen to mask underlying respiratory function

While not a specific case study related to the PACU, a coronial communique[8] reminds readers that supplemental oxygen may mask the signs of poor or deteriorating respiratory function as it elevates oxygenation and therefore pulse oximetry readings which would otherwise be falling if the patient were breathing room air[8]. The use of capnography in cases where supplemental oxygen is being used would allow faster, more accurate detection of alterations in respiratory function[3].

Opioid analgesia

Patients in the PACU are at risk of respiratory depression and hypoxaemia which is further compounded by the need for analgesia for post-operative pain management[15]. Carlisle states that opioid-related adverse events can be prevented in the perioperative setting through the improvement of monitoring practices[10]. One observational study and two quality improvement projects were identified in the literature relating to the use of capnography in the PACU for patients receiving opioid analgesia[3,10,12]

A prospective observational study conducted by Jungquist et al. included orthopaedic patients in the PACU wearing three types of electronic monitoring – pulse oximetry, capnography and minute ventilation. The study aimed to examine the effectiveness of these devices in identifying respiratory adverse events in patients[3]. All patients had supplemental oxygen and 48 out of 60 patients wore all three types of monitoring[3]. Findings revealed that 50 per cent (n=24) of patients displayed signs of opioid induced respiratory depression (OIRD), detected as hypoventilation through unchanged oxygen saturation, increased ETCO2 and decreased minute ventilation[3]. Jungquist et al. concluded that while capnography and minute ventilation were effective in the PACU for identifying patients with respiratory compromise, analysing oxygen saturation alone (in patients with assisted oxygen) is more reactive which may compromise intervention response times and expose patients to an increased risk of subsequent adverse events[3]. Jungquist et al. concluded that a proactive approach rather than a reactive approach is beneficial to identify patients at risk of OIRD[3].

Carlisle conducted a quality improvement project that involved the implementation of capnography as standard monitoring in the PACU to reduce the risk of OIRD with 71 per cent (n=174) of patients displaying at least one risk factor for OIRD[10]. Nursing education concerning OIRD risk assessment and capnography was implemented and twelve months after its implementation a significant rise in the frequency of capnography monitoring in high risk ORID patients was observed[10]. Carlisle concluded that the implementation resulted in an improvement in the number of high-risk patients receiving capnometry monitoring and a decrease in the number of OIRD cases[10].

Another quality improvement project was conducted by Oswald et al. to improve the monitoring of high-risk patients and patients receiving opioids in the PACU through the use of capnography[12]. Capnography identified 44 per cent (n=14) of patients had high ETCO2 and 48 per cent (n=16) of patients had a low respiratory rate (< 10 bpm). Capnography identified respiratory depression earlier than pulse oximetry oxygen saturation observations in 100 per cent (n=33) of patients[12].

Obstructive sleep apnoea (OSA)

OSA is the obstruction of the upper airway during sleep[9]. It is a sleep disorder that is caused by the relaxation of the pharyngeal muscles resulting in decreased airflow[9]. While this condition is increasing in prevalence, 80 per cent of surgical patients continue to be undiagnosed at the time of surgery due to poor understanding of symptoms[9]. In turn, this increases the risk of post-operative respiratory adverse events resulting in partial or complete airway obstruction[4]. Capnography monitoring of post-operative patients with OSA has been implemented in two quality improvement projects found in the literature with further recommendations for use supported by a best practice evidence summary.

A quality improvement project conducted by Scully et al. included patients with OSA, 36 per cent of which were preoperatively identified as high risk of OSA[9]. An OSA screening tool was implemented as well as a nursing education package that focused on capnography. Capnography was subsequently used on 76 per cent (n=241) of OSA patients, allowing nurses to easily detect hypoventilation and intervene accordingly[9]. Respiratory complications relating to OSA occurred in 10.8 per cent (n=34) of patients who required high level care[9]. Scully et al. concluded that the implementation of capnography in the PACU resulted in an improvement in the respiratory assessment skills of nurses and a coextensive decrease in respiratory complications for OSA patients[9]. Similarly, a quality improvement project conducted by Latham et al. included patients screened for OSA,

with the implementation of an OSA screening tool and capnography in the PACU after nursing education[4]. It was found that 67 per cent (n=41) of post-operative patients were identified as high risk for OSA with 76 per cent (n=31) of these patients having no previous diagnosis of OSA[4]. The conclusion drawn by Latham et al. was that capnography monitoring effectively identified patients at risk of respiratory complications, allowing for early nursing interventions to ensure safe patient care[4].

The use of capnography for monitoring post-operative patients at risk of OSA in the PACU has been recommended as best practice by the 2019 Joanna Briggs Institute (JBI) evidence summary to prevent respiratory adverse events[16]. Education for health care providers on capnography monitoring for post-operative patients and the interpretation of capnography findings, used in conjunction with clinical observation and assessment, is also recommended as best practice[16].

Paediatric patients

In the PACU, hypoventilation and apnoea are the most common respiratory events that occur among paediatric patients[15]. Two studies completed by Langhan et al. reviewed hypoventilation and capnography monitoring in children in the PACU after analgesia[11,15].

