Inhibitory effects of carbon dioxide insufflation on pneumoperitoneum and bowel distension after percutaneous endoscopic gastrostomy

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Abstract

AIM: To evaluate the inhibitory effects of carbon dioxide (CO2) insufflation on pneumoperitoneum and bowel distension after percutaneous endoscopic gastrostomy (PEG).

METHODS: A total of 73 consecutive patients who were undergoing PEG were enrolled in our study. After eliminating 13 patients who fitted our exclusion criteria, 60 patients were randomly assigned to either CO2 (30 patients) or air insufflation (30 patients) groups. PEG was performed by pull-through technique after three-point fixation of the gastric wall to the abdominal wall using a gastropexy device. Arterial blood gas analysis was performed immediately before and after the procedure. Abdominal X-ray was performed at 10 min and at 24 h after PEG to assess the extent of bowel distension. Abdominal computed tomography was performed at 24 h after the procedure to detect the presence of pneumoperitoneum. The outcomes of PEG for 7 d post-procedure were also investigated.

RESULTS: Among 30 patients each for the air and the CO2 groups, PEG could not be conducted in 2 patients of the CO2 group, thus they were excluded. Analyses of the remaining 58 patients showed that the patients’ backgrounds were not significantly different between the two groups. The elevation values of arterial partial pressure of CO2 in the air group and the CO2 group were 2.67 mmHg and 3.32 mmHg, respectively (P = 0.408). The evaluation of bowel distension on abdominal X ray revealed a significant decrease of small bowel distension in the CO2 group compared to the air group (P < 0.001) at 10 min and 24 h after PEG, whereas there was no significant difference in large bowel distension between the two groups. Pneumoperitoneum was observed only in the air group but not in the CO2 group (P = 0.003). There were no obvious differences in the laboratory data and clinical outcomes after PEG between the two groups.

CONCLUSION: There was no adverse event associated with CO2 insufflation. CO2 insufflation is considered to be safer and more comfortable for PEG patients because of the lower incidence of pneumoperitoneum and less distension of the small bowel.

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Key words: Percutaneous endoscopic gastrostomy; Carbon dioxide insufflation; Pneumoperitoneum; Abdominal distension; Randomized control study
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INTRODUCTION

Percutaneous endoscopic gastrostomy (PEG) has been widely accepted for enteral access since the introduction of the procedure in 1980[1,2]. The procedure of PEG is rapid, but it requires maximal insufflation of the stomach with air in order to tightly attach the gastric wall to the abdominal wall. Percutaneous puncture into the stomach with a needle is conducted under the fully insufflated stomach and a gastrostomy tube is placed thereafter. Abdominal distension and pneumoperitoneum are frequent symptoms after PEG[3,4]. Carbon dioxide (CO₂) insufflation was initially introduced for colonoscopy polypectomy in the field of gastrointestinal endoscopy[5-12]. Applications of CO₂ insufflation for endoscopic procedures have also been reported for the performance of routine colonoscopy, small bowel endoscopy, endoscopic retrograde cholangiopancreatography (ERCP), peroral cholangioscopy, and endoscopic submucosal dissection in the upper and lower gastrointestinal tract[13-15]. These studies showed that CO₂ insufflation reduces the post-procedural abdominal distension and pain without CO₂ retention and adverse events. However, there has been no report on the safety and efficacy of CO₂ insufflation with PEG procedures. In the present study, we evaluated the inhibitory effects of CO₂ insufflation on bowel distension and pneumoperitoneum after PEG by randomized controlled trial. The safety of CO₂ insufflation was also investigated.

