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Effect of end-expiratory carbon dioxide monitoring on painless colonoscopy procedures in obstructive sleep apnea patients

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Abstract

Background Carbon dioxide (CO2) accumulation during prolonged painless colonoscopy procedures in patients with obstructive sleep apnea syndrome (OSAS) can lead to an increased incidence of various complications. The disposable end-expiratory CO2 device monitors the respiratory function and CO2 elimination of patients in real time, providing timely feedback to physicians. This enhances the safety and success of the procedure and improves the overall medical experience for the patient.

Method A total of 158 patients with OSAS underwent colonoscopy and were divided into two groups. The study group received end-expiratory CO_2 monitoring, while the control group underwent routine monitoring. Perioperative interventions, patient satisfaction, and postoperative complications were compared between the two groups using a case–control method. All colonoscopic procedures were performed by surgeons.

Result The study group exhibited a lower incidence of hypoxemia and higher utilization of upper airway ventilation devices, resulting in greater postoperative satisfaction ($P=0.019$, $P=0.002$, $P<0.001$, respectively). Conversely, the control group experienced a higher incidence of postoperative nausea and vomiting as well as abdominal pain and abdominal distension ($P=0.006$, $P=0.038$, $P<0.012$).

Conclusion Employing disposable end-expiratory CO_2 monitoring during painless enteroscopic procedures in patients with OSAS reduces the incidence of hypoxemia, enhances postoperative satisfaction, and decreases the incidence of postoperative complications.

Trial registration number ChiCTR2400083702; Registration date: April 2024.

Keywords OSAS, CO_2, Hypoxemia, Postoperative nausea and vomiting, Colonoscopy

Introduction

Obstructive sleep apnea syndrome (OSAS) primarily manifests as recurrent upper airway obstruction, apnea, and hypoventilation during sleep, making it a common sleep disorder. OSAS significantly affects sleep quality to varying degrees and is associated with a range of diseases, including cardiovascular disease and diabetes. In severe cases, it can lead to myocardial infarction, stroke, and even neurocognitive sequelae (Read et al. 2023; Gomase et al. 2023). Patients with OSAS usually experience hypertension, coronary heart disease, and

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other cardiovascular diseases (Holt et al. 2019). OSAS diagnosis is based on full polysomnography (Kuna et al. 2011). OSAS is now acknowledged as a major public health issue, affecting 5–15% of the population, with occurrence rising steadily with age, affecting people up to 60–65 years, with an average age of 40–50 years (Young et al. 1993). Patients with OSAS face multiple risks during intravenous anesthesia, as they are susceptible to airway collapse during anesthesia induction and surgery. Intravenous anesthetics such as propofol and midazolam further relax the upper airway muscles and increase the risk of obstruction (JA 2014). These medications also suppress the respiratory center and decrease the respiratory drive, causing hypoventilation or apnea, particularly during and after surgery. This is especially dangerous for patients with OSAS, who are already prone to apnea (Fahlenkamp et al. 2014). Due to airway blockage and respiratory suppression, patients with OSAS frequently experience hypoxemia during and after surgery. Ongoing hypoxemia can harm vital organs and increase perioperative complications (Porhomayon et al. 2014). Respiratory suppression also leads to CO_2 retention, increasing the risk of hypercapnia, further depressing respiration, and creating a vicious cycle. Hypoxemia and hypercapnia increase the burden on the heart and may trigger arrhythmia, myocardial ischemia, and myocardial infarction (Gottlieb and Punjabi 2020). Intravenous anesthetic drugs may be metabolized slowly in patients with OSAS, leading to delayed postoperative awakening, prolonged recovery time, and hospitalization; however, a standardized and effective treatment remains unavailable.

