BRIEF ARTICLE

Carbon dioxide accumulation during analgosedated colonoscopy: Comparison of propofol and midazolam

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Abstract

AIM: To characterize the profiles of alveolar hypoventilation during colonoscopies performed under sedoanalgesia with a combination of alfentanil and either midazolam or propofol.

METHODS: Consecutive patients undergoing routine colonoscopy were randomly assigned to sedation with either propofol or midazolam in an open-labeled design using a titration scheme. All patients received 4 μg/kg per body weight alfentanil for analgesia and 3 L of supplemental oxygen. Oxygen saturation (SpO_2) was measured by pulse oximetry (POX), and capnography ($PcCO_2$) was continuously measured using a combined dedicated sensor at the ear lobe. Instances of apnea resulting in measures such as stimulation of the patient, a chin lift, a mask maneuver, or withholding of sedation were recorded. $PcCO_2$ values (as a parameter of sedation-induced hypoventilation) were compared between groups at the following distinct time points: baseline, maximal rise, termination of the procedure and 5 min after termination of the procedure. The number of patients in both study groups who regained baseline $PcCO_2$ values ($\pm$ 1.5 mmHg) five minutes after the procedure was determined.

RESULTS: A total of 97 patients entered this study. The data from 14 patients were subsequently excluded for clinical procedure-related reasons or for technical problems. Therefore, 83 patients (mean age 62 $\pm$ 13 years) were successfully randomized to receive propofol (n = 42) or midazolam (n = 41) for sedation. Most of the patients were classified as American Society of Anesthesiologists (ASA) II [16 (38%) in the midazolam group and 15 (32%) in the propofol group] and ASA III [14 (33%) and 13 (32%) in the midazolam and propofol groups, respectively]. A mean dose of 5 (4-7) mg of IV midazolam and 131 (70-260) mg of IV propofol was used during the procedure in the corresponding study arms. The mean SpO_2 at baseline (%) was 99 $\pm$ 1 for the midazolam group and 99 $\pm$ 1 for the propofol group. No cases of hypoxemia (SpO_2 < 85%) or apnea were recorded. However, an increase in $PcCO_2$ that indicated alveolar hypoventilation occurred in both groups after administration of the first drug and was not detected with pulse oximetry alone. The mean interval between the initiation of sedation and the time when the $PcCO_2$ value increased to more than 2 mmHg was 2.8 $\pm$ 1.3 min for midazolam and 2.8 $\pm$ 1.1 min for propofol. The mean maximal rise was similar for both drugs: 8.6 $\pm$ 3.7 mmHg for midazolam and 7.4 $\pm$ 3.2 mmHg for propofol. Five minutes after the end of the procedure, the mean difference from the baseline values was significantly lower for the propofol treatment compared with midazolam (0.9 $\pm$ 3.0 mmHg *vs* 4.3 $\pm$ 3.7 mmHg, P = 0.0000169), and significantly more patients in the propofol group had regained their baseline value $\pm$ 1.5 mmHg (32 of 41 *vs* 12 of 42, P = 0.0004).

CONCLUSION: A significantly higher number of patients sedated with propofol had normalized $PcCO_2$ values five minutes after sedation when compared with patients sedated with midazolam.

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Key words: Colonoscopy; Deep sedation; Propofol; Hypoventilation; Blood gas monitoring; Transcutaneous

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INTRODUCTION

Colonoscopies are usually performed under sedation with an intravenous sedative that is often combined with an analgesic drug[1,2]. A combination of the benzodiazepine midazolam with an opioid is the most commonly used regimen in Western countries[3]. During the last few years, propofol (2,6-diisopropylphenol) sedation has gained increasing attention among endoscopists as an alternative sedative in GI endoscopy[4-6]. With a fast onset of action of 30-60 s, a distribution half-life of 2-4 min, and a rapid recovery time, propofol combines the major characteristics of an ideal sedative[7].

