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Safety of Microstream Capnography Monitoring in Patients Under Sedation for Colonoscopy

Sedasyon Altında Kolonoskopi Uygulanan Hastalarda Mikrostream Kapnograf Monitörizasyonunun Güvenilirliği

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Abstract

Aim: The purpose of this study was to investigate the effectiveness of micro stream capnography in early recognition of adverse events during sedation for colonoscopy.

Methods: This prospective randomized study was performed implemented on 82 adults scheduled for elective colonoscopy. SpO_2, $ETCO_2$ and integrated pulmonary index (IPI) values were measured with the use of micro stream capnography and recorded. Arterial blood gas samples were taken at the beginning, 10^{th} minute and end of the procedure and analyzed.

Results: The correlation between mean values of IPI and mean values of $ETCO_2$, SpO_2 and $PaCO_2$ was not statistically significant. There was a statistically significant correlation between IPI value at the beginning and $PaCO_2$ value at the end of the procedure. Correlation of IPI value at the 10th minute with SpO_2 at the 10^{th} minute and SPO_2 value at the end of the procedure was statistically significant.

Conclusion: Non-invasive $ETCO_2$ monitoring with micro stream capnography is correlated with $PaCO_2$ values in arterial blood gas analysis, which is useful for monitoring of sedation and hypoventilation during colonoscopy procedures. However, IPI monitoring is not of clinical benefit to early recognition of hypoventilation. Non-invasive $ETCO_2$ monitoring with micro stream capnography should be a part of routine monitoring for safe anesthetic practice outside the operating room.

Keywords: Capnography, $EndCO_2$, IPI, micro stream, $PaCO_2$

Öz

Amaç: Bu çalışmanın amacı, kolonoskopi için uygulanan sedasyon sırasında advers olayların erken tanısı için mikrostream kapnografinin etkinliğini araştırmaktır.

Yöntemler: Bu prospektif randomize çalışma, elektif kolonoskopi planlanan 82 yetişkin üzerinde gerçekleştirildi. SpO_2, $EndCO_2$ ve IPI değerleri mikrostream monitör ile ölçüldü ve kaydedildi. Başlangıç, 10. dakika ve işlem sonu arteriyel kan gazı örneği alındı ve analiz edildi.

Bulgular: Entegre pulmoner indeks (IPI) ortalama değerleri ile $EndCO_2$, SpO_2 ve $PaCO_2$ ortalama değerleri arasında istatistiksel olarak anlamlı korelasyon bulunmadı. IPI başlangıç değeri ile $PaCO_2$ prosedür sonu değeri arasında istatistiksel olarak anlamlı bir ilişki saptandı; IPI 10. dakika değerinin, SpO_2 10. dakika ve SpO_2 prosedür sonu değerleriyle karşılaştırılması istatiksel olarak anlamlı bulundu.

Sonuç: Kolonoskopik prosedürler sırasında sedasyon ve hipoventilasyonun izlenmesi için, mikrostream kapnografı ile non-invazif $EndCO_2$ takibi, arteriyel kan gazı örneklerindeki $PaCO_2$ değerleri ile uyumludur. Ancak IPI monitorizasyonu, hipoventilasyonun erken tanınmasında klinik yarar sağlamaz. Operasyon odası dışında güvenli anestezi uygulaması için mikrostream kapnograf ile non-invazif $EndCO_2$ monitorizasyonu rutin izlemenin bir parçası olmalıdır.

Anahtar Sözcükler: Kapnograf, $EndCO_2$, IPI, mikro stream, $PaCO_2$

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Introduction

Recently, sedation for colonoscopy has become a frequent anesthetic practice. Possible hypoxic episodes due to sedation are monitored with pulse-oxymeter saturation (SpO_2) and respiratory depression or apnea is detected with SpO_2 measurement. However, the quality of ventilation monitoring is not satisfactory in patients receiving sedation (1). Carbon dioxide (CO_2) measurements, which can be analysed via arterial blood gas sampling correctly, are the best method to assess alveolar ventilation. However, it is difficult to take several arterial blood samples and biochemically analyse them during a short procedure such as colonoscopy. Therefore, the end-tidal carbon dioxide ($ETCO_2$) monitoring has become the favorite method of carbon dioxide monitoring. It is a continuous and non-invasive method of measuring CO_2. Capnographs are indispensable for expiratory carbon dioxide measurements in the operation theaters. However, these monitors can measure $ETCO_2$ only in intubated patients. Thus, various devices have been developed for monitoring $ETCO_2$ non-invasively in spontaneously breathing patients (2,3).