A randomised control trial conducted by Langhan et al. included 201 children, with 98 patients in the control group and 103 in the intervention group. PACU nurses were randomly allocated to be able to see the capnography monitor with the intervention group and not see the monitor with the control group[11]. Standard monitoring including pulse oximetry was applied and 94 per cent of patients received supplemental oxygen[11]. The results found decreased rates of hypoventilation and apnoea over time between the children in the intervention group (with capnography) and the children in the control group (with pulse oximetry)[11]. The results were related to a higher rate of identification of respiratory issues and improved effectiveness of interventions by nursing staff[11]. Decreased rates of slow breathing over time were found in the control group compared to the intervention group and no difference in hypoxaemia was found over time between the two groups[11]. Langhan et al. concludes that capnography identified most of the respiratory events among children in the PACU, resulting in fewer adverse events due to improved nursing interventions[11].

A prospective cross-sectional study conducted by Langhan et al. included 194 children randomly selected with capnography monitors concealed from the view of PACU nurses[15]. Standard monitoring including pulse oximetry was applied and 86.5 per cent of patients received supplemental oxygen[15]. Capnography detected hypoventilation or apnoea in 45.5 per cent (95% CI 38.5%, 52.5%) of patients and oxygen desaturations in 19 per cent (95% CI 13%, 24%) of patients, with interventions in 9 per cent (95% CI 5%, 13%) of patients[15]. Hypoventilation or apnoea was observed as more likely to occur in patients who received narcotic medication and supplemental oxygen[15]. Langhan et al. concluded that capnography as part of standard monitoring could improve the detection of respiratory depression and improve the safety of patients in the PACU[15].

Implications for perioperative nursing practice or research

This review examined the limited available literature regarding the effective use of capnography monitoring in the PACU to ensure safe patient outcomes. The articles obtained for the review were mainly quality improvement projects and prospective studies from the USA and Canada, and one Australian coronial communique. Jungquist et al. suggests that the limited types of studies conducted to date may have been driven by ethical considerations relating to experimental approaches to care of PACU patients[3]. Differences may also be present in the capnography thresholds from the studies conducted overseas potentially skewing the results and final outcomes.

The majority of studies identified in this review draw from analysis of the comparative effectiveness of capnography across classes of treatment where capnography has been identified as beneficial and best practice. This includes patients having supplemental oxygen, those receiving opioid analgesia, patients with OSA and paediatric patients. Some studies have noted the effectiveness of capnography monitoring compared to pulse oximetry alone in identifying compromised ventilation justifying the expanded adoption across the PACU environment for all patients where supplemental oxygen is applied. The empirical results indicate with sufficient clarity that capnography presents ventilatory data faster and with superior accuracy to pulse oximetry allowing for rapid response and improved patient outcomes. Ventilation changes will also be detected even

with the use of assisted oxygen, allowing respiratory deterioration to be more easily detected in the cohort[3]. The combined use of pulse oximetry and capnography in the post-operative period would provide clinicians with a complete assessment of a patient's ventilatory status to improve patient safety and prevent respiratory adverse events[1,2]. Such recommendations are well supported in the data and the study outcomes with nursing education indicated to improve the assessment skills of PACU nurses combined with further research to ensure the effective implementation of capnography in the PACU.

Knowledge translation

PACU nurses are a vital part of the perioperative team, ensuring the safety and care of the post-operative patient. As adverse respiratory events are frequent, the value of capnography monitoring in the PACU is clear and highly recommended as best practice in the reviewed literature. Although not currently standard practice in Australian PACUs, the use of capnography monitoring is unlimited and encouraged for use in all patients receiving supplemental oxygen as well as patients who have been administered opioid analgesia, patients with OSA or patients from the paediatric population. Further education among the nursing profession is suggested to improve the analysis, interpretation and response to capnography measures resulting in improved respiratory assessments and monitoring skills of PACU nurses.

Conclusion and recommendations

Capnography is an underutilised tool for monitoring and responding to events of compromised ventilation in the PACU. To date, mandatory use of capnography or its adoption as part of the best practice suite of standard observations has not been implemented except for intubated patients. Research in this study area suggests that the accuracy and sensitivity of ETCO2 capnography in identifying ineffective ventilation should support its adoption more broadly across PACU environments to complement pulse oximetry readings for patients on supplemental oxygen.

All 12 studies that were specifically related to capnography demonstrated that ETC02 monitoring could highlight an adverse respiratory event several minutes faster than pulse oximetry alone. This is because a coincident drop in blood oxygen saturation may not be logged by pulse oximetry observations for some time after an event of compromised ventilation, by which time the drop in oxygen saturation may be rapid, severe and fatal. The research has demonstrated that adoption of capnography monitoring is likely to result in more rapid and life-saving interventions for patients receiving supplemental oxygen.

The body of evidence available emanates from three main study areas where the risk of compromised ventilation is perceived to be higher – patients receiving opioid analgesia, patients presenting with OSA and patients from the paediatric population. It is however suggested that broader adoption of capnography for all patients receiving supplemental oxygen in the PACU would likely be supported by further research in this area. A number of studies have also emphasised the importance of nursing education in monitoring and interpreting capnography results. This point should not be understated and is critical to such an initiative.

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