Accepted Manuscript online: 2023-03-06 Article published online: 2023-05-09

Invasive CO_2 monitoring with arterial line compared to end tidal CO_2 during peroral endoscopic myotomy*

Authors

Rodrigo Duarte-Chavez[1], Amy Tyberg[1], Avik Sarkar[1], Haroon M. Shahid[1], Bhargav Vemulapalli[1], Sardar Shah-Khan[1], Monica Gaidhane[1], Michel Kahaleh[1]

Institutions

1 Robert Wood Johnson Medical School, Rutgers University, New Brunswick, New Jersey, United States

submitted 8.9.2022
accepted after revision 10.2.2022
published online 6.3.2023

Bibliography
Endosc Int Open 2023; 11: E468–E473
DOI 10.1055/a-2048-1312
ISSN 2364-3722

Georg Thieme Verlag KG, Rüdigerstraße 14, 70469 Stuttgart, Germany

Corresponding author
Michel Kahaleh, MD, Distinguished Professor of Medicine, Chief of Endoscopy, Rutgers Robert Wood Johnson Medical School, 51 French Street, MEB 479, New Brunswick, NJ 08901
Fax: +1-732-235-7307
mkahaleh@gmail.com

ABSTRACT

Background and study aims Peroral endoscopic myotomy (POEM) has become a recognized treatment for achalasia. The technique requires CO_2 insufflation. It is estimated that the partial pressure of CO_2 ($PaCO_2$) is 2 to 5 mm Hg higher than the end tidal CO_2 ($etCO_2$), and $etCO_2$ is used as a surrogate for $PaCO_2$ because $PaCO_2$ requires an arterial line. However, no study has compared invasive and noninvasive CO_2 monitoring during POEM.

Patients and methods Seventy-one patients who underwent POEM were included in a prospective comparative study. $PaCO_2$ plus $etCO_2$ was measured in 32 patients (invasive group) and $etCO_2$ only in 39 matched patients (noninvasive group). Pearson correlation coefficient (PCC) and Spearman's Rho were used to calculate the correlation between $PaCO_2$ and $ETCO_2$.

Results $PaCO_2$ and $ETCO_2$ were strongly correlated: PCC R value: 0.8787 $P \leq 0.00001$, Spearman's Rho R value: 0.8775, $P \leq 0.00001$. Within the invasive group, the average difference between $PaCO_2$ and $ETCO_2$ was 3.39 mm Hg (median 3, standard deviation 3.5), within the 2- to 5-mm Hg range. The average procedure time (scope in to scope out) was increased 17.7 minutes ($P = 0.044$) and anesthesia duration was 46.3 minutes. Adverse events (AEs) included three hematomas and one nerve injury in the invasive group and one pneumothorax in the noninvasive group. There were no differences in AE rates between the groups (13 % vs 3 % $P = 0.24$).

Conclusions Universal $PaCO_2$ monitoring contributes to increased procedure and anesthesia times without any decrease in AEs in patients undergoing POEM. CO_2 monitoring with an arterial line should only be performed in patients with major cardiovascular comorbidities; in all other patients, $ETCO_2$ is an appropriate tool.

Introduction

Achalasia is a motor disorder of the esophagus characterized by impaired relaxation of the lower esophageal sphincter, as a consequence of the loss of myenteric neurons. There are multiple options available for its treatment, including medications, pneumatic balloon dilation, and surgical myotomy [1, 2]. POEM is an endoscopic technique that evolved from the concept of natural orifice transluminal endoscopic surgery. The procedure involves the creation of a submucosal tunnel and then myotomy of the muscular fibers of the distal esophagus, including the lower esophageal sphincter. First described in humans more than a decade ago, the reported safety and clinical efficacy of this treatment modality in all types of achalasia, as

* Digestive Disease Week: This study was presented as an abstract during DDW 2022

well as in other spastic disorders of the esophagus, has been well demonstrated [3, 4].