Micro stream capnograph is a medical device providing continuous monitoring of $ETCO_2$ non-invasively through a nasal sampling line at the patient's bedside (4,5). Micro stream monitor can also assess the Integrated Pulmonary Index (IPI) value which is a mathematically determined factor based on parameters of capnography ($ETCO_2$, respiratory rate) and pulse oximetry (pulse rate and SpO_2). Previously, reliability of this device was studied in critically ill patients with spontaneous breathing, and non-invasive $ETCO_2$ was found to be correlated with arterial blood gas analyses (6,7).

Patients presenting for gastrointestinal endoscopy under sedation may have a high-risk profile and despite many studies to increase the safety of endoscopic procedures, mortality and morbidity associated with cardiopulmonary complications during endoscopic procedures remain a challenge.

In this study, we aimed to investigate the efficacy of micro stream capnography for early recognition of adverse events in patients under sedation for colonoscopy. We assessed the correlation between non-invasive $ETCO_2$ measurement and arterial blood gas analyses and the correlation of IPI with $ETCO_2$, SPO_2 and $PaCO_2$.

Methods

After obtaining approval from the Local Ethics Committee of Şişli Etfal Training and Research Hospital (03.03.2015/883) and verbal and written informed consent from all patients, this prospective randomized study was performed in the gastrointestinal endoscopy unit at our hospital between March and September 2015.

A total of 100 adults aged >18 years, graded as American Society of Anesthesiologists physical status (ASA) I-III, and scheduled for elective colonoscopy were included in the study. Those, who did not want to participate, children, pregnant women, patients with severe cardiac or respiratory insufficiency, neuropsychiatric disorders, alcohol or drug addiction, allergy to anesthetics, peripheral vascular diseases or airway deformities, were excluded from the study.

All patients were inserted an 18-gauge intravenous catheter. No premedication was used. In the procedure room, the patient was placed in the lateral decubitus position. Standard monitoring with electrocardiography, non-invasive systemic blood pressure and pulse oxymeter (SPO_2) was done and heart rate (HR), mean arterial blood pressure (MABP) and SPO_2 values at the baseline were recorded. A nasal sample line (Nasal FilterLine™, Covidien, Colorado, USA) was placed; $ETCO_2$ and respiratory rate (RR) and IPI were measured and recorded with a microstream monitor (CapnoStream™, Covidien, Colorado, U.S.A.). Bispectral Index (BIS) monitoring (BIS monitor™, Covidien, Colorado, U.S.A.) was also performed and baseline value was recorded.

All patients received standard anesthetic induction with 1 $\mu g.kg^{-1}$ fentanyl (Talinat® 0.5 mg/10 mL ampule, VEM, İstanbul, Turkey) and 1.0 mg.kg-1 propofol (Propofol® 1% 10 mL ampule, Fresenius, Uppsala, Sweden). During the procedure, all patients were given additional 0.5 $mg.kg^{-1}$ dose of propofol, when necessary, to maintain the Ramsey Sedation Score (RSS) between 3 and 4.

Immediately after sedation a radial arterial cannula was inserted. Beginning arterial blood gas sample was taken and analysed at the beginning of the procedure. Two more samples were taken at the 10^{th} minute and at the end of the procedure. pH, PaO_2, $PaCO_2$, SO_2, HCO_3 and base excess values were recorded. HR, MABP, SPO_2, RSS, BIS, $ETCO_2$, IPI and RR were recorded synchronously with arterial blood gas samplings. The correlation of IPI values with patient status are shown in Table 1.

Table 1. Patient status according to Integrated Pulmonary Index (IPI)

10	Normal
8-9	Within normal range
7	Close to normal range; requires attention
5-6	Requires attention and may require intervention
3-4	Requires intervention
1-2	Requires immediate intervention

Oxygen insufflation was done with oxygen flowing at 2 L/min via nasal prongs in patients with a SPO_2<90% and these patients were recorded.

Anesthesia time was the time from anesthetic induction to recovery. Endoscopy time was defined as the time from endoscopy start to endoscopy completion. Recovery time was the time from the end of endoscopy until patient's recovery to RSS 2.

Patients who achieved an Aldrete score of 9 were discharged.

The total propofol dose was calculated and recorded. Allergic reactions, which were observed during the procedure, bradycardia (HR<50 beats per min), tachycardia (20% increase in HR), hypotension (MABP <60 mmHg), hypertension (20% increase in MABP), respiratory depression, desaturation (SPO_2<90%), hypoventilation (>20% reduction in $ETCO_2$ compared with baseline value), nausea, vomiting, hemorrhage and perforation were recorded.

Results

A total of 82 patients were included in this study. Fail arterial cannulation, clotted blood sample and discontinuation of colonoscopy due to inadequate colon cleansing were the reasons for exclusion of 18 patients.

The male-to-female ratio was 42/40; 34 patients were graded as ASA I, 36 patients - ASA II and 12 patients - ASA III. Demographic characteristics of the patients are shown in Table 2.

Variations in HR, SpO_2, MABP and $ETCO_2$ at three times analysis were statistically significant (p<0.001). $ETCO_2$ measurements at the 10th minute and end of the procedure were statistically significantly higher compared to that at the beginning of the procedure (p=0.002) (p=0.005). There was no statistically significant difference between $ETCO_2$ measurements at the 10th minute and end of the procedure (p=0.416). IPI values at the beginning, 10th minute and at the end of the procedure were not statistically different (p=0.152).

Bispectral index (BIS) value was statistically significantly decreased at the 10th minute and end of the procedure compared to that at the beginning of the procedure (p<0.001) (Table 3).

Table 2. Demographical data

	Minimum-Maximum	Mean ± SD
Age (years)	23-86	51.04±12.42
Weight (kg)	50-100	71.78±11.19
Anesthesia duration (min)	14-30	20.82±4.35
Endoscopy duration (min)	13-27	19.3±4.51
Recovery period (min)	2-6	3.56±1.11
Propofol consumption (mg)	70-240	107.01±33.51

SD: Standard deviation, min: Minute

RSS scores were statistically significantly different than the baseline values (p<0.001). There was no statistically significant difference between baseline and 10th minute RSS scores and between RSS scores at the10th minute and end of the procedure. There was a statistically significant difference between baseline RSS score and that at the end of the procedure (p=0.001).

Correlations in pH, PaO_2, $PaCO_2$, HCO_3 and SpO_2 were statistically significant (Table 4).

No statistically significant difference was determined in $PaCO_2$ and $ETCO_2$ between all measurements (Table 5).

The correlation between the mean IPI value and the mean $ETCO_2$, SpO_2 and $PaCO_2$ values was not statistically significant (Table 6).

There was a statistically significant correlation between baseline IPI value and $PaCO_2$ value at the end of the procedure; IPI value at the 10th minute and SpO_2 value at the 10th minute; IPI value at the 10th minute and SPO_2 value at the end of the procedure (Table 7).

Desaturation was observed in three patients and treated with oxygen supplement. Hypotension was observed in nine patients; five patients received fluid and ephedrine intravenously and four patients received fluid replacement. Bradycardia was observed in the presence of hypotension. $ETCO_2$ measurement revealed hypoventilation in nine patients while IPI levels under 7 were recorded in four patients. Arterial blood gas $PaCO_2$ showed hypoventilation in 13 patients. Complication associated with the procedure was not observed in any patient.

Statistical Analysis

For statistical analysis, NCSS (Number Cruncher Statistical System) 2007 (Kaysville, Utah, USA) program was used. Study data was evaluated with descriptive statistical methods (mean, standard deviation, median, frequency, percentage minimum, maximum). Quantitative data in normal distribution was compared with the repeated measures ANOVA. Correlation between the variables was evaluated with Pearson's correlation coefficient. A p value of less than 0.01 or 0.05 was considered statistically significant.

Discussion

Recently $ETCO_2$ measuring has become a part of routine monitoring and capnographs are commonly used in operation theaters and intensive care units (7-9). Capnographic monitoring also prevents redundant blood gas analyses, thus reduces unnecessary costs (9).