To prevent various perioperative complications in patients with OSAS, the risk of airway collapse can be reduced by using the head-high or lateral position as much as possible during anesthesia induction and surgery (JA 2014). When choosing anesthesia medications, patients prefer those with minimal respiratory suppressive effects and avoid those that could worsen respiratory issues. Careful monitoring and management of anesthetic drug dosages is crucial to prevent oversedation (Chung et al. 2014). Propofol acts quickly with a rapid onset and recovery, while sufentanil offers potent analgesic effects, effectively relieving pain during the procedure and enhancing patient comfort. When used together, the recovery time is faster, allowing patients to regain consciousness quickly and prepare to leave the operating room. However, for patients with OSA, it is crucial to closely monitor and manage their respiration to prevent respiratory depression and airway obstruction (Lee et al. 2011). Employing sophisticated airway management techniques, such as tracheal intubation, laryngeal mask airway, and nasopharyngeal airway, improves the likelihood of successful airway intubation and readiness for unexpected airway blockages (Isono 2017). Anesthesia use outside the operating room is increasing, and patients with OSAS undergoing painless colonoscopy are exposed to higher respiratory and cardiovascular risks due to their respiratory system specificities. Additionally, anesthesia administration outside the operating room remains difficult when using only the aforementioned techniques. Monitoring the respiration of patients with OSAS in real-time is crucial.

However, the current continuous pulse oxygen saturation (SpO_2) can be misleading because the patients may exhibit elevated SpO_2 values despite having respiratory issues (Fu et al. 2004). Therefore, employing more precise monitoring devices may be the only way to reduce potential risks. End-tidal carbon dioxide partial pressure ($PetCO_2$) monitoring can assess ventilation status, allowing anesthesiologists to promptly detect inadequate ventilation due to airway obstruction. Both mainstream $PetCO_2$ monitoring and bypass $PetCO_2$ monitoring offer distinct advantages and play crucial roles depending on the surgical procedure, the patient's condition, and the type of anesthesia used. Mainstream $PetCO_2$ monitoring is typically employed in patients under general anesthesia, especially those requiring airway management such as tracheal intubation or the use of a laryngeal mask airway (Sang Hoon 2019). By continuously monitoring the end-tidal carbon dioxide ($EtCO_2$) levels, anesthesiologists can assess ventilation in real time, ensuring that the airway remains open and carbon dioxide is effectively expelled. This method provides precise CO_2 concentration data, enabling anesthesiologists to detect ventilation issues, airway obstructions, or gas exchange problems promptly. During surgery, where anesthetic agents and airway management can impact respiratory patterns, mainstream $PetCO_2$ monitoring offers timely feedback. For high-risk surgeries, such as cardiac or major surgeries, this type of monitoring ensures that the patient receives optimal respiratory support, reducing the risk of hypoxemia or hypercapnia (Kremeier et al. 2020; Blankman et al. 2016).

In contrast, bypass $PetCO_2$ monitoring is ideal for patients who do not require intubation, particularly those using non-invasive ventilation (NIV) devices like mask ventilation. It samples CO_2 levels from the breathing circuit via a bypass tube, without directly affecting the airway. In certain cases, patients may only need local anesthesia or mild sedation rather than general anesthesia. In such situations, bypass $PetCO_2$ monitoring allows anesthesiologists to monitor respiratory status and ensure there is no respiratory suppression or ventilation failure. This method is especially useful for patients with difficult airways (e.g., those with obesity, enlarged tongue bases, or a history of neck surgeries), as it provides a

practical alternative, particularly when frequent airway adjustments are required during anesthesia (Gita and Samir 2024; Shogo et al. 2023). With the increasing number of pain-free procedures performed outside the operating room, which are typically short and quick, the risks associated with anesthesia remain. During a painless gastrointestinal endoscopy, patients are typically administered sedative and analgesic medications via intravenous injection, with the dosage adjusted based on the patient's response and needs under the doctor's guidance. Most patients undergo the procedure under mild sedation, without feeling pain, and typically do not remember the procedure. Throughout the examination, the patient's vital signs, such as heart rate, blood pressure, and blood oxygen saturation, are closely monitored to ensure safety (Li et al. 2019). Therefore, bypass $PetCO_2$ monitoring may be better suited for such situations. This study aims to explore the application of bypass $PetCO_2$ monitoring for effective respiratory support and anesthesia management in painless colonoscopies through a prospective case–control study (Cook 2016; Ishiwata et al. 2018). Bypass $PetCO_2$ monitoring is more flexible and can be used in a wider range of situations, including patients on non-invasive ventilation, spontaneously breathing patients, and situations where airway devices need to be changed frequently (Casati et al. 2001; Sättigungsabfall postoperativ häufiger als erwartet 2017). Whether monitoring by paracentesis $PetCO_2$ reduces anesthetic risk remains unclear. Therefore, this study aimed to explore the use of microparacentesis $PetCO_2$ monitoring for effective respiratory support and anesthesia management during painless colonoscopy in a prospective case–control study.