In recent years, several randomized trials have compared midazolam *vs* propofol with regard to patient safety and satisfaction[4,8-10]. In most studies, recovery time, measured as completely regained alertness after the endoscopic procedure, was used as the main endpoint. Although the advantages of propofol regarding these pharmacokinetic properties are unquestionable, there is still an ongoing debate on the potential respiratory impairment hazards of propofol when used by non-anesthesiologists. In contrast to benzodiazepines, a reversal agent for propofol does not exist; consequently, the use of propofol requires special attention. Furthermore, a deeper level of sedation may be reached with propofol that carries the risk of unintentional deep sedation or even general anesthesia[11,12].

Standard monitoring with pulse oximetry (POX) may miss hypoventilation, which is much better reflected by an increase in arterial carbon dioxide tension[13,14]. Arterial blood gas analysis is the 'gold standard' method to measure the arterial partial pressure of carbon dioxide ($PaCO_2$). However, arterial sampling, including arterial catheterization, is invasive and expensive. Transcutaneous carbon dioxide tension ($PcCO_2$) measurement is used as a noninvasive surrogate measure of $PaCO_2$ and to estimate $PaCO_2$ or determine trend changes in the measurement. Recently, considerable progress has been made in the technical aspects of $PcCO_2$ monitoring. A single earlobe sensor can now measure $PcCO_2$ and pulse oximetry simultaneously. Transcutaneous carbon dioxide tension measurement has been shown to be a reliable monitoring technique that corresponds well with $PaCO_2$ values measured in arterial blood gas samples[15-17].

The aim of this study was to evaluate the profile of $PcCO_2$ as a marker of hypoventilation during sedation with propofol or midazolam in colonoscopies.

MATERIALS AND METHODS

This was an open-labeled, blinded, randomized prospective study. Consecutive outpatients undergoing elective colonoscopy and opting for sedation were randomly assigned to receive propofol or midazolam. The patients were assigned using randomly numbered opaque envelopes. As a standard procedure, all patients received 3 L/min supplemental oxygen and analgesia with 4 μg/kg per body weight (BW) alfentanil (Rapifen®, Janssen-Cilag, Baar, Switzerland) prior to sedation[18]. The first bolus of the sedative drug was administered exactly one minute after the alfentanil. Midazolam (Dormicum®, Hoffmann La Roche AG, Basel, Switzerland) was administered in a first dose of 2 mg; further boluses of 1 mg were administered with an interval of at least 1 min or more depending on the clinical outcome. Propofol (Disoprivan®, AstraZeneca, Zug, Switzerland) was administered in two boluses of 20 mg followed by further boluses of 10 mg after an interval of at least 20 s. The sedative drugs were administered by registered nurses under the supervision of the endoscopist based on the clinical response of the patient; the nurses followed our institutional protocol as published elsewhere (nurse-administered propofol sedation or NAPS)[18]. The nurse administering the sedation had no tasks except to monitor the patient and administer sedation. A different nurse assisted the endoscopist with the technical performance of the procedure. Monitoring consisted of the measurement of continuous oxygen saturation, electrocardiography and heart rate, as well as regular measurements of blood pressure. The primary method of monitoring was the nurse's clinical assessment of the patient, including measurement of respiratory effort by visual assessment and by palpation of the chest wall and abdominal excursion and/or palpation of exhaled breath.

A short personal history was obtained from all the patients, and their general physical condition was assessed using the American Society of Anesthesiologists (ASA) classification. Exclusion criteria were as follows: (1) a known history of intolerance to propofol (including sensitivity to eggs and soybeans); (2) an age less than 18 or more than 85 years; (3) an ASA score of IV or V; (4) a known high grade of aortic (gradient > 80 mmHg) or carotid stenosis (> 75%); and (5) intravenous drug abuse.