MATERIALS AND METHODS

Participants

Consecutive patients who were scheduled for PEG from November 2009 to March 2011 at our institution were recruited for this study. Exclusion criteria included any of the following: chronic obstructive pulmonary diseases (COPD), severe congestive heart failure (cardiothoracic ratio on chest radiography > 60%), previous gastrointestinal surgery, for the purpose of decompression via PEG, hypercapnea [arterial partial pressure of CO₂ (PCO₂) > 50 mmHg], and refusal to participate. Randomization was conducted individually into two treatment groups (1:1) using a computer-generated sequence. Sealed envelopes were used for the allocation of individual patients and opened by assistants at the endoscopy unit just before the procedure of PEG. The present study was approved by the Ethics Committee of our institution, and written informed consent was obtained from the patients or the patients’ family members.

Percutaneous endoscopic gastrostomy procedure and carbon dioxide monitoring

CO₂ was administered using a commercially available CO₂ regulator system (UCR, Olympus Optical Co., Ltd., Tokyo, Japan). The flow rate of the CO₂ insufflation was 1.5 L/min using the wide size of the connective tube, the volume of which was equivalent to the medium strength setting of the air insufflation system. Endoscopy assistants set up the insufflation system according to the allocation of the individual patients.

Conscious sedation was conducted by the intravenous administration of midazolam, the amount of which was previously determined by their primary doctor depending on the condition of the patient. An endoscope (GIF-H180, Olympus Optical Co., Ltd., Tokyo, Japan) was inserted up to the second portion of the duodenum to screen the upper gastrointestinal tract and pulled back to the stomach. Then, the stomach was fully inflated with air or CO₂ and the site for placement was determined by transillumination of the abdominal wall and finger pressure against the stomach. The abdominal skin surface of the placement area was cleansed with povidone-iodine and local anesthesia was performed by administering 1% lidocaine. After test-puncturing with a 21-gauge needle, 3-point sutures were made using a gastropexy device (Easy Tie, Boston Scientific Japan K.K., Tokyo, Japan) to fix the stomach against the abdominal wall in order to form tight fistula formation. A Seldinger needle was then punctured at the center of the 3-point sutures and a loop wire was inserted through the outer sheath of the needle. The loop wire was grasped by a snare from the endoscope, and a 20F gastrostomy tube was placed by the pull-through technique. The materials used for PEG tube placement were a Ponsky PEG (Bard Access Systems, Inc., Salt Lake City, UT, United States) or a Safety PEG kit (Boston Scientific Co., Natick, MA, United States). The endoscope was reinserted into the stomach to secure the proper placement of the gastrostomy tube. Arterial blood gas analysis was conducted just before and immediately after the PEG procedure to measure PCO₂, arterial partial pressure of O₂ (PO₂), pH and base excess.

Evaluation of post-procedural outcomes

The clinical pathway after PEG was determined as follows. Prophylactic intravenous administration of cefmetazole was conducted for 3 d following PEG. The gastrostomy tube was drained for 24 h and feeding was then started in those patients without serious events. Initial feeding was 100 mL of 5% glucose solution followed by 500 mL of glucose solution on the next day. Commercially available isotonic nutrients were administered from the third day and gradually increased up to 800 kcal/d for 7 d. Target calorie intake was achieved within 2 wk.

Abdominal computed tomography (CT) was conducted 24 h after PEG to detect pneumoperitoneum. In patients with pneumoperitoneum, the volume of the
Statistical analysis

The continuous values were expressed as mean ± SD and analyzed using the Student’s t-test. The analysis of dichotomous categorical variables was performed using the χ² test. The analysis of the grades of bowel distension was conducted by Fisher’s exact test. Statistical significance was defined as a P value of less than 0.05. All data were analyzed using JMP software for Windows (Version 5.1; SAS Institute Inc., Cary, NC, United States).