Methods

Study design and population

A randomized controlled trial was conducted at the Digestive Endoscopy Center of Chenggong Hospital, affiliated with Xiamen University, between April 20 and August 20, 2024.

The inclusion criteria were patients aged 18–60, classified as grade I–II by the American Society of Anesthesiologists (ASA), and with a confirmed diagnosis of stable OSAS requiring colonoscopy. The exclusion criteria included patients under 18 or over 60 years of age who did not have OSAS or had OSAS in an unstable stage; had severe medical or surgical conditions, such as severe cardiovascular conditions (e.g., heart failure and arrhythmias), respiratory issues (e.g., chronic obstructive pulmonary disease and respiratory failure), advanced liver and kidney dysfunction, acute neurological conditions (e.g., stroke and brain injury), significant metabolic disturbances (e.g., poorly controlled diabetes and electrolyte imbalances), allergies to anesthesia drugs, and acute gastrointestinal disorders or bowel obstruction; did not have an indication for colonoscopic surgery; or could not cooperate with the study. Patients were randomized into the study group and the control group using a computer-generated randomization sequence. The randomization list was prepared by an independent statistician who was not involved in the study. Allocation concealment was ensured by using sequentially numbered, opaque, sealed envelopes (SNOSE). The envelopes were opened only after the patient had provided informed consent and was deemed eligible for the study. The study was conducted in a single-blinded manner. While the patients were unaware of their group assignments, the anesthesiologists and surgeons could not be blinded due to the nature of the intervention. However, the data analysts who performed statistical analyses were blinded to group allocation to minimize bias. The ethics document for the study was submitted to the Affiliated Chenggong Hospital of Xiamen University and approved by the hospital's Ethics Committee (No: 73JYY2024137384). The trial was registered before patient enrollment at https://clinicaltrials.gov/ (ChiCTR2400083702; principal investigator, Shanshan Liu; registration date, April 2024). Participants provided informed consent and could withdraw at any time without affecting their treatment. Alternatives ensured consent for those unable to sign. Participation was voluntary, and privacy was protected.

Interventions

All the participants received intravenous general anesthesia with 0.25 mg/kg propofol and 5 ug sufentanil. Before anesthesia, all the participants underwent nasal cannula oxygenation, pulse oximetry, non-invasive blood pressure monitoring, and electrocardiogram (ECG) monitoring. In the study group, real-time monitoring was performed by attaching a sampling tube to a portable end-expiratory CO_2 monitor. The monitor measures the concentration of CO2 in the exhaled gas using infrared spectroscopy. The sampling tube collects the gas sample and transmits it to the monitor for analysis. In contrast, the control group used the sampling tube solely to provide oxygen to the patients without connecting it to the CO_2 monitor. The surgeon waits until the patient shows no motor response before performing the colonoscopy and injecting CO_2 into the bowel. The anesthesiologist intervenes according to the intraoperative vital signs changes, such as placing an upper airway ventilation tool and lifting the jaw. If the patient's oxygen saturation drops below 90%, or if the $PetCO_2$ of the study group patients falls below 20% of the pre-anesthesia value or suddenly drops to zero, indicating potential respiratory issues, the anesthesiologist will promptly intervene by inserting an oropharyngeal