Table 3. Hemodynamical data			
Heart Rate	**Minimum/ Maximum**	**Mean ± SD**	**[a]p**
Beginning	53/123	85.87±12.36	<0.001**
10th minute	55/109	77.90±9.41	
End	54/111	78.28±9.69	
Difference			**[b]p**
Beginning-10th minute	-47/27	-7.97±11.49	<0.001**
Beginning-end	-46/29	-7.59±11.28	<0.001**
10th minute-end	-15/25	-0.38±5.28	0.525
SPO_2	**Minimum/ Maximum**	**Mean ± SD**	**[a]p**
Beginning	93/100	98.01±1.64	<0.001**
10th minute	87/100	94.24±2.16	
End	90/100	95.19±2.00	
Difference			**[b]p**
Beginning-10th minute	-13/2	-3.77±2.55	<0.001**
Beginning-end	-9/2	-2.82±2.24	<0.001**
10th minute-end	-9/3	-0.94±1.65	<0.001**
MABP	**Minimum/ Maximum**	**Mean ± SD**	**[a]p**
Beginning	51/134	86.44±15.65	<0.001**
10th minute	50/138	77.90±14.18	
End	46/167	78.89±16.42	
Difference			**[b]p**
Beginning-10th minute	-59/18	-8.54±13.47	<0.001**
Beginning-end	-53/43	-7.56±15.59	<0.001**
10th minute-end	-34/39	-0.98±11.36	0.442
END CO_2	**Minimum/ Maximum**	**Mean ± SD**	**[a]p**
Beginning	26/44	36.11±3.25	0.001**
10th minute	30/50	37.62±3.83	
End	29/50	37.32±3.51	
Difference			**[b]p**
Beginning-10th minute	-12/11	1.51±4.21	0.002**
Beginning-end	-8/13	1.20±3.66	0.005**
10th minute-end	-9/12	0.30±3.29	0.416
IPI	**Minimum/ Maximum**	**Mean ± SD**	**[a]p**
Beginning	6/10	9.33±0.97	0.152
10th minute	4/10	9.03±1.27	
End	5/10	9.00±1.24	
BIS	**Minimum/ Maximum**	**Mean ± SD**	**[a]p**
Beginning	96/100	98.49±1.14	<0.001**
10th minute	46/77	60.70±6.44	
End	49/88	67.82±5.99	

Table 3. Continued			
Difference			**[b]p**
Beginning-10th minute	-53/-21	-37.80±6.37	<0.001**
Beginning-end	-50/-12	-30.67±5.98	<0.001**
10th minute-end	-33/7	-7.13±6.12	<0.001**

SD: Standard deviation, SPO_2: Saturation, MABP: Mean arterial blood pressure, End CO_2: End tidal carbondioxide, IPI: Integrated pulmonary index, BIS: Bispectral index
p<0.05 is statistically meaningful; [a]Repeated Measures ANOVA, [b]Paired samples t test

Non-invasive devices have been developed to monitor $ETCO_2$ values in spontaneously breathing patients. These are usually used in intensive care units to monitor $ETCO_2$ in patients receiving non-invasive mechanical ventilation (10-12). One of them is micro stream capnography, which measures $ETCO_2$ and IPI values through a nasal cannula (6).

Sedation is given in the endoscopy units for gastroscopy and colonoscopy procedures and patient's recovery is usually monitored with SpO_2 (8). $ETCO_2$, which is the most important value in assessing ventilation, is not monitored routinely during sedation. Most recent guidelines do not recommend a routine use of capnography during endoscopic sedation (6). Anesthesia outside the operating room is difficult to practice. To make anesthetic procedures safer, some questions need to be answered: Should $ETCO_2$ routinely be monitored? To what degree are the measurements correlated with arterial blood gas analyses? Is IPI value is predictive of hypoventilation? In this study, the answers to these questions were investigated on patients monitored with micro stream capnograph during colonoscopy.

Arterial blood gas analyses in endoscopic procedures with or without sedation to evaluate oxygenation and ventilation showed no variations in $PaCO_2$ values in patients under sedation, but a decrease in PaO_2 values. This decrease was of short duration and recovered to the baseline value. In the literature all studies were conducted in upper gastrointestinal system endoscopy and under benzodiazepine sedation (13-15). However, propofol is commonly used for sedation in colonoscopy procedures today. However, propofol has respiratory depressant effects (16).