RESULTS

Patients

A flow diagram of this study is presented in Figure 1. A total of 73 patients were enrolled for this study. Thirteen patients were excluded by the exclusion criteria; 6 patients for COPD, 3 patients for hypercapnea, 2 patients for severe congestive heart failure, and one each for post-digital gastrectomy and for the purpose of decompression. The remaining 60 patients were equally randomized and underwent PEG with air or CO₂ insufflation. All of the PEG procedures in the air group were successfully performed, whereas those in the CO₂ group were not completed in two patients using the above-described PEG procedure. One of the reasons for failure was inability to insert an endoscope into the stomach because of benign esophageal stenosis. The other reason was failure of gastropexy, although the PEG was performed without gastropexy. These two patients were excluded from the analyses.

The demographic data of the patients are shown in Table 1. The mean age and male/female ratio were not significantly different in the two groups. The serum albumin concentration, an indicator of nutritional status, did not differ significantly.

Percutaneous endoscopic gastrostomy procedures

There were no significant differences in the amount of midazolam administered and the duration of the procedure between the two groups. The mean elevations of PCO₂ in the air and CO₂ groups were 2.67 mmHg and 3.32 mmHg, respectively (P = 0.408). The mean depressions of PO₂ in the air and CO₂ groups were 3.72 mmHg and 1.34 mmHg, respectively (P = 0.302). The mean pH after PEG of the CO₂ group was significantly lower than that of the air group (P = 0.018), whereas the depression of pH during the procedure was not significantly different between the two groups (P = 0.125). There were no significant differences in base excess between the two groups (data not shown) (Table 2).

Bowel distension

The most frequent distension grades of the small bowel at 10 min in the air and CO₂ groups were grade IV and grade II, respectively; and those at 24 h were grade II and grade I, respectively (Figure 2) (P < 0.001). The most frequent distension grades of the large bowel in the air and CO₂ groups were grade II at both 10 min and 24 h in the two groups (Figure 2).

Pneumoperitoneum

Pneumoperitoneum was observed in 8 patients of the air group, whereas there was no patient with pneumoperitoneum in the CO₂ group by abdominal CT (P = 0.003). The mean volume of the free air of the 8 patients in the air group was 36.3 mL. In addition to the 8 patients, faint extragastric air leakage around the stoma was observed in 5 patients of the air group. No such transluminal air leak was observed in any patient of the CO₂ group.

Postprocedural outcomes

The values of CRP levels and leukocyte counts were not different between the two groups at any time. The rates

Figure 1  Flow diagram showing selection of study subjects. CO₂: Carbon dioxide.
of the patients with fever of more than 38 ℃ in the air and CO₂ groups were 33.3% and 17.9%, respectively \((P = 0.179)\). The numbers of patients who did not follow the clinical pathway during the first 7 d post-procedure were 4 each for the air and CO₂ groups (13.3% and 14.2%, respectively). The reasons for the discontinuation of the pathway were aspiration after feeding (3 and 2 patients for the air and CO₂ groups, respectively), stomal infection (1 patient each for the two groups), and hemorrhage in 1 patient in the CO₂ group. Among these complications, 1 patient in the air group and 3 patients in the CO₂ group were interrupted for feeding until the complications recovered. There was no mortality within 30 d in this study (Table 3).

**DISCUSSION**

The present study is the first investigation of the effects of CO₂ insufflation during PEG. Our results clearly indicate that the use of CO₂ insufflation reduces the post-procedural abdominal distension and pneumoperitoneum compared to air insufflation. The usefulness and safety of CO₂ insufflation for colonoscopy, ERCP and double balloon enteroscopy have been reported, including effects on the respective therapeutic procedures\(^5\)--\(^12\). PEG is also an endoscopic operation, but the procedure is simple and of relatively short duration compared to the above-mentioned endoscopic procedures. However, the PEG procedure requires maximal insufflation of the stomach and penetration of the gastric wall by a needle and a gastrotomy tube\(^13\). The reported frequencies of pneumoperitoneum range from 8.6% to 56%\(^14\)--\(^16\). The variation of the frequency may depend on multiple factors. Abdominal CT scan is a more