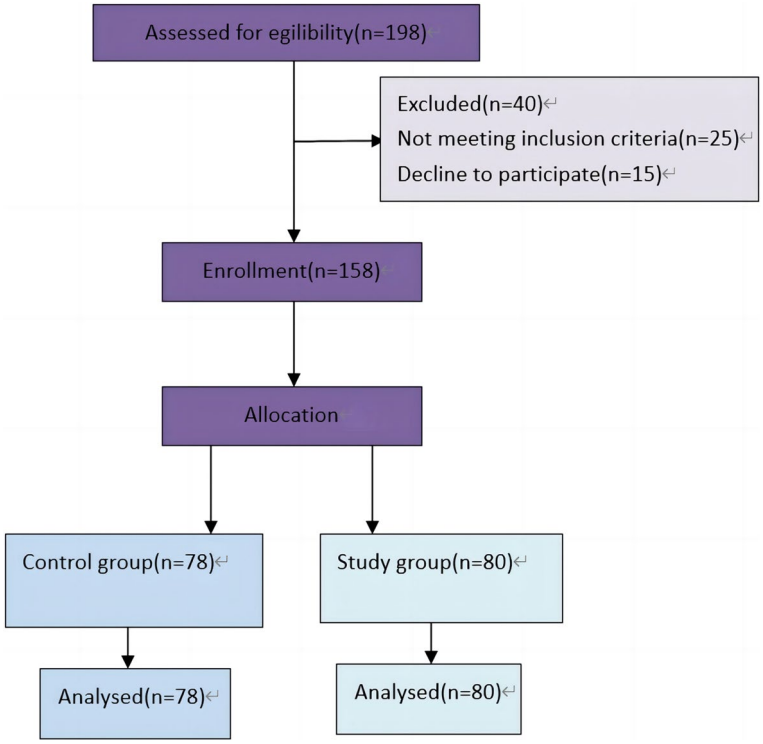

Fig. 1 CONSORT flow diagram of study enrollment and analusis. Note: *The incidence of hypoxemia was higher in the control group than in the study group, $P=0.019$

or nasopharyngeal airway, or by adjusting ventilation parameters to restore normal respiratory function.

Information recording

Demographic data, including age, gender, body mass index (BMI), and ASA classification, were recorded at enrollment. Heart rate, respiration, pulse oximetry, and blood pressure were recorded in both groups 5 min before anesthesia (T0), at the beginning of the operation (T1), 10 min after the beginning of the operation (T2), 20 min after the beginning of the operation (T3), and at the end of the operation (T4). Main indicators of hypoxemia, respiratory depression, apnea, patient satisfaction, and interventions were recorded during the perioperative period. The second indicators were nausea and vomiting, abdominal pain, and abdominal distension after surgery.

Statistical analysis

The statistical analysis was performed using SPSS software (version 25 for Windows, IBM Inc., Chicago, IL, USA). In this study, the normality of the distribution of demographic data was assessed using the Shapiro–Wilk test and the Kolmogorov–Smirnov test. The

Table 1 Comparison of demographic information between the two groups

	Control group ($n=78$)	Study group ($n=80$)	T/χ^2	P值
Age (years)	47.08 ± 8.32	48.23 ± 9.44	−0.810	0.419
Gender			0.076	0.782
Male	56 (71.8)	59 (28.2)		
Female	22 (73.8)	21 (26.3)		
Body mass index (BMI) (kg/m^2)	30.24 ± 4.579	30.55 ± 5.061	−0.399	0.691
ASA classification			0.096	0.756
I	38 (48.7)	37 (51.3)		
II	40 (46.3)	43 (53.8)		
Surgical duration (minutes)	25.26 ± 3.985	26.38 ± 3.616	−1.849	0.066
Surgical duration (minutes)	26.88 ± 6.752	28.50 ± 8.002	−1.373	0.172
Hospital stay (days)	3.88 ± 1.032	4.11 ± 1.147	−1.312	0.192

Shapiro–Wilk test is particularly suitable for small sample sizes, while the Kolmogorov–Smirnov test is more robust for larger datasets. A *P*-value of less than 0.05 was considered statistically significant for all analyses. Quantitative variables were expressed as mean ± standard deviation (SD) when normally distributed, and as median with interquartile range (IQR) for non-normally distributed data. Qualitative variables were presented as frequencies and percentages.