All endoscopic examinations were performed according to the department's standard operating procedures with different types of Pentax video colonoscopies (Pentax, Hamburg, Germany) using regular room air to insufflate the colon. The colonoscopies were conducted by seven different expert endoscopists, including four experienced gastroenterologists and three residents in their last year of gastroenterology training, who all had performed more than 400 colonoscopies each. The pro-

cedures were performed in an x-ray suite equipped for fluoroscopy (straightening maneuvers and confirming instrument position when necessary). The decision to perform an ileal intubation or an endoscopic intervention (e.g., polypectomy) depended on the clinical situation and was decided by the endoscopist.

The local ethics committee approved the study protocol, and written informed consent was obtained from the patients before study enrollment.

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We used a recently developed combined POX/ $PcCO_2$ sensor (V-Sign™, Sentec AG, Therwil, Switzerland) weighing 3 g that was placed at the right earlobe with a dedicated ear clip. We used a recently developed combined POX/$PcCO_2$ sensor (V-Sign™, Sentec AG, Therwil, Switzerland) weighing 3 g that was placed at the right earlobe with a dedicated ear clip[17]. This fully digital sensor combines the elements of an electrochemical Severinghaus-type carbon dioxide tension sensor with those of conventional optical POX sensors, thus providing noninvasive and continuous estimation of $PaCO_2$ and SaO_2[19]. The sensor was warmed to a constant surface temperature of 42 ℃ to improve local arterialization and to accelerate carbon dioxide diffusion. After the sensor was positioned, the SpO_2 values were available immediately, whereas the $PcCO_2$ values required an equilibration time of approximately 4-5 min. The system is designed to be "ready-for-use" by automated recalibration every time the sensor is placed on the docking station between measurements. The system was previously shown to deliver accurate and reproducible results for $PcCO_2$ and POX[17]. The system was also shown to have an excellent cor-

relation between oxygen saturation and carbon dioxide measurements when the combined sensor was compared with arterial blood gas analysis[17,20].

Readings from the POX/$PcCO_2$ sensor (placed at the right ear lobe) were continuously recorded and stored on a personal computer. An independent observer who was blinded to the type of sedation recorded the readings. Similarly, the procedural personnel were blinded to the $PcCO_2$ data. All collected data were visualized using statistic graphics software (Igor Pro 4.01, WaveMetrics Inc., Lake Oswego, OR). Values at defined time points were thereafter identified manually. $PcCO_2$ values (as a parameter of sedation-induced hypoventilation) were compared between the study groups at the following distinct time points: at baseline, at the time point of maximal increase, at the time point when the cecum was reached, at the end of the procedure and 5 min after the end of the procedure.

The primary endpoint was defined as the number of patients in both study groups who regained their baseline $PcCO_2$ value (± 1.5 mmHg) five minutes after the end of the procedure. Secondary end points included the mean time lag between the application of the sedative drug and an increase of the $PcCO_2$ curve of more than 2 mm Hg, safety parameters defined as apnea with the need for intervention (in case of a decrease in SaO_2 values below 85% for more than 20 s), the frequency of SaO_2 decreases below 90% and a decrease of the heart rate below 50 bpm. Apnea was defined as a lack of spontaneous respiratory effort for more than 20 s and was assessed clinically by the nurse administrating the sedation. An increase of $PcCO_2$ above the baseline was defined as hypoventilation. The target sedation level was a quiet patient in both of the groups as implemented using our NAPS protocol, which has been in practice at this center for several years. The recovery time for all of the patients was defined as the time required for completion of the procedure, i.e., a complete withdrawal of the instrument and simultaneous conclusion of all sedation. As a standard of practice, the patients were transferred to a quiet recovery room following the final 5-min recording of the $PcCO_2$ readings in the endoscopy suite.

All of the parameters were analyzed using descriptive statistics (mean, standard deviation). Categorical outcomes were analyzed using the χ^2 or F test as appropriate. Continuous parameters were analyzed using an analysis of variance, and for non-continuous parameters, the Mann-Whitney Test was used. $P < 0.05$ was defined as statistically significant. All tests were two-sided. For all statistical calculations, SPSS software (SPSS for Windows, Version 11.0, SPSS Inc., Chiago, Illinois) was used. The sample size calculation was based on the primary outcome of this study of detecting a $PcCO_2$ difference of < 1.5 mmHg from the baseline at 5 min after the end of the procedure in the propofol group. In a pilot study in a similar population, a difference in values between midazolam and propofol was observed in 4 of 26 patients (15.4%). As we expected a clinical/physiological relevant effect, the sample size was determined to detect an ad-

Table 1 Demographic data of the randomized groups

	Sedation with Midazolam ($n = 42$)	Sedation with Propofol ($n = 41$)	*P* value
Age (yr, mean ± SD)	62 ± 13	62 ± 13	NS
M : F (*n*)	19:23	20:21	NS
ASA I	12 (29%)	13 (32%)	NS
ASA II	16 (38%)	15 (37%)	NS
ASA III	14 (33%)	13 (32%)	NS
Smoker	6 (15%)	6 (15%)	NS
Mean dosage of sedative in mg (range)	5 (4-7)	131 (70-260)	-

ASA: American Society of Anesthesiologists classification; NS: Not significant.

Table 2 Oxygen saturation measured by pulse oximetry at baseline and changes during endoscopy according to sedatives

	Midazolam ($n = 42$)	Propofol ($n = 41$)	*P* value
SpO_2 at baseline (%)	99 ± 1	99 ± 1	NS
Mean max decrease of SpO_2 (%)	6 ± 3	4 ± 2	NS

SpO_2: Oxygen saturation measured by pulse oximetry; NS: Not significant.

Table 3 Procedure outcomes according to the defined endpoints (*n*)

	Midazolam ($n = 42$)	Propofol ($n = 41$)	*P* value
$\Delta PcCO_2 < \pm 1.5$ mmHg (from baseline and five min after end)	12	32	0.0004
$SpO_2 < 85\%$	0	0	NS
$SpO_2 < 90\%$	6	0	0.05
HR < 50 bpm	5	1	NS
Decrease MAP > 25%	17	17	NS

HR: Heart rate; MAP: Mean arterial pressure; SpO_2: Oxygen saturation measured by pulse oximetry; $\Delta PcCO_2$: Difference of transcutaneous carbon dioxide tension; NS: Not significant.

ditional increase of 75% in the midazolam group with a power of 80%. Thirty-eight patients in each group would be required to detect such a difference ($P = 0.05$) (nQuery Advisor, Version 5.0, Statistical Solutions, Saugus, MA, United States).

RESULTS

Among the 133 colonoscopies performed during the study period, 97 patients were successfully randomized to the study. Fourteen randomized patients had to be subsequently excluded for the following reasons: in 5 patients, the procedure was not completed because of incomplete bowel preparation; in 5 patients, a short disconnection of the sensor provided no continuous data; in two patients, a calibration fault occurred because of the prototype calibration unit used, and the endoscopist refrained from recalibration; and in two patients, the sedative drug was not correctly administered according to the protocol. Therefore, the final study population contained 83 patients. Demographic characteristics of the study groups are shown in Table 1. The mean duration of the procedures was 26 ± 13 min for the midazolam group and 27 ± 18 min for the propofol group (not significant).

Decreased ventilation activity was detected in all patients to whom a sedative was administered; on average, the $PcCO_2$ values increased by 8.0 ± 3.7 mmHg. The mean SpO_2 values at baseline and the mean maximal decrease during sedation are shown in Table 2.

When comparing midazolam and propofol, different profiles were observed for the $PcCO_2$ readings, as shown in Figure 1. The increase in $PcCO_2$ was mostly related to a short delay in the administration of incremental dosages of the sedatives. The mean time interval after the first application of the drug until the $PcCO_2$ value had increased by more than 2 mmHg was 2.8 ± 1.3 min for midazolam and 2.8 ± 1.1 min for propofol. Although there was no significant difference in the mean increase in $PcCO_2$ following administration of midazolam or propofol, the patients who received midazolam tended to remain in a prolonged state of decreased ventilation when compared with the patients receiving propofol. The difference in $PcCO_2$ values (baseline compared with the end of the procedure) was significantly higher in the patients receiving midazolam. Therefore, the patients who received propofol had a $PcCO_2$ level that was significantly closer to the baseline five minutes after the end of the procedure when compared with the patients who received midazolam (Tables 2, 3, Figure 2).