Table 1 Demographic data of the air and carbon dioxide insufflation groups

|                          | Air group \((n = 30)\) | CO₂ group \((n = 28)\) | \(P\) value |
|--------------------------|------------------------|------------------------|------------|
| Age (mean ± SD, yr)      | 81.9 ± 8.8             | 82.3 ± 9.5             | 0.873      |
| Gender (male/female)     | 8/22                   | 5/23                   | 0.421      |
| Underlying diseases      |                        |                        |            |
| Cerebrovascular disease  | 20                     | 16                     |            |
| Dementia                 | 5                      | 7                      |            |
| Neuromuscular disease    | 2                      | 1                      |            |
| Pneumonia                | 1                      | 4                      |            |
| Malignant tumor          | 1                      | 0                      |            |
| Cardiac disease          | 1                      | 0                      |            |
| Albumin (mean ± SD, g/dL) | 3.12 ± 0.46          | 3.05 ± 0.69            | 0.645      |

CO₂: Carbon dioxide.
sensitive modality to detect intraabdominal free air compared to plain radiography. The methods or devices used for the PEG procedure may also affect the frequency of pneumoperitoneum. The performance of gastropexy may have a preventive effect on pneumoperitoneum. We introduced the gastropexy technique in the present study using a T-fastener type fixation device just before the percutaneous needle puncture\[^{[17]}\]. Our intention with gastropexy is to prevent peritonitis if the gastrostomy tube dislodges in the early phase after PEG. In the present study, the frequency of pneumoperitoneum in the air group was 27\%, the value of which was comparable to the previous reports. However, the amount of the free air was fairly small (36.3 mL on average), which would be difficult to detect by plain abdominal radiography. Although there are no reports of the preventive effects on pneumoperitoneum by the gastropexy, the procedure is supposed to reduce the amount of the free air.

Most cases of pneumoperitoneum are considered to have no clinical significance and to require no further interventions\[^{[13,14,16]}\]. Pneumoperitoneum after PEG usually causes no symptoms and spontaneously recovers. However, a few patients with pneumoperitoneum showed severe symptoms and underwent laparotomy in larger scale analyses. Dabalob et al\[^{[18]}\] reported that 20\% of patients with pneumoperitoneum developed peritonitis which required exploratory celiotomy. Blum et al\[^{[19]}\] retrospectively analyzed 722 patients who had undergone PEG, and reported that pneumoperitoneum was observed in 5 out of 6 patients who had complications requiring laparotomy. They postulated that the presence of intraabdominal free fluid in addition to the free air is an indication of peritonitis requiring surgical intervention.

The inhibitory effect of CO\(_2\) insufflation on pneumoperitoneum or pneumomediastinum at the perforation of endoscopic submucosal dissection was reported by Nonaka et al\[^{[13]}\]. They showed 3 cases of perforation with endoscopic submucosal dissection (2 cases with esophageal cancer and 1 case with gastric cancer) using CO\(_2\) insufflation but no subcutaneous or mediastinal emphysema or pneumoperitoneum developed after perforation.

CO\(_2\) insufflation has also been reported to reduce post-procedural abdominal pain as well as abdominal distension during colonoscopy and double balloon enteroscopy\[^{[5,7]}\]. The reduction of abdominal symptoms by CO\(_2\) insufflation was also reported for ERCP\[^{[10]}\], although the effects remain controversial\[^{[19]}\]. Although the mean duration of the PEG procedure was only about 14 min in the present study, a significant reduction in small bowel distension was observed in the CO\(_2\) group compared to the air group. The evaluation of the bowel distension was analyzed by radiography at 10 min and 24 h after PEG. The result of remarkable reduction of small bowel distension at only 10 min after the procedure was consistent with the report of Nakajima et al\[^{[20]}\]. Almost all of the patients in our study were unable to express their symptoms due to their underlying diseases and we could not use a visual analog scale for their abdominal pain and distension, but CO\(_2\) insufflation may reduce the abdominal symptoms after PEG.