Results

Initially, 198 patients were included in this study. However, 25 patients were excluded due to poorly controlled diabetes, hypertension, asthma, or other conditions. Additionally, 15 patients refused to participate. Ultimately, 158 patients were included in the final analysis: 80 in the study group and 78 in the control group. Figure 1 presents the CONSORT flowchart. No significant differences were found between groups in terms of baseline demographic characteristics (Table 1). No statistically significant differences were found in the baseline vital signs, heart rate (HR), and blood pressure (BP) at T0, T1, and T2 (Table 2).

Main indicators

Statistically significant differences were found between the two groups in terms of the main indicators of hypoxemia, postoperative patient satisfaction, and placement of upper airway ventilation devices (oropharyngeal/nasopharyngeal airway). Hypoxemia incidence was higher in the control group than that in the study group ($P=0.109$). The proportion of patients satisfied with the postoperative evaluation ($P<0.001$) and that of patients using upper airway ventilation devices ($P=0.002$) were higher in the control group compared with than in the study group (Table 3 and Fig. 2).

Second indicators

Statistically significant differences were observed in postoperative complications such as postoperative nausea and vomiting (PONV) ($P=0.006$), abdominal pain ($P=0.038$), and abdominal distension ($P=0.012$) between the two groups. The incidence of postoperative complications was higher in the control group than that in the study group (Table 4, Fig. 3).

Discussion

This study revealed that patients with OSAS who underwent colonoscopic surgery and micro-bypass end-expiratory CO_2 monitoring experienced a reduced incidence of intraoperative hypoxemia. Additionally, a higher percentage of these patients required upper airway ventilation equipment during the procedure, leading to greater overall postoperative satisfaction. The *P*-value for the incidence of hypoxemia in this study was 0.109, which exceeds the significance threshold ($P<0.05$), suggesting that the intervention may not have significantly reduced the occurrence of hypoxemia. However, the lack of statistical significance in medical research can arise from various factors. In this case, the sample size may have been insufficient, limiting the statistical power needed to detect a meaningful difference. Additionally, the incidence of hypoxemia could be influenced by factors beyond anesthetic interventions, such as the patient's baseline health status, the dosage of anesthetic agents, and the quality of intraoperative management. These variables may have concealed the potential effects of

Table 2 Comparison of baseline vital signs at different time points between the two groups

	Control group ($n=78$)	Study group ($n=80$)	T	*P*
Heart rate (beats/min)				
T0	74.97 ± 3.247	74.54 ± 2.695	0.919	0.360
T1	71.60 ± 2.493	71.35 ± 2.886	0.588	0.557
T2	71.31 ± 4.638	72.45 ± 3.318	−1.777	0.078
T3	69.94 ± 2.982	69.49 ± 3.561	0.859	0.392
T4	68.87 ± 0.827	68.71 ± 2.678	0.508	0.613
Respiratory rate (breaths/min)				
T0	18.79 ± 0.779	-	-	-
T1	7.99 ± 0.764	-	-	-
T2	14.92 ± 1.510	-	-	-
T3	16.83 ± 1.390	-	-	-
T4	16.10 ± 1.447	-	-	-
Oxygen saturation (SpO_2)				
T0	99.50 ± 0.503	99.54 ± 0.502	−0.469	0.640
T1	98.64 ± 0.738	98.51 ± 0.503	1.276	0.204
T2	98.44 ± 1.100	98.09 ± 1.443	10,710	0.089
T3	97.88 ± 1.441	97.45 ± 1.668	1.751	0.082
T4	99.15 ± 0.722	99.20 ± 0.833	−0.372	0.710
Blood pressure (mmHg)				
Diastolic blood pressure (DBP)				
T0	77.17 ± 1.436	76.91 ± 0.830	1.358	0.177
T1	67.62 ± 1.605	67.29 ± 4.467	0.617	0.539
T2	64.94 ± 3.906	64.69 ± 3.609	0.415	0.678
T3	65.44 ± 0.499	65.63 ± 1.060	−1.440	0.153
T4	71.95 ± 2.512	71.81 ± 3.307	0.292	0.771
Systolic blood pressure (mmHg)				
T0	116.92 ± 1.394	116.45 ± 1.757	1.878	0.062
T1	101.95 ± 1.385	101.66 ± 2.244	0.967	0.335
T2	128.05 ± 3.137	128.41 ± 2.385	−0.813	0.417
T3	127.58 ± 2.344	128.40 ± 3.495	−1.742	0.084
T4	119.33 ± 2.733	119.06 ± 1.426	0.778	0.438

Note: 5 min before anesthesia (T0), at the beginning of the operation (T1), 10 min after the beginning of the operation (T2), 20 min after the beginning of the operation (T3), and at the end of the operation (T4)

Table 3 Comparison of key indicators between the two groups

	Study group ($n=80$)	Control group ($n=78$)	χ^2	*P*
Hypoxemia (*n*)	12 (15.4)	25 (31.3)	5.543	0.019
Respiratory depression (*n*)	32 (41.0)	-	-	-
Apnea (*n*)	15 (19.2)	-	-	-
Patient satisfaction			17.864	< 0.001
Yes (*n*)	69 (88.5)	47 (58.5)		
No (*n*)	9 (11.5)	33 (41.3)		
Interventions				
Lift the jawbone (*n*)	45 (57.7)	39 (48.8)	1.268	0.260
Placement of oropharyngeal/nasopharyngel airway (*n*)	27 (34.6)	119 (13.8)	9.413	0.002
Oxygen delivery via pressure mask	7 (9.0)	9 (11.3)	0.225	0.635

the intervention. Even in the absence of statistical significance, small improvements may still have clinical relevance. Chen et al. found that micro-bypass end-expiratory CO_2 monitoring in patients with OSAS can detect more respiratory events and provide timely and reliable respiratory support (Weihu et al. 2011). The enhanced detection of respiratory events via end-tidal respiratory carbon dioxide ($EtCO_2$) monitoring can assist in prompt interventions, such as the implementation of upper airway ventilation devices (Soto et al. 2004). Such interventions can potentially prevent the worsening of hypoxemia and other respiratory issues, thereby improving outcomes in patients with OSAS, both perioperatively and postoperatively (Lightdale et al. 2006). Moreover, $EtCO_2$ monitors provide instantaneous feedback on the patient's ventilatory condition, enabling adjustments in sedation and ventilation strategies as needed. According to Scully et al. (Scully et al. 2019), utilizing micro-bypass

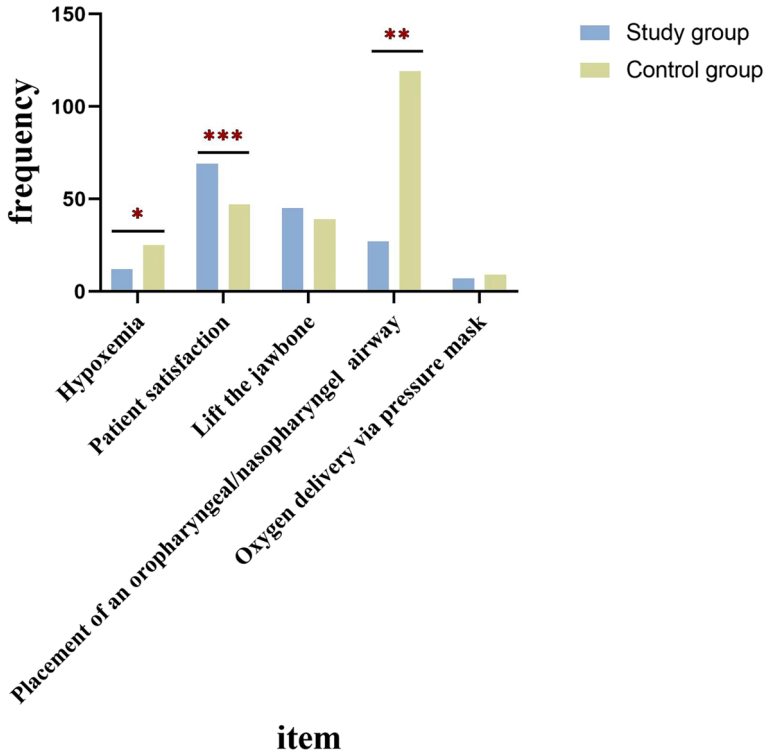

Fig. 2 Comparison between the two groups in terms of hypoxemia, postoperative patient satisfaction, placement of upper airway ventilation devices (oropharyngeal/nasopharyngeal airway), and oxygen delivery via pressure mask. **The incidence of placement of upper airway ventilation devices (oropharyngeal/nasopharyngeal airway) was higher in the control group than in the study group, $P=0.02$. ***The patient satisfaction in the study group was higher than that in the control group, $P<0.001$

Table 4 Comparison of postoperative complications between the two groups

	Study group (*n* = 80)	Control group (*n* = 78)	χ^2	*P*
Nausea and vomiting (*n*)	6 (7.7)	19 (23.8)	7.646	0.006
Abdominal pain (*n*)	11 (14.1)	22 (27.5)	4.290	0.038
Abdominal distension (*n*)	9 (11.5)	22 (27.5)	6.380	0.012

monitoring of $EtCO_2$ can effectively address hypoventilation in individuals with OSAS, thereby decreasing the incidence of respiratory issues. In a study evaluating the efficacy of $PetCO_2$ monitors in enhancing patient safety during bronchoscopy, endoscopy, and intervention procedures, a 43.2% reduction in sedation-related adverse events was observed. Furthermore, a significant decrease in the incidence of hypoxemia was noted among colonoscopy patients receiving propofol sedation (Corbett et al. 2022; Friedrich-Rust et al. 2014). This contributes to the optimization of anesthetic management (Langhan et al. 2017). No respiratory depression or pauses in breathing were recorded in the control group in this study because no end-expiratory CO_2 monitoring device was used.

In practical clinical practice, EtCO2 monitoring in OSA patients can significantly reduce the incidence of postoperative complications such as nausea and vomiting, which has important clinical significance (Gaddam et al. 2013; Kaw 2015). PONV is common anesthesia-related complications that can affect patient recovery and postoperative comfort. EtCO2 monitoring allows for real-time assessment of the patient's ventilation status, promptly identifying respiratory depression and hypoventilation, thereby optimizing anesthetic management and effectively reducing the occurrence of these complications. This enhances patient satisfaction and recovery quality postoperatively (Fujimoto et al. 2020). Although these improvements may seem modest, they can significantly improve patient comfort and reduce healthcare costs in clinical practice. From a cost-effectiveness perspective, while EtCO2 monitoring equipment involves higher initial costs, it effectively reduces postoperative complications, length of hospital stay, and treatment expenses. By promptly identifying respiratory depression and hypoventilation, it helps reduce the occurrence of severe complications (such as hypoxemia), thereby avoiding high treatment costs and the risk of extended hospitalization. Moreover, by reducing postoperative complications and improving patient safety, it not only decreases additional treatment costs but also increases patient satisfaction, further reducing the need for re-treatment due to complications (Zhou et al. 2021). This makes EtCO2 monitoring highly valuable in clinical practice for OSA patient populations, offering significant potential cost-effectiveness and warranting widespread adoption in relevant clinical settings.

