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Air and carbon dioxide volumes insufflated during colonoscopy

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Background: **During colonoscopy, air or carbon dioxide is insufflated to secure adequate visualization of the colon, and endoscopy trainees are reminded to use as little gas as possible to avoid patient discomfort. However, the volume of gas insufflated by endoscopists during colonoscopy is unknown. The aim of the present study was to measure volumes of carbon dioxide and air insufflated during colonoscopy.**

Methods: **A total 249 consecutive patients participating in a colorectal cancer screening program were randomized to undergo colonoscopy with either carbon dioxide or air insufflation. Gas volumes insufflated during the procedure were measured with a mass-flowmeter. Four experienced endoscopists performed all of the examinations.**

Results: **Gas volumes were successfully measured in 218 (87%) patients. A mean of 8.3 L of carbon dioxide (range 1.2-19.8 L) and 8.2 L of air (range 1.8-18 L) were insufflated ($p = 0.9$). Mean volumes insufflated per minute were estimated to be 0.26 L and 0.24 L, respectively, in the carbon dioxide and air groups ($p = 0.5$). Statistically significant differences in the volumes of gas insufflated per minute were observed among some of the endoscopists.**

Conclusions: **The volumes of carbon dioxide and air used during colonoscopy can be estimated. Differences in volumes of gas used by experienced endoscopists were detected. (Gastrointest Endosc 2003;58:203-6.)**

Colonoscopy is the reference standard procedure for both detection of and surveillance for neoplastic lesions in the colorectum. There is also increasing interest in colonoscopy as a primary screening modality for colorectal cancer.[1-3] In addition to its invasive nature and risk of complications, a major concern is the reputation of colonoscopy as an uncomfortable and painful procedure.[4] Air insufflation during colonoscopy is believed to be one major reason for this.[5] Three randomized, controlled trials have shown that the use of carbon dioxide (CO_2) instead of air reduces pain and discomfort after colonoscopy.[6-8] However, the use of CO_2 has not been adopted widely, air insufflation being used in the majority of centers around the world.[9]

Endoscopy trainees are regularly reminded to insufflate as little gas as possible to avoid patient discomfort. To our knowledge, however, no studies have investigated how much gas endoscopists insufflate into the colon during colonoscopy. As an add-on study to a recently published trial,[6] the present study describes a method for measuring the volume of CO_2 and air used during colonoscopy and estimates the volume of gas insufflated by experienced endoscopists.

PATIENTS AND METHODS

Patients and examinations

All participants in a colorectal cancer screening trial (NORwegian Colorectal Cancer Prevention, NORCCAP)[10] referred for colonoscopy from October 1999 until March 2000 were randomly assigned to either CO_2 or air insufflation during the procedure.[6] Participants (men and women, aged 55-64 years) were referred for colonoscopy if an adenoma (biopsy specimen confirmed) was found at flexible sigmoidoscopy and/or a test for fecal occult blood was positive. Patients with a prior colonic resection or severe heart or lung disease, and those undergoing treatment for a malignant disease were excluded from the screening examinations.[10] The colonoscopies were performed with standard videocolonoscopes by 1 of 4 experienced endoscopists, experience being defined as having performed more than 1000 colonoscopies before initiation

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Table 1. Mean total volumes of CO_2 and air and mean volumes insufflated per minute by the different endoscopists

	CO_2			Air		
Endoscopist	No. (No. to cecum)	Mean (SD) volume in mL	Mean (SD) volume per min in mL/min	No. (No. to cecum)	Mean (SD) volume in mL	Mean (SD) volume per min in mL/min
1	9 (8)	9382 (3965)	297 (92)	8 (4)	6676 (3544)	219 (35)
2	11 (11)	7127 (5144)	209 (112)	6 (4)	9084 (2136)	245 (45)
3	21 (20)	9409 (4617)	224 (133)	25 (23)	7612 (3594)	198 (74)
4	68 (58)	7946 (3037)	281 (121)	70 (65)	8582 (3481)	279 (115)

Values are given in mean (SD) mL per minute. Numbers of examinations (No.). Numbers of examinations with successful cecum intubation (No. to cecum) are given in the respective subgroups.

of the trial. Colonoscopies were performed without use of any sedative medication. Patient and examination characteristics, such as age, gender, examination time (time during which the colonoscope was within the bowel), and time to reach the cecum were recorded. Examinations in which cecal intubation was unsuccessful were excluded from the analysis of time to reach the cecum but are included in all other analyses.