There were no significant differences in clinical outcomes after PEG between the two groups. These results indicate that the reduction of pneumoperitoneum and bowel distension did not affect the outcomes after PEG. We experienced 8 out of 58 patients with complications, including 5 cases of aspiration, 2 cases of peristomal infection and 1 case of hemorrhage in this study. These complications were not derived from the CO\(_2\) or air insufflation itself.

The elevation of PCO\(_2\): using CO\(_2\) insufflation in this study was very low and the degree of elevation was comparable to that of air insufflation. These results indicate that the elevation of PCO\(_2\): is not derived from CO\(_2\) insufflation itself but derived from conscious sedation by midazolam. This assumption is consistent with previous reports\[^{[8,10,21,23]}\]. Because the PEG procedure is of short duration, strict continuous monitoring of CO\(_2\): status by the measurement of transtracheal PCO\(_2\): or partial pressure of end-tidal CO\(_2\): would not be necessary. Suzuki et al\[^{[13]}\] reported that the PCO\(_2\): level increased with the duration of CO\(_2\): insufflation for endoscopic submucosal

### Table 2 The amount of administered midazolam, duration of percutaneous endoscopic gastrostomy procedure, and arterial blood gas analyses immediately before and after the procedure (mean ± SD)

|                        | Air group | CO\(_2\) group | P value |
|------------------------|-----------|----------------|---------|
| Amount of midazolam (mg) | 2.53 ± 1.14 | 2.53 ± 1.45 | 0.995   |
| Duration of procedure (s) | 835 ± 145 | 889 ± 128 | 0.143   |
| Arterial blood gas analysis |           |               |         |
| PCO\(_2\): (mmHg) | Before procedure | 38.9 ± 4.9 | 38.6 ± 4.4 | 0.837   |
|                        | After procedure | 41.6 ± 5.6 | 41.9 ± 4.8 | 0.778   |
| Elevation during procedure | 2.67 ± 2.82 | 3.32 ± 3.14 | 0.408   |
| PO\(_2\): (mmHg) | Before procedure | 83.0 ± 11.8 | 84.4 ± 9.3 | 0.612   |
|                        | After procedure | 79.0 ± 10.6 | 83.1 ± 9.8 | 0.213   |
| Depression during procedure | 3.72 ± 8.95 | 1.34 ± 7.07 | 0.302   |
| pH                     | Before procedure | 7.479 ± 0.035 | 7.471 ± 0.023 | 0.295   |
|                        | After procedure | 7.454 ± 0.031 | 7.435 ± 0.031 | 0.018   |
| Depression during procedure | 0.025 ± 0.031 | 0.036 ± 0.027 | 0.125   |

PCO\(_2\): Pressure of carbon dioxide; PO\(_2\): Pressure of oxygen.

### Table 3 Changes in laboratory data and clinical outcomes after percutaneous endoscopic gastrostomy (mean ± SD)

|                          | Air group | CO\(_2\) group | P value |
|--------------------------|-----------|----------------|---------|
| CRP (mg/dL)              |           |               |         |
| Before PEG               | 1.58 ± 1.63 | 1.51 ± 2.71 | 0.906   |
| 1 d after PEG            | 2.92 ± 3.23 | 1.66 ± 1.58 | 0.068   |
| 7 d after PEG            | 2.12 ± 3.23 | 1.14 ± 1.75 | 0.158   |
| Leucocytes (/\(\mu L\))  |           |               |         |
| Before PEG               | 6330 ± 1990 | 7330 ± 2210 | 0.077   |
| 1 d after PEG            | 7760 ± 3230 | 8570 ± 2110 | 0.269   |
| 7 d after PEG            | 6690 ± 2150 | 7410 ± 2400 | 0.238   |
| Fever more than 38 \(^\circ\)C, n (%)) | 10 (33.3) | 5 (17.9) | 0.179   |
| Discontinued clinical pathway, n (%) | 4 (13.3) | 4 (14.2) | 0.916   |

CRP: C-reactive protein; PEG: Percutaneous endoscopic gastrostomy; CO\(_2\): Carbon dioxide.
dissection under general anesthesia. They also found that patients with lower respiratory function showed a tendency toward CO₂ retention compared to patients with normal respiratory function. Our study excluded patients with COPD and severe chronic heart failure, but the target patients for PEG are usually elderly and often have impaired cardiorespiratory function. Further investigation of the safety of CO₂ insufflation for elderly patients will be required. In conclusion, CO₂ insufflation during the PEG procedure is considered to be safe and provides comfort by reducing pneumoperitoneum and bowel distension.

COMMENTS

Background
Carbon dioxide (CO₂) insufflation has been reported to reduce the post-procedural abdominal distension and pain in gastrointestinal endoscopy for diagnostic and therapeutic purposes. However, there has been no report on the safety and efficacy of CO₂ insufflation for percutaneous endoscopic gastrostomy (PEG) procedures.

Research frontiers
Utilizing the nature that CO₂ is rapidly absorbed from the bowel, the authors investigated the effect of CO₂ insufflation on patients undergoing PEG.

Innovations and breakthroughs
CO₂ insufflation remarkably reduced pneumoperitoneum and small bowel distension without any adverse events.

Applications
Safety of CO₂ insufflation during PEG procedure for elderly patients was demonstrated in this report. Further investigation in patients with cardiopulmonary disorders is necessary.

Peer review
This is the first randomized control study of CO₂ insufflation in PEG procedure and describes the effects of CO₂ insufflation on pneumoperitoneum and bowel distension after PEG. The presented article is a major contribution in the research field.