This reflects proactive management of potential respiratory issues, leading to greater overall patient

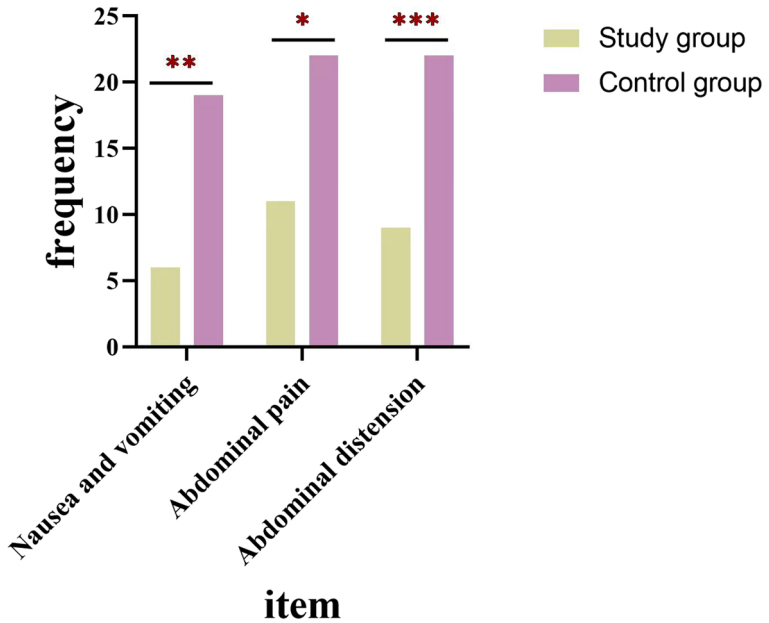

Fig. 3 Comparison of postoperative complications between the two groups. Note: *The incidence of nausea and vomiting was higher in the control group than in the study group, *P* = 0.006. **The incidence of abdominal pain was higher in the control group than in the study group, *P* = 0.038. ***The abdominal pain in the control group was higher than in the study group, *P* = 0.012

satisfaction in the postoperative period. This increased satisfaction likely stems from an enhanced sense of safety and well-being provided by vigilant monitoring and timely intervention.

Limitation

The limitations of this study primarily include a small sample size, being conducted at a single center, insufficient control of potential confounding factors (such as endoscopist technique and patient emotional state), a lack of long-term follow-up on postoperative effects, and the absence of a cost-effectiveness analysis for $EtCO_2$ monitoring. These limitations may affect the generalizability and depth of the study's findings. Future research will aim to address these issues by increasing the sample size, conducting multi-center validation, controlling for more confounding variables, incorporating long-term follow-up, and providing a more comprehensive evaluation of the economic feasibility of $EtCO_2$ monitoring.

Conclusion

This study evaluated the practical utility of a microbypass end-expiratory CO_2 monitoring device during the perioperative period in patients with OSAS undergoing colonoscopy. The findings revealed that this device could promptly identify intraoperative ventilation dysfunction in patients with OSAS and offer timely and effective ventilation interventions, resulting in fewer postoperative adverse events due to well-managed intraoperative anesthesia. The results can enhance the precision of surgical procedures for patients with OSAS, improve patient comfort, provide surgeons with more objective data, and ultimately improve the quality of patient care and satisfaction.

Supplementary Information

The online version contains supplementary material available at https://doi.org/10.1186/s13741-025-00509-9.

Additional file 1.

Authors' contributions

Pengxia Wang: Conceptualization, Methodology, Writing – original draft,Writing – review & editing. Qiuxiang Jiang: Formal analysis, Data curation, Kaihui Li:Data curation, Yinying Zeng:Data curation, Zhangxing Chen:Supervision, Project administration Shanshan Liu: Supervision, Writing – review & editing,Project administration, Funding acquisition.

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Data availability

No datasets were generated or analysed during the current study.

Declarations

Declarations

All authors certify that they have no affiliations with or involvement in any organization or entity with any financial interest (such as honoraria; educational grants; participation in speakers' bureaus; membership, employment, consultancies, stock ownership, or other equity interest; and expert testimony or patent-licensing arrangements), or non-financial interest (such as personal or professional relationships, affiliations, knowledge, or beliefs) in the subject matter or materials discussed in this manuscript.

Ethics approval and consent to participate

The ethics document for the study was submitted to the Affiliated Chenggong Hospital of Xiamen University and approved by the hospital's Ethics Committee (No. 73JYY2024137384).

Informed consent statements

All individuals included in the study obtained informed consent.

Competing interests

The authors declare no competing interests.

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