Despite increasing efforts to increase the safety of endoscopic procedures, mortality and morbidity associated with cardiopulmonary complications during endoscopic procedures remain a challenge. In this study, we measured $ETCO_2$ and IPI values with micro stream capnography, which has advanced technology and works even with very low tidal volumes such as 50 mL without trapping moisture and water. We aimed to investigate the safety of endoscopic procedures monitored by micro stream capnography.

Table 4. Data of arterial blood gas analysis			
Ph	**Minimum/ Maximum**	**Mean ± SD**	**[a]p**
Beginning	7.31/7.43	7.36±0.02	0.018*
10th minute	7. 30/7.47	7.36±0.02	
End	7.31/7.45	7.36±0.02	
Difference			**[b]p**
Beginning-10th minute	-0.08/0.06	-0.01±0.02	0.011*
Beginning-end	-0.07/0.07	0.00±0.02	0.185
10th minute-end	-0.03/0.03	-0.003±0.013	0.052
PO_2 (mmHg)	**Minimum/ Maximum**	**Mean ± SD**	**[a]p**
Beginning	56/200	93.22±21.22	<0.001**
10th minute	53.9/138	84.60±16.24	
End	62.7/201.7	93.24±20.68	
Difference			**[b]p**
Beginning-10th minute	-128.6/39	-8.63±20.86	<0.001**
Beginning-end	-43.2/71.6	0.02±16.01	0.991
10th minute-end	-130/32.8	-8.65±20.72	<0.001**
$PaCO_2$ (mmHg)	**Minimum/ Maximum**	**Mean ± SD**	**[a]p**
Beginning	33/56.8	41.34±3.88	0.001**
10th minute	34.3/58	42.87±4.04	
End	34/56	42.46±3.86	
Difference			**[b]p**
Beginning-10th minute	-8/15	1.53±3.39	<0.001**
Beginning-end	-10.6/13	1.12±3.70	0.009**
10th minute-end	-8/9.20	0.42±3.52	0.298
HCO_3	**Minimum/ Maximum**	**Mean ± SD**	**[a]p**
Beginning	19.5/28.8	24.83±1.37	0.174
10th minute	19.9/28.0	24.44±1.55	
End	19.7/27.0	24.39±1.39	
Difference			**[b]p**
Beginning-10th minute	-3.4/1.8	-0.16±0.92	0.120
Beginning-end	-3.0/1.5	-0.11±0.74	0.174
10th minute-end	-3.0/2.8	0.05±0.87	0.617
BE	**Minimum/ Maximum**	**Mean ± SD**	**[c]p**
Beginning	-6/2	-0.78±1.40 (-1.0)	0.854
10th minute	-5/2	-0.84±1.41 (-1.0)	
End	-5/2	-0.78±1.43 (-1.0)	
Difference			**[d]p**
Beginning-10th minute	-2/2	0.06±0.75	0.431
Beginning-end	-2/3	0.00±0.83	0.950
10th minute-end	-2/2	-0.06±0.80	0.452

Table 4. Data of arterial blood gas analysis			
Blood SPO_2	**Minimum/ Maximum**	**Mean ± SD**	**[a]p**
Beginning	90/99.8	96.71±1.80	<0.001**
10th minute	84.5/99.4	95.33±2.93	
End	92/99.2	96.39±1.57	
Difference			**[b]p**
Beginning-10th minute	-11.3/7.6	-1.38±3.33	<0.001**
Beginning-end	-7/7	-0.32±2.28	0.214
10th minute-end	-14.1/4.5	-1.06±3.09	0.003**

SD: Standard deviation; SPO_2, Saturation
p<0.05 is statistically meaningful; [a]Repeated measures ANOVA. [b]Paired samples t-test. [c]Friedman test. [d]Wilcoxon signed rank test

Table 5. Accuracy of $PaCO_2$ and end CO_2 values			
$PaCO_2$ - End CO_2 difference	**Minimum/ Maximum**	**Mean ± SD**	**p**
Beginning	-2.60/18.8	5.22±4.26 (5,10)	0.802
10th minute	-4/16.8	5.25±4.98 (5,0)	
End	-5/18.1	5.13±3.85 (5,0)	

SD: Standard deviation
P<0.05 is statistically meaningful; Friedman test

Table 6. Correlation between mean values of IPI and mean values of $EndCO_2$. SpO_2 and $PaCO_2$		
	Mean IPI values	
	rho	**p**
Mean SpO_2	0.180	0.106
Mean end CO_2	0.124	0.269
Mean $PaCO_2$	-0.092	0.412

IPI: Integrated Pulmonary Index

There have been different studies examining the efficiency of micro stream capnography conducted in different age groups and intubated and extubated patients (10,17,18).

There are few studies in the literature investigating $ETCO_2$ measurements with microstream during endoscopic procedures. These studies were mostly conducted on patients who underwent upper gastrointestinal endoscopy (4,5,11).

In their study including 163 children undergoing 174 elective gastroinstestinal procedures, Lightdale et al. (11) randomized the patients to micro stream capnography and control groups. Endoscopy staff, who were blinded to additional capnography monitoring, reported poor ventilation in 3% of all procedures and no apnea, whereas capnography indicated alveolar hypoventilation and apnea during 56% and 24% of the procedures, respectively. The researchers concluded that sedation for endoscopy was safer with capnograph monitoring.

Table 7. Correlation of IPI values with SpO_2, End CO_2 and $PaCO_2$

	IPI Beginning		IPI 10th minute		IPI End	
	rho	p	rho	p	rho	p
SpO_2 Beginning	-0.024	0.829	0.073	0.518	-0.036	0.746
SpO_2 10th minute	-0.010	0.927	0.334	0.002**	0.079	0.487
SpO_2 End	0.045	0.688	0.246	0.028*	0.179	0.107
End CO_2 Beginning	0.187	0.093	0.219	0.051	0.136	0.222
End CO_2 10th minute	-0.071	0.531	0.166	0.142	0.178	0.115
End CO_2 End	-0.077	0.494	0.028	0.806	0.090	0.421
$PaCO_2$ Beginning	0.073	0.512	-0.079	0.485	-0.168	0.131
$PaCO_2$ 10th minute	-0.056	0.623	-0.119	0.298	-0.016	0.891
$PaCO_2$ End	0.266	0.016*	-0.012	0.919	-0.069	0.539

IPI: Integrated Pulmonary Index

Yarchi et al. (4) measured $ETCO_2$ with the micro stream capnography in patients who received either general anesthesia or sedation for endoscopic procedures and underlined the importance of $ETCO_2$ monitoring especially in upper gastrointestinal procedures under general anesthesia.

Qadeer et al. (5) monitored $ETCO_2$ with the micro stream capnography in patients undergoing endoscopic retrograde cholangiopancreatograpy and endoscopic ultrasonography. They concluded that capnography monitoring improves patient safety during procedural sedation for endoscopy by reducing the frequency of respiratory depression.

Kugelman et al. (17) assessed correlation of capnographic $ETCO_2$ measured with micro stream and arterial blood gas $PaCO_2$ in premature infants ventilated with high frequency ventilation. The study results indicated correlation and feasibility of microstream capnography.

Casati et al. (10) conducted a similar study in adults, who underwent orthopedic or vascular surgery under general anesthesia, and compared $ETCO_2$ and $PaCO_2$ between intubated ventilated and spontaneously breathing non-intubated patients. The $ETCO_2$ and $PaCO_2$ values showed a perfect correlation in both groups as no significant difference was observed in $ETCO_2$ and $PaCO_2$ between intubated (7.3±4 mmHg) and non-intubated (6.5±4.8 mmHg) patients. Micro stream capnographical $ETCO_2$ showed a closer correlation to $PaCO_2$ in spontaneously breathing non-intubated patients. In our study this difference was 5.22±4.26 mmHg at the beginning, 5.25±4.98 mmHg at the 10th minute and 5.13±3.85 mmHg at the end of sedation in our spontaneously breathing non-intubated patients. These data were not statistically significantly different, which indicates safety of $ETCO_2$ monitoring with micro stream capnography.