REFERENCES
1. Gauderer MW, Ponsky JL, Izant RJ. Gastrostomy without laparotomy: a percutaneous endoscopic technique. J Pediatr Surg 1980; 15: 872-875
2. Gauderer MW, Ponsky JL, Izant RJ. Gastrostomy without laparotomy: a percutaneous endoscopic technique. 1980. Nutrition 1998; 14: 736-738
3. Schrag SP, Sharma R, Jaik NP, Seaman MJ, Lukaszczyk JJ, Martin ND, Hoey BA, Stawicki SP. Complications related to percutaneous endoscopic gastrostomy (PEG) tubes. A comprehensive clinical review. J Gastrointestin Liver Dis 2007; 16: 407-418
4. Rogers BHG. The safety of carbon dioxide insufflation during colonoscopic electrosurgical polypectomy. Gastrointest Endosc 1974; 20: 115-117
5. Hussein AM, Bartram CI, Williams CB. Carbon dioxide insufflation for more comfortable colonoscopy. Gastrointest Endosc 1984; 30: 68-70
6. Stevenson GW, Wilson JA, Wilkinson J, Norman G, Goodacre RL. Pain following colonoscopy: elimination with carbon dioxide. Gastrointest Endosc 1992; 38: 564-567
7. Domagk D, Brethhauer M, Lenz P, Aabakken L, Ullrich H, Maaser C, Domschke W, Kucharzik T. Carbon dioxide insufflation improves intubation depth in double-balloon enteroscopy: a randomized, controlled, double-blind trial. Endoscopy 2007; 39: 1064-1067
8. Brethhauer M, Seip B, Aasen S, Kordal M, Hoff G, Aabakken L. Carbon dioxide insufflation for more comfortable endoscopic retrograde cholangiopancreatography: a randomized, controlled, double-blind trial. Endoscopy 2007; 39: 58-64
9. Maple JT, Keswani RN, Hovis RM, Saddedin EZ, Jonnalagadda S, Azar RR, Hagen C, Thompson DM, Waldbaum L, Edmondowicz SA. Carbon dioxide insufflation during ERCP for reduction of postprocedure pain: a randomized, double-blind, controlled trial. Gastrointest Endosc 2009; 70: 278-283
10. Ueki T, Mizuno M, Ota S, Ogawa T, Matsuishi H, Uchida D, Numata N, Ueda A, Morimoto Y, Kominami Y, Nanba S, Kurome M, Ohe I, Nakagawa M, Araki Y. Carbon dioxide insufflation is useful for obtaining clear images of the bile duct during peroral cholangiography (with video). Gastrointest Endosc 2010; 71: 1046-1051
11. Nonaka S, Saito Y, Takisawa H, Kim Y, Kikuchi T, Oda I. Safety of carbon dioxide insufflation for upper gastrointestinal tract endoscopic treatment of patients under deep sedation. Surg Endosc 2010; 24: 1638-1645
12. Saito Y, Uraoka T, Matsuda T, Emura F, Ikeharra H, Mashimo Y, Kikuchi T, Kozu T, Saito D. A pilot study to assess the safety and efficacy of carbon dioxide insufflation during colorectal endoscopic submucosal dissection with the patient under conscious sedation. Gastrointest Endosc 2007; 65: 537-542
13. Gottfried EB, Plumser AB, Clair MR. Pneumoperitoneum following percutaneous endoscopic gastrostomy. A prospective study. Gastrointest Endosc 1986; 32: 397-399
14. Wojtowycz MM, Arata JA, Micklós TJ, Miller FJ. CT findings after uncomplicated percutaneous gastrostomy. AJR Am J Roentgenol 1988; 151: 307-309
15. Dulabon GR, Abrams JE, Rutherford EJ. The incidence and significance of free air after percutaneous endoscopic gastrostomy. Am Surg 2002; 68: 590-593
16. Wiesen AJ, Sideridis K, Fernandes A, Hines J, Indaram A, Weinstein L, Davodoff S, Bank S. True incidence and clinical significance of pneumoperitoneum after PEG placement: a prospective study. Gastrointest Endosc 2006; 64: 886-889
17. Rogers BH, Kaminiski MV, All J. Stabilizing sutures for percutaneous endoscopic gastrostomy. Gastrointest Endosc 1989; 35: 241-243
18. Blum CA, Selander C, Ruddy JM, Leon S. The incidence and clinical significance of pneumoperitoneum after percutaneous endoscopic gastrostomy: a review of 722 cases. Am Surg 2009; 75: 39-43
19. Doulon ES, Velayudham A, Clarke BW, Isaacs KL, Ganga- rosa LM, Galanko JA, Grimm IS. A randomized, controlled, double-blind trial of air insufflation versus carbon dioxide insufflation during ERCP. Gastrointest Endosc 2010; 72: 68-77
20. Nakajima K, Lee SW, Sonoda T, Milsom JW. Intraoperative carbon dioxide colonoscopy: a safe insufflation alternative for locating colon lesions during laparoscopic surgery. Surg Endosc 2005; 19: 321-325
21. Nelson DB, Freeman ML, Silvis SE, Cass OW, Yakshe PN, Vennes J, Stahrke LL, Herman M, Hodges J. A randomized, controlled, trial of transcutaneous carbon dioxide insufflation during ERCP. Gastrointest Endosc 2000; 51: 288-295
22. Kikuchi T, Fu KJ, Saito Y, Uraoka T, Fukuzawa M, Fukunaga S, Sakamoto T, Nakajima T, Matsuda T. Transcutaneous monitoring of partial pressure of carbon dioxide during endoscopic submucosal dissection of early colorectal neoplasia with carbon dioxide insufflation: a prospective study. Surg Endosc 2010; 24: 2231-2235
23. Suzuki T, Minami H, Komatsu T, Masuda R, Kobayashi Y, Sakamoto A, Sato Y, Inoue H, Serada K. Prolonged carbon dioxide insufflation under general anesthesia for endoscopic submucosal dissection. Endoscopy 2010; 42: 1021-1029

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