Carbon dioxide (CO_2) insufflation is a crucial component of third space endoscopy, and permits work in the submucosal space with less risk of barotrauma because it is reabsorbed faster than air [3, 5]. Controlled or minimized CO_2 insufflation during the creation of the submucosal tunneling, as well as during the myotomy, can still be associated with complications [6]. The recognition and treatment of the physiological changes that occur as a consequence of CO_2 is of utmost importance to improve patient safety. End tidal CO_2 ($ETCO_2$) offers an acceptable estimate of alveolar CO_2 measured as arterial CO_2 (PaCO2) [7], and is recommended as a surrogate for $PaCO_2$ in most patients, although its reliability can be compromised in patient with pulmonary diseases [7, 8].

$PaCO_2$ provides the most accurate evaluation of alveolar CO_2 but requires the presence of an arterial line. Interestingly, no study has evaluated whether there are any differences between invasive and noninvasive CO_2 monitoring during POEM. The aim of our study was to elucidate if the use of an arterial line with direct measurement of $PaCO_2$ was of any benefit, when compared to only $ETCO_2$.

Patients and methods

Patient population

A prospective comparative study was performed in our institution. Information on all patients 18 years or older who underwent POEM for the treatment of achalasia and were able to provide consent was included in a prospectively collected database. Information on patients with known pulmonary disease or advanced cardiovascular disease was excluded. A total of 71 patients were included in the study. In the group in which $PaCO_2$ plus ETCO2 was measured, also known as invasive group, included 32 patients, an arterial line was placed prior to starting the POEM and the $PaCO_2$ was checked on average every 28 minutes. The group in which only $ETCO_2$ was measured, also known as the noninvasive group, included 39 matched patients. $ETCO_2$ was recorded every 12 minutes on average in both groups.

Periprocedure details

All the patients at our institution require a thorough evaluation before a diagnosis of achalasia is made, which includes a history and physical focusing on the Eckardt score, esophagogastroduodenoscopy, high-resolution manometry and endoluminal impedance measurement. Absolute contraindications for POEM are severe coagulopathy unable to be reversed as well as end-stage cirrhosis with sequelae of portal hypertension such as esophageal or gastric varices.

After the decision has been made for POEM, patients are placed on a full liquid diet for 2 days prior to the procedure, and then nil per os (NPO) for at least 8 hours. Preprocedurally patients are given a high-dose proton pump inhibitor (PPI), scopolamine patch and ondansetron to prevent nausea as well as prophylactic antibiotics, usually a quinolone.

The procedure is performed under general anesthesia with endotracheal intubation, paralytics are usually administered throughout the procedure, and pressure-controlled ventilation is favored over volume-controlled ventilation. In the pediatric population, the available evidence about the best anesthetic practices for POEM is scarce, and usually management is driven by the available data from adult patients [9]. The patient is placed in the supine position, and the endoscopist performs the procedure at the head of the bed, which allows for continuous visualization of the patient's abdomen to monitor for the development of capnoperitoneum [10]. A high-definition gastroscope is required, with 4-mm transparent cap attached to the distal end. Several endoscopic knives and an electrosurgical generator are used for dissection; however, a hybrid knife (ERBE, Marietta, Georgia, United States) is preferred to allow simultaneous injection and dissection. A posterior approach is usually chosen for dissection and myotomy, and submucosal injection is performed using a solution consisting of normal saline and methylene blue. A coag gasper (Olympus, Center Valley, Pennsylvania, United States) is used to prevent or treat bleeding. CO_2 is used for insufflation with an insufflator with adjustable output flow rate ranging from ultralow to high (ERBE). Medium flow is used before tunneling and then is switched to low during submucosal dissection and myotomy; if there is persistent elevation of CO_2 on $ETCO_2$, the flow is switched to ultralow. There is also continuous communication with the anesthesia team and the respiratory rate is also increased to decrease the CO_2. When there is persistent CO_2 elevation along with elevated peak pressure despite the aforementioned measures, the neck, chest and abdomen are examined to look for signs of CO_2 extravasation at those sites. When there is significant abdominal distention, suctioning of the stomach is performed using the endoscope, and then percutaneous needle decompression of pneumoperitoneum is carried out with a 14G needle to decrease the level of CO_2 on $ETCO_2$. If there is persistent elevation of CO_2, the procedure is temporarily stopped until the CO_2 on $ETCO_2$ drops below 40 mm Hg. After the myotomy is performed, the tunnel can be lavaged with diluted gentamycin on a case-by-case basis. Finally, the tunnel is closed using endoscopic clips or endoscopic suturing.