None of the study patients manifested apnea or hypoxemia below 85%. Drops in oxygen saturation below 90% tended to occur more often during sedation with midazolam than with propofol (Table 3).

DISCUSSION

Achieving higher safety standards for sedation in routine endoscopy has been a priority over the last few years. In keeping with this objective, the present study showed that patients undergoing colonoscopy under sedation developed relative hypoventilation (as reflected by retention of CO_2) that persisted for a significantly longer period in patients sedated with midazolam than in patients sedated with propofol. The results support the findings of a meta-analysis that suggested that propofol sedation during colonoscopy is associated with a lower risk of complications when compared with traditional sedative agents[21].

Although the use of oxygen saturation monitoring during sedation is routinely used by most gastroenterologists and the administration of supplemental oxygen has become a widely accepted practice, little attention has been paid to the development of alveolar hypoventilation[17]. Because of the buildup of CO_2 in the patient's alveoli and blood, hypoventilation can be effectively detected by capnography, which has recently become a focus of interest as an additional monitoring parameter during gastrointestinal procedures. This procedure has become
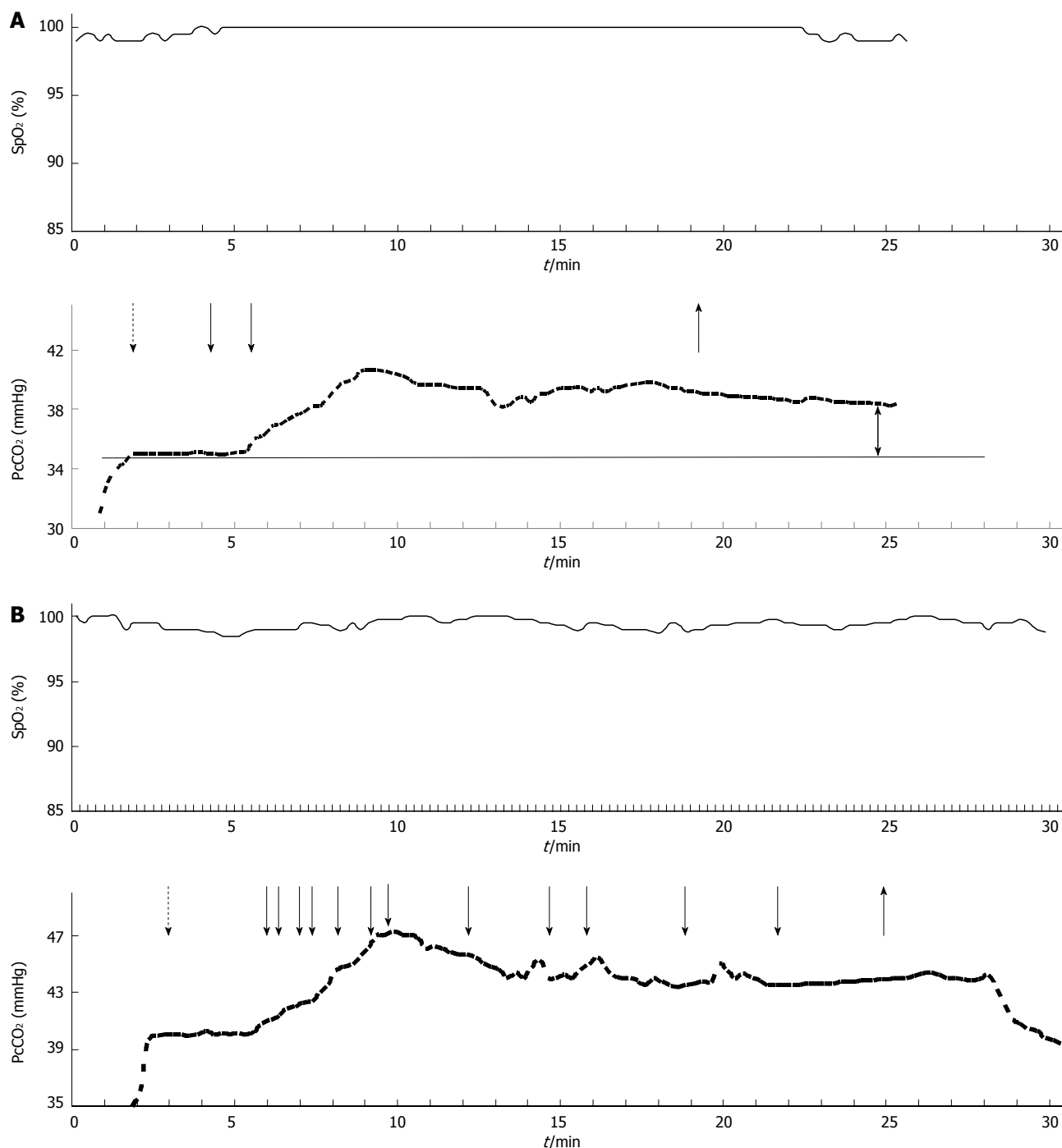
Figure 1 A typical course of oxygen saturation measured by pulse oximetry and transcutaneous carbon dioxide tension following administration of alfentanil (dashed arrow) and midazolam (A) or propofol (B) (solid arrows as indicated). The upright arrow indicates the end of the procedure. The double arrow highlights the difference after termination of the procedure.