Singh et al. (19) reported microstream capnograph monitoring also to be easy to use during interhospital transport of intubated critically ill children, because the monitor had low weight, long battery life, audiovisual alarms, quantitative and graphic real-time detection of $ETCO_2$ (20). Besides, micro stream capnography monitoring was also safe in confirming proper endotracheal tube positioning. Our study was realized outside the operating room. This is why easy transport of the monitor and also easy usage were very important.

A small number of studies reported that accurate $ETCO_2$ measurements could not be done in non-intubated patients who received general anesthesia (21-22).

Cheng et al. (22) compared patients receiving general anesthesia with controlled ventilation and patients receiving total intravenous anesthesia with spontaneous breathing through the normal airway during gynecologic laparoscopic surgery and recorded $ETCO_2$ and $PaCO_2$ values at different time intervals and positions. $ETCO_2$ was sampled through a suction catheter inserted into the nasopharynx. The results of this study showed that $ETCO_2$ and $PaCO_2$ values were correlated during the first 20 minutes after the change to the Trendelenburg position, but afterwards, $PaCO_2$ monitoring was still necessary. This study indicated that patient's position during capnographic monitoring may be important. In our study, we had relatively precise correlation between the measurements. This may be a result of a lateral decubitis position given to all patients. However, $ETCO_2$ sampling and monitoring should also be considered. We used a nasal sampling line belonging to the microstream capnograph monitor, which may also be helpful to achieve precise measurements.

Bower et al. (23) evaluated sedation depth during endoscopic procedures by measuring BIS and Observer's Assessment of Alertness/Sedation which were correlated to each other. A BIS level near 82 was sufficient for sedation. BIS monitoring can inform the anesthesiologist about the patient's sedation status objectively. In our study, we evaluated the sedation depth using both the RSS and BIS. The mean RSS score was 4 and BIS was 60.7±6.44. Our sedation depth was quite sufficient for colonoscopical examination and the colonoscopist was satisfied.

IPI was presented as a factor combining the best of all monitoring techniques to based on parameters of capnography and pulse oximetry. The use of IPI in monitoring

patients under sedation was questioned in recent studies. In their study, Berkenstandt et al. (24) observed only a limited agreement between respiratory physiological parameters and IPI. Riphaus et al. (6) evaluated clinical value of IPI during sedation for interventional upper GI-endoscopy and concluded that IPI monitoring does not add significant clinical benefit to standard monitoring. On the contrary, Garah et al. (25) in their study on 109 pediatric patients undergoing mainly upper endoscopy under sedation found that IPI had a high sensitivity in predicting apnea episodes and hypoxia events. In our study, IPI values were correlated with $ETCO_2$, SpO_2 and $PaCO_2$ values.

In our study, desaturation was observed in three patients. These patients were treated with oxygen supplement. Micro stream capnography was useful in detection of hypoventilation in nine patients. We observed that an IPI of <7 in four of our patients correlated with 10^{th} minute SpO_2 values. We believe that desaturation was rarely observed in our patients in comparison with hypoventilation because of short duration of sedation. In case of long duration of anesthesia outside the operating room, hypoventilation may occur more frequently. In such patients, the use of micro stream capnography may play an important role in preventing and decreasing hypoxic events. In our study, IPI monitoring did not add a clinical benefit to early recognition of hypoventilation.

Conclusion

In conclusion, even if IPI monitoring does not add a clinical benefit to early recognition of hypoventilation, we believe that non-invasive $ETCO_2$ monitoring with micro stream capnography is useful for monitoring sedation and hypoventilation during colonoscopy procedures and it was found to be well correlated with $PaCO_2$ values in arterial blood gas sampling. This study shows that non-invasive $ETCO_2$ monitoring with micro stream capnography should be a part of routine monitoring for safe anesthetic practice outside the operating room.

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Authorship Contributions

Surgical and Medical Practices: S.O., H.Ş.T., C.T.I., P.S., L.K. Concept: S.O., H.Ş.T., C.T.I., P.S., L.K. Design: S.O., H.Ş.T., C.T.I., P.S., L.K. Data Collection or Processing: S.O., H.Ş.T., C.T.I., P.S., L.K. Analysis or Interpretation: S.O., H.Ş.T., C.T.I., P.S., L.K. Literature Search: S.O., H.Ş.T., C.T.I., P.S., L.K. Writing: S.O., H.Ş.T., C.T.I., P.S., L.K.

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