Patients are extubated post procedure and recover in the postprocedure area of the endoscopy unit. Most of our patients are admitted to the hospital 1 night for observation and kept NPO until a gastrografin esophagram is performed the next day to rule out contrast extravasation. After a negative study, a clear liquid diet is started and if the diet is tolerated, patients are discharged home on antibiotics to complete 5 days of treatment. High-dose PPI and antiemetics are continued on discharge. Patients continue a clear liquid diet for 3 days, and then transition to a full liquid diet for another 3 days and then a soft diet, which is advanced as tolerated.

Statistical analysis

Data were captured in a registry (NCT05051358) deemed exempt by WCG IRB (February 17, 2021).

Information on demographics, procedural details, post-procedure outcomes, and adverse events (AEs) was collected and

▶ **Table 1** Demographics of both groups, $PaCO_2$ plus $ETCO_2$ and $ETCO_2$ only.

Groups	**$PaCO_2$ + $ETCO_2$ group**			**$ETCO_2$ only group**		
Cases	N = 32			N = 39		
Males/females	14/18 (44 %/56 %)			15/24 (38 %/62 %)		
Age (standard deviation)	54.41 mean (16.04)			58.6 mean (19.44)		
Esophageal myotomy	13 cm mean			13 cm mean		
Gastric myotomy	3 cm mean			3 cm mean		
Achalasia subtypes	I n = 10 (31 %)	II n = 17 (53 %)	III n = 5 (16 %)	I n = 12 (31 %)	II n = 21 (54 %)	III n = 6 (15 %)
Severe tortuosity/sigmoid esophagus	3 %			5 %		

$PaCO_2$, partial pressure of CO_2, $ETCO_2$, end tidal CO_2.

▶ **Table 2** Comparison between both groups, $PaCO_2$ plus $ETCO_2$ and $ETCO_2$ only.

Groups	**$PaCO_2$ + $ETCO_2$ group**			**$ETCO_2$ only group**			***P* value**
Cases	N = 32			N = 39			
Males/females	14/18			15/24			
	Average	Median (range)	SD	Average	Median (range)	SD	
Procedure time in minutes (scope in and out)	96.7	80 (50 to 291)	50.7	79	70 (22–172)	33.2	0.04
Age	54.41	58 (22–88)	16.04	58.6	63 (18–94)	19.44	0.33
pH	7.37	7.38 (7.22 to 7.5)	0.064	N/A	N/A	N/A	
$PaCO_2$ (mm Hg)	41.23	41 (26 to 64)	7.3	N/A	N/A	N/A	
$PaCO_2$ frequency in minutes	Every 28	Every 27 (14.5 to 56)	7.8	N/A	N/A	N/A	
$ETCO_2$ (mm Hg)	37.8	38 (26 to 60)	5.6	36.7	37 (27 to 48)	4.21	0.27
$ETCO_2$ frequency in minutes	Every 12.3	Every 11.6 (4.9 to 29.2)	4.9	Every 11.9	Every 12.8 (3 to 14.5)	3.6	0.74
Adverse event	13 % (3 hand hematoma, 1 nerve injury)			3 % (1 pneumothorax[1])			0.24

$PaCO_2$, partial pressure of CO_2, $ETCO_2$, end tidal CO_2; SD, standard deviation; N/A, not applicable.
[1] Inadvertent use of air instead of CO_2 during the procedure.

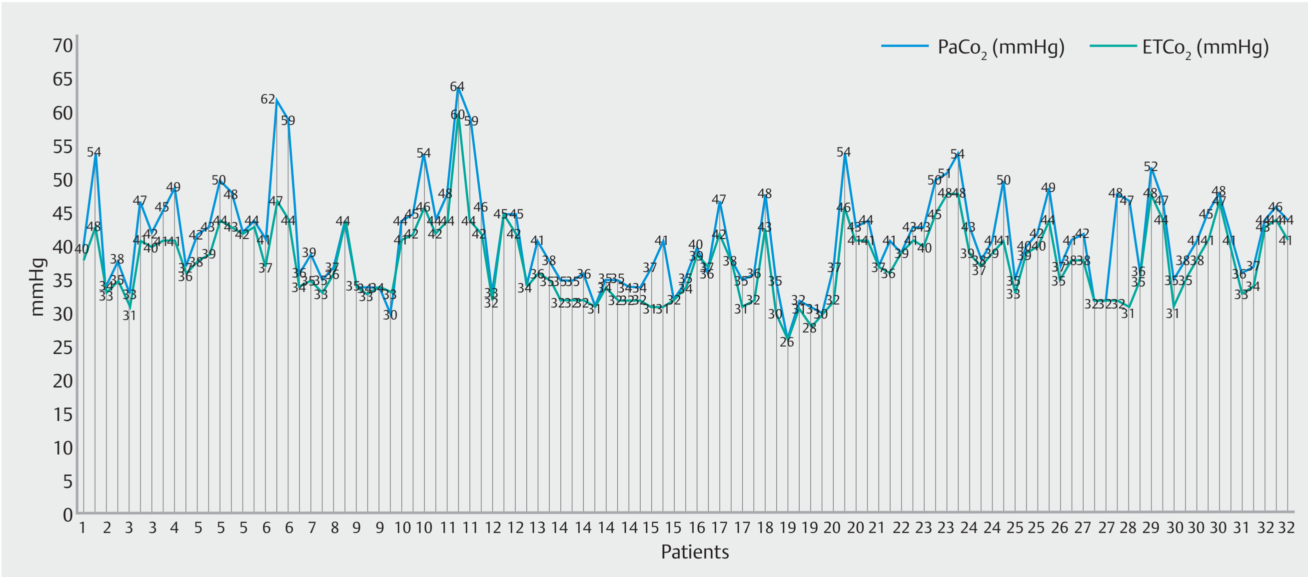
compared. Results are reported as mean ± standard deviation (SD) or median (range) for quantitative variables and percentages for categorical variables. The difference in procedure time, anesthesia time as well as AEs were reported in both groups. Significant associations were defined as $P < 0.05$.

We calculated Pearson correlation coefficient (PCC) and Spearman's Rho to calculate the correlation between $PaCO_2$ and $ETCO_2$. $PaCO_2$ plus $ETCO_2$ were measured in 32 patients (invasive group) and $ETCO_2$ only in 39 matched patients (noninvasive group).

Two-sided $P < 0.05$ were considered statistically significant. All descriptive and statistical analyses were conducted using MedCalc V18.9 (MedCalc Software, Ostend, Belgium).

Results

Both groups had similar demographics and there were no significant differences in age, length of myotomy, subtype of achalasia or severe tortuosity when comparing the groups (▶ **Table 1**). The average procedure time (scope in and out) was increased 17.7 minutes ($P = 0.04$) in the invasive monitoring group (▶ **Table 2**). Anesthesia duration was increased 46.3 minutes in addition to endoscopy time in the invasive monitoring group ($P \leq 0.00001$). Within the $PaCO_2$ group, the average difference between $PaCO_2$ and $ETCO_2$ was 3.39 mm Hg (Median 3, SD 3.5), within the 2– to 5-mm Hg range (▶ **Fig. 1**). The Frequency of $ETCO_2$ monitoring in the two groups was not significantly different ($P = 0.74$). $PaCO_2$ and $ETCO_2$ were strongly correlated in patients undergoing POEM, PCC R value: 0.8787 $P \leq 0.00001$, Spearman's Rho R value: 0.8775, $P \leq 0.00001$.



▶ **Fig. 1** Correlation between $PaCO_2$ and $ETCO_2$.

There were no differences between the groups in AEs (13 % vs 3 % $P = 0.24$). AEs included three hematomas and one nerve injury related to arterial line placement in the invasive group and one pneumothorax due to inadvertent air insufflation in the noninvasive group. The episode of pneumothorax in the noninvasive group was caused by inadvertent use of air instead of CO_2 insufflation, and required stopping the procedure as well as chest tube placement. After the pneumothorax resolved the patient decided not to pursue another procedure.

The three hematomas in the invasive group were managed conservatively while the patient with nerve injury is undergoing ambulatory physiotherapy.

Discussion

Appropriate distention is required for good visibility during endoscopy. Initially air was being used for insufflation during endoscopy and in the 1970 s, it was discovered that use of electrosurgical instruments during air insufflation could lead to a fatal explosion in the bowels and barotrauma, [11]. CO_2 happens to be less expensive and more rapidly absorbed than regular air, because CO_2 is absorbed 160 times faster than nitrogen and 12 times faster than oxygen, the two main components of air. After being absorbed, the CO_2 is transported by the blood to the lungs and then exhaled [12].

POEM involves the creation of a tunnel across the submucosal space with frequent exposure of the mediastinum. The most common AEs associated with POEM are related to excess insufflation, including pneumomediastinum, pneumothorax, pneumoperitoneum, and subcutaneous emphysema because endoscopically insufflated gas may be inadvertently absorbed into surrounding tissues, compromising cardiorespiratory function. According to prior studies, insufflation-related AEs are quite variable in incidence, ranging from 7.5 % to 55.5 % [13–17].

Initial studies of POEM showed that use of CO_2 was associated with less risk of insufflation-related complications when compared to air, and although its use did not completely eliminate the risk, it was decreased substantially [18, 19]. The use of general anesthesia also facilitates achievement of positive intrathoracic pressure and decreases risk of mediastinal emphysema [20].

CO_2 plays various roles in the human body, including regulation of blood pH, respiratory drive, and affinity of hemoglobin for oxygen; therefore, CO_2 levels should be closely monitored to maintain them under 45 mm Hg [13, 21]. It is estimated that partial pressure of CO_2 ($PaCO_2$) is 2 to 5 mm Hg higher than $ETCO_2$ [22, 23], and the recommended level of $ETCO_2$ during POEM is approximately 40 mm Hg. Another parameter to consider is the peak inspiratory pressure or P_{max}; elevated peak pressure (> 38 cm H_20 or 20 % above the baseline) along with abdominal distention could represent increased abdominal pressure, and the need for percutaneous needle decompression of pneumoperitoneum [21, 24].

Previous studies have demonstrated the adequacy of $ETCO_2$ to evaluate hypercapnia and monitor ventilation during anesthesia because it is continuous and noninvasive [7, 8, 22, 25, 26].

This prospective comparative study confirmed that, among patients undergoing POEM, $ETCO_2$ correlates strongly with $PaCO_2$ with an average difference that is within the expected 2- to 5-mm Hg range as reported in studies in non-POEM patients [22, 23]. The gradient between $ETCO_2$ and $PaCO_2$ is directly proportional to the degree of physiologic dead space [27–29]. Although the typical alveolar CO_2 concentration is slightly greater than $PaCO_2$, $ETCO_2$ is normally 2 to 5 mm Hg lower than $PaCO_2$ due to mixing of CO_2-containing alveolar gas with exhaled gas devoid of CO_2 from the anatomical dead space. As a result, $ETCO_2$ levels are maintained in a normal physiologic range (30–40 mm Hg), corresponding to a $PaCO_2$ range of 35 to 45 [21–23]. Because the observed average difference in $ETCO_2$ and $PaCO_2$ in our study was within the 2– to 5-mm Hg range, $ETCO_2$ can be used as a noninvasive surrogate measure for $PaCO_2$ in patients undergoing POEM. In patients with concurrent lung disease, the reliability of $ETCO_2$ can be compromised because the 2- to 5-mm Hg gradient can increase with any increase in the dead space volume; indeed, the addition of alveolar dead space further dilutes $ETCO_2$ relative to $PaCO_2$. In such patients, endoscopists should exercise caution because the same $ETCO_2$ values may reflect greater $PaCO_2$ values, and thus, increased risk of hypercapnia-related complications [7, 8].

Although it is recognized that POEM poses unique anesthesia-related challenges, standardized management has yet to be established and the necessity for arterial line placement has not previously been investigated. In our study, there was no significant difference in AEs between the invasive and noninvasive groups, suggesting that using $ETCO_2$ as a safe surrogate measure for $PaCO_2$ allows for prompt recognition and response to emergent hypercapnia-related complications. While there was an instance of pneumothorax in the noninvasive group due to use of air for insufflation instead of CO_2, it was inadvertent and not due to using $ETCO_2$ as a surrogate measure for $PaCO_2$. However, compared to POEM procedures performed in the invasive group, those performed in the noninvasive group had a significantly shorter mean procedure time and anesthesia duration. Longer procedure times and anesthesia durations among the invasive group due to the placement of an arterial line may increase the risk of complications. In our study, the widespread placement of arterial line was associated with an increased incidence of hematoma and nerve injuries.

A retrospective case series review by Loser et al demonstrated that insufflation-related cardiorespiratory responses are likely inevitable during POEM. The cardiorespiratory response tends to include an increased peak inspiratory pressure, $ETCO_2$ levels, mean arterial pressures, and heart rate [24]. The goal of periprocedural monitoring is to identify abnormalities at an early stage to prevent or mitigate harm to the patient [7]. Previous studies have reported the safety of $ETCO_2$ during POEM [13, 21, 24]. Our study has several strengths, including being the first to compare invasive versus noninvasive CO_2 monitoring in patients undergoing POEM, demonstrating that $ETCO_2$ correlates strongly with $PaCO_2$ and should be used as a surrogate of $PaCO_2$ in patients undergoing POEM, and universal $PaCO_2$ monitoring contributes to increased duration of anesthesia, as well as total procedure and turnover time.

Conclusions

In conclusion, POEM is a relatively new procedure, continuously evolving. It has unique perioperative aspects that need to be understood by the team performing the procedure, which includes the endoscopist, the anesthesiologist, anesthetist, perioperative nurses and endoscopy technician.

One of the limitations of our study is that it was not randomized. However, it demonstrates the viability of $ETCO_2$ as a surrogate measure for $PaCO_2$, allowing recognition of CO_2-related complications without the need for arterial line placement during the POEM procedure. Invasive CO_2 monitoring with an arterial line should be performed in patients with major cardiopulmonary comorbidities on a case-by-case basis.

Competing interests

Dr. Tyberg is a consultant for Ninepoint Medical, Endogastric Solutions, and Obalon Therapeutics. Dr. Sarkar has done consulting work for US Endoscopy and Obalon Therapeutics. Dr. Shahid has done consulting work for US Endoscopy. Dr. Kahaleh has received grant support from Boston Scientific, Fujinon, W.L. Gore, Apollo Endosurgery, Cook Endoscopy, GI Dynamics, Merit Medical, Interscope Med, Olympus, ERBE, and MI Tech. He is a consultant for Boston Scientific and Laboratories Inc., AbbVie. None of that funding was related to this paper. Dr. Gaidhane is a consultant for 3 D Matrix.

Clinical trial

ClinicalTrials.gov (http://www.clinicaltrials.gov/)
NCT05041608
TRIAL REGISTRATION: Retrospective study NCT05041608 at ClinicalTrials.gov (http://www.clinicaltrials.gov/)

References

[1] Inoue H, Shiwaku H, Iwakiri K et al. Clinical practice guidelines for peroral endoscopic myotomy. Dig Endosc 2018; 30: 563–579

[2] Zaninotto G, Bennett C, Boeckxstaens G et al. The 2018 ISDE achalasia guidelines. Dis Esophagus 2018; 31: doi:10.1093/dote/doy071

[3] Inoue H, Minami H, Kobayashi Y et al. Peroral endoscopic myotomy (POEM) for esophageal achalasia. Endoscopy 2010; 42: 265–271

[4] Weusten B, Barret M, Bredenoord AJ et al. Endoscopic management of gastrointestinal motility disorders – part 1: European Society of Gastrointestinal Endoscopy (ESGE) Guideline. Endoscopy 2020; 52: 498–515

[5] Bapaye A, Korrapati SK, Dharamsi S et al. Third space endoscopy: lessons learnt from a decade of submucosal endoscopy. J Clin Gastroenterol 2020; 54: 114–129

[6] Yamashita-Ichimura M, Toyama E, Sasoh M et al. Bladder pressure monitoring and CO2 gas-related adverse events during per-oral endoscopic myotomy. J Clin Monit Comput 2018; 32: 1111–1116

[7] Rackley CR. Monitoring during mechanical ventilation. Respir Care 2020; 65: 832–846

[8] Ortega R, Connor C, Kim S et al. Monitoring ventilation with capnography. N Engl J Med 2012; 367: e27

[9] Sbaraglia F, Familiari P, Maiellare F et al. Pediatric anesthesia and achalasia: 10 years' experience in peroral endoscopy myotomy management. J Anesth Analg Crit Care 2022: doi:10.1186/s44158-022-00054-7

[10] Tanaka E, Murata H, Minami H et al. Anesthetic management of peroral endoscopic myotomy for esophageal achalasia: a retrospective case series. J Anesth 2014; 28: 456–459

[11] Williams CB. Who's for CO2? Gastrointest Endosc 1986; 32: 365–367

[12] Bretthauer M, Kalager M, Adami HO et al. Who is for CO2? Slow adoption of carbon dioxide insufflation in colonoscopy Ann Intern Med 2016; 165: 145–146

[13] Darisetty S, Nabi Z, Ramchandani M et al. Anesthesia in per-oral endoscopic myotomy: A large tertiary care centre experience. Indian J Gastroenterol 2017; 36: 305–312

[14] Akintoye E, Kumar N, Obaitan I et al. Peroral endoscopic myotomy: a meta-analysis. Endoscopy 2016; 48: 1059–1068

[15] Ren Z, Zhong Y, Zhou P et al. Perioperative management and treatment for complications during and after peroral endoscopic myotomy (POEM) for esophageal achalasia (EA) (data from 119 cases). Surg Endosc 2012; 26: 3267–3272

[16] Jayan N, Jacob JS, Mathew M et al. Anesthesia for peroral endoscopic myotomy: A retrospective case series. J Anaesthesiol Clin Pharmacol 2016; 32: 379–381

[17] Talukdar R, Inoue H, Nageshwar Reddy D. Efficacy of peroral endoscopic myotomy (POEM) in the treatment of achalasia: a systematic review and meta-analysis. Surg Endosc 2015; 29: 3030–3046

[18] Cai MY, Zhou PH, Yao LQ et al. Thoracic CT after peroral endoscopic myotomy for the treatment of achalasia. Gastrointest Endosc 2014; 80: 1046–1055

[19] Zhang XC, Li QL, Xu MD et al. Major perioperative adverse events of peroral endoscopic myotomy: a systematic 5-year analysis. Endoscopy 2016; 48: 967–978

[20] Bang YS, Park C. Anesthetic consideration for peroral endoscopic myotomy. Clin Endosc 2019; 52: 549–555

[21] Yang D, Pannu D, Zhang Q et al. Evaluation of anesthesia management, feasibility and efficacy of peroral endoscopic myotomy (POEM) for achalasia performed in the endoscopy unit. Endosc Int Open 2015; 3: E289–E295

[22] Razi E, Moosavi GA, Omidi K et al. Correlation of end-tidal carbon dioxide with arterial carbon dioxide in mechanically ventilated patients. Arch Trauma Res 2012; 1: 58–62

[23] Sullivan KJ, Kissoon N, Goodwin SR. End-tidal carbon dioxide monitoring in pediatric emergencies. Pediatr Emerg Care 2005; 21: 327–332 quiz 333–325

[24] Loser B, Werner YB, Punke MA et al. Anesthetic considerations for patients with esophageal achalasia undergoing peroral endoscopic myotomy: a retrospective case series review. Can J Anaesth 2017; 64: 480–488

[25] Fujimoto S, Suzuki M, Sakamoto K et al. Comparison of End-Tidal, Arterial, Venous, and Transcutaneous PCO2. Respir Care 2019; 64: 1208–1214

[26] Gaur P, Harde M, Gujjar P et al. A study of partial pressure of arterial carbon dioxide and end-tidal carbon dioxide correlation in intraoperative and postoperative period in neurosurgical patients. Asian J Neurosurg 2017; 12: 475–482

[27] Yamanaka MK, Sue DY. Comparison of arterial-end-tidal PCO2 difference and dead space/tidal volume ratio in respiratory failure. Chest 1987; 92: 832–835

[28] Fletcher R. The arterial-end-tidal CO2 difference during cardiothoracic surgery. J Cardiothorac Anesth 1990; 4: 105–117

[29] Burrows FA. Physiologic dead space, venous admixture, and the arterial to end-tidal carbon dioxide difference in infants and children undergoing cardiac surgery. Anesthesiology 1989; 70: 219–225