relevant as the use of newer anesthetic drugs such as propofol has increased[15].

Several studies to date have evaluated the importance of CO_2 buildup during endoscopic procedures[14-16,22]. Freeman *et al*[15] were the first to show that profound hypoventilation may frequently occur undetected during a gastrointestinal endoscopy, especially if additional oxygen is given and the decline of oxygen saturation is thus prevented; we observed a similar effect in our study. Freeman *et al*[15] also found that the degree of hypoventilation

was more closely related to the sedative drug dose than to the underlying medical illness. In 30 colonoscopies, with 90% receiving fentanyl and 37% additionally receiving midazolam, Freeman *et al*[15] recorded a mean PCO_2 increase of 6.4 ± 3.8 mmHg, whereas during ERCP with a higher rate of deeper sedation, the mean values were 14.2 ± 10.2 mmHg. Our results showed a mean increase in $PcCO_2$ of 8.6 ± 3.7 mmHg despite a continuous SpO_2 above 90%; these results are similar to the experience of Freeman *et al*[15].
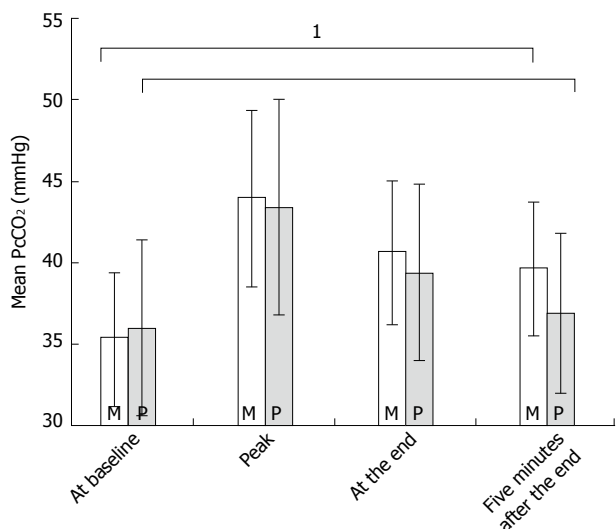
Figure 2 Mean transcutaneous carbon dioxide tension values in mmHg (± SD) at four distinct time points during colonoscopies according to sedative use (for the whole group). [1]A significant difference in the transcutaneous carbon dioxide tension values measured five minutes after the end of the procedure when compared with the baseline values. M: Midazolam; P: Propofol.

The pattern of the registered $PcCO_2$ readings differed noticeably in our study according to the pharmacological properties of the administered drugs. The pattern of the initial rise of $PcCO_2$ was similar, but the $PcCO_2$ level decreased much earlier after the administration of propofol than after the administration of midazolam. Although propofol had to be administered more often in a repeated fashion to maintain the desired sedation level, its effect ceased much faster than the effect of midazolam. This pharmacologic pattern seems to be reflected by the shape of the $PcCO_2$ curve.

We did not observe severe hypoxemia or apnea in either of the study groups; the increase in CO_2 could, however, indicate silent risk during poor sedative practice. In the study by Freeman *et al*[15]. We did not observe severe hypoxemia or apnea in either of the study groups; the increase in CO_2 could, however, indicate silent risk during poor sedative practice. In the study by Freeman *et al*[15], one case demonstrated an increase of the $PcCO_2$ curve above 80 mmHg prior to respiratory arrest. Nelson *et al*[16] showed that the monitoring of $PcCO_2$ may be useful for the endoscopist to guide sedation using midazolam and fentanyl and that this monitoring can help to prevent severe carbon dioxide retention. Thus, we believe that determining the $PcCO_2$ level can be helpful for the endoscopist when deciding whether to administer a further incremental dose of the sedative.

The combination used in this study of alfentanil, which is a potent opioid with a rapid onset of action, and midazolam is uncommon. Typically, this substance alfentanil is administered in combination with propofol for patient-controlled sedation or for short sedoanalgesia in emergency medicine[23]. The rationale to use this substance alfentanil as a single bolus at the beginning of the procedure was (1) to provide the patients with optimal analgesia during the most painful passage of the sigmoid colon; and (2) to determine whether differences in alveolar hypoventilation at the end of the procedure can be completely attributed to the pharmacologic effect of the sedatives. Furthermore, if propofol is used in outpatient procedures, alfentanil may be an ideal drug to use in combination because of its pharmacokinetic properties and analogous profile of action. Because alfentanil (similarly to all opioids) can induce or enhance alveolar hypoventilation, our protocol prescribed a single low dose of 4 μg/kg per BW of alfentanil and a strict time interval of administration one minute before the first titration dose of the sedative was given.

Alveolar hypoventilation exists when the arterial $PaCO_2$ increases above 45 mmHg, which can occur as the result of various underlying factors. Sedation directly or indirectly influences alveolar hypoventilation by a predominant central effect, thereby causing an increase in the $PaCO_2$. Therefore, recognition and adequate monitoring of this physiological change through indirect means such as transcutaneous monitoring of $PcCO_2$ could play an important role during sedation. The peak $PcCO_2$ value may not be clinically relevant; however, the time period during which reduced ventilation occurs may represent a period of increased risk for some patients. Because of the S-shape of the oxygen dissociation-curve, hypoventilation accompanied by a decrease in PaO_2 may remain unnoticed over time. Although a patient would have adequate arterial saturation with the administration of supplemental oxygen, an adverse physiologic trend that may be reflected by changes in the $PaCO_2$ may go unnoticed.

Transcutaneous CO_2 monitoring in adults has yielded conflicting results because of technological limitations, such as the time required for calibration, the need to warm the skin to 42 degrees, the effect of sweating and the influence of skin metabolism and thickness. Technical problems precluded an accurate interpretation of the data in 7 of the 97 patients and thus represent a limitation in our study.

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warm the skin to 42 degrees, the effect of sweating and the influence of skin metabolism and thickness. Technical problems precluded an accurate interpretation of the data in 7 of the 97 patients and thus represent a limitation in our study.

The main focus of this study was to evaluate the impairment of ventilation induced by midazolam or propofol during colonoscopies. Most trials comparing the use of propofol and midazolam in the endoscopy suite have focused on differences in recovery time (assessed using a discharge scoring system, for example)[24]. The present study suggests that there is also a significant difference in the duration of hypoventilation during the postprocedural period. Although alveolar hypoventilation is generally well tolerated by most patients, it may nevertheless be of clinical relevance in patients with compromised health. Iber *et al*[25] showed that in 4% of patients sedated with midazolam, a relevant decrease of oxygen saturation below 89% occurred during the 30 min after the endoscopic procedure, which is contrast to our practical experience with propofol, where the effect occurs exclusively during the time when the attention on the patient is greatest. During the endoscopic procedure, the $PcCO_2$ monitoring indicated no increased hypoventilation risk for propofol when compared with midazolam.

Insufflation of the colon with carbon dioxide (CO_2) rather than air has been shown to reduce pain and discomfort because CO_2 is rapidly absorbed by the intestinal lining. In previous studies, measurement of end tidal CO_2 ($ETCO_2$) and the mean pCO_2 demonstrated these procedures to be safe. However, no studies have used transcutaneous continuous pCO_2 monitoring, which could be valuable given the increasing use of this insufflation technique for pain relief during colonoscopies[26].

A metanalysis by Qadeer *et al*[21] showed that propofol sedation had a lower rate of cardiopulmonary complications than traditional agents used during colonoscopy procedures. This current study highlights another physiological mechanism that may be detrimental when propofol is used in larger cohorts. Therefore, assessing the $PcCO_2$ during sedation could serve as an added safety measure to detect alveolar hypoventilation.

In conclusion, hypoventilation occurs frequently during sedation for colonoscopy and is often undetected during routine pulse oximetry. A significantly higher number of patients sedated with propofol had normalized $PcCO_2$ values five minutes after sedation when compared with patients sedated with midazolam. Understanding the role of CO_2 retention will be important in increasing the further safety standards of sedation during endoscopy. More studies are required to identify and prevent hypercapnia and thus ensure the safe practice of sedation during routine gastrointestinal endoscopies.

ACKNOWLEDGMENTS

COMMENTS

Background
Colonoscopies are usually performed under sedation and monitored by pulse oximetry. With the increasing use of newer sedative agents such as propofol, there is an ongoing discussion about safety and monitoring requirements.

Research frontiers
The surveillance of carbon dioxide tension (e.g., measuring end tidal CO_2 by capnography) could provide more accurate information than pulse oximetry regarding ventilation impairment. Until now, little experience has been reported for transdermal CO_2 measurement systems used for this purpose.

Innovations and breakthroughs
Monitoring studies with capnography showed that hypoventilation and even short apneas that are not detected by pulse oximetry (POX) may occur during endoscopic sedation. However, an increasing body of scientific data shows that sedation during endoscopy with benzodiazepines and propofol is a safe procedure. The development of a new sensor combining transcutaneous carbon dioxide and pulse oximetry measurements provides the opportunity to explore a new monitoring method during endoscopic sedation.

Applications
The study results suggest that hypoventilation occurs often during endoscopic sedation but lasts for a shorter period if patients are sedated with propofol rather than midazolam.

Terminology
$PcCO_2$: Transcutaneous carbon dioxide tension is measured electrochemically using a Severinghaus-type sensor placed on the earlobe; POX: Pulse oximetry measures the oxygen saturation of the blood using an optical sensor.

Peer review
In this study, the authors investigated carbon dioxide accumulation after sedation with propofol or midazolam during colonoscopies. Non-invasive, continuous transcutaneous carbon dioxide tension ($PcCO_2$) monitoring was performed using a recently developed POX/$PcCO_2$ sensor that was placed at the earlobe. The results of the study show that a significantly higher number of patients sedated with propofol had normalized $PcCO_2$ values five minutes after sedation when compared with the patient group sedated with midazolam. The study is well designed and performed, and the POX/$PcCO_2$ sensor could be used in future studies rather than capnography.

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