Devices

Gas insufflators. The two gases (air and CO_2) were administered from two different insufflators. The recently described[8] Endoscopic CO_2 Regulator (Olympus-Key Med, Essex, United Kingdom) was used for CO_2 and the Regulator Präzival (Hydrogas, Oslo, Norway) for air. The devices were pressure and flow controlled with a maximum outlet pressure set at 0.5 bar and a maximum flow of 4 L per minute. During the trial, the air inlet on the endoscopy processor was switched off.

Water container. A novel type of water container was used (MH 970; Olympus Optical Co. [Europa], Hamburg, Germany). This device, in contrast to the conventional model, has an input connector for a gas tube in the lid. Thus, the gas reservoirs could be connected to the water bottle by using a flexible tube. The water container was connected to the endoscope to provide both gas and water.

Gas/water valve. The conventional gas/water valves of endoscopes allow gas to leak continuously from the valve into the environment when the valve is not covered with a finger to redirect the flow through the endoscope. To measure the volume of gas insufflated into the colon alone, the conventional gas/water valve was replaced with a type that prevents gas leakage to the atmosphere (MAJ 521; Olympus [Europa]). For gas insufflation, the button on this type of valve has to be pushed halfway down. For rinsing the endoscope lens with water, the button is depressed fully downward. Before and during each examination, valve function was checked for leakage by the endoscopy assistant. When leakage was detected before the procedure, the damaged valve was replaced; cases in which leakage was observed during the procedure were excluded from analysis.

Flowmeter. Gas volume insufflated during colonoscopy was measured by using a mass flowmeter (El-Flow; Bronkhorst Hi Tec, Ruurlo, The Netherlands); a connected rate totalizer (FW 0110P; Flow-teknikk Ltd., Oslo, Norway) was used for displaying the total gas volumes. The flowmeter was placed between the endoscopy processor and the gas reservoirs. Pressing the gas/water valve would let gas out of the reservoir, through the tube, the mass flowmeter, and the water container to reach the colon through the endoscope. The mass flowmeter continuously registered flow rate and gas volume. These data then were transformed automatically to the rate totalizer and shown on its display.

Randomization and blinding

Sealed envelopes were used to allocate randomly patients to the CO_2 or air group. Single-day sessions were randomized instead of individual participants to prevent unblinding as a result of handling gas couplings between the examinations. Endoscopists and patients were both blinded as to type and volume of gas used. The endoscopy assistants were responsible for handling the CO_2 and air devices, and the flowmeter. The CO_2 and air devices, as well as the flowmeter, were kept out of sight of the endoscopist to prevent unblinding.

Statistics

The data were analyzed by using the two-sample t test and two-way analysis of variance (ANOVA). Statistical significance was defined as a p value less than 0.05 with two-tailed tests. The p values for pairwise comparisons were adjusted for multiplicity by the Bonferroni method. Other p values reported are not adjusted. Statistical analyses were performed with statistical software (SPSS 10.0; SPSS Inc., Chicago Ill.). Values are given as mean (SD) if not stated otherwise.

Ethics

The present study is part of the NORCCAP trial, which was approved by the regional ethics committee. Informed consent was obtained from all participants before entry into the study.

RESULTS

A total of 249 patients were included, 123 in the CO_2 group and 126 in the air group. The groups were similar regarding age (mean 59 years, range 55-64

Table 2. Mean CO_2 and air volumes (total and per minute) insufflated during colonoscopy

	Mean (SD) volume (mL)*	Min	Max	Mean (SD) volume per minute (mL/min)†	Min per minute	Max per minute
CO_2, n = 109	8274 (3724)	1203	19,888	258 (123)	33	950
Air, n = 109	8247 (3468)	1863	18,000	244 (105)	30	800

Volumes are given in mean (SD) milliliter (mL).
*p = 0.96.
†p = 0.51.

Table 3. ANOVA tables for volume insufflated and volume insufflated per minute

	Effect	MS	df	F	p Value
Volume	Gas	6,086,291	1	0.474	0.492
	Endoscopist	1,348,323	3	0.105	0.957
	Interaction	32,686,326	3	2.547	0.057
	Residual	12,833,785	211		
Volume/min	Gas	8445	1	0.680	0.410
	Endoscopist	61,607	3	4.962	0.002
	Interaction	10,824	3	0.872	0.457
	Residual	12,415	211		

MS, Mean square; *df,* degrees of freedom; *F, F* test.

years) and gender (37% women in CO_2 group; 38% women in air group). The cecum was reached in 90% of colonoscopies in both groups. There were differences in the cecal intubation ratios between the different endoscopists, ranging from 70% (Endoscopist 1) to 93% (Endoscopist 3) (Table 1). There was a trend toward faster cecal intubation in the CO_2 group compared with the air group (mean 12.4 [7] minutes vs. mean 14.8 [9] minutes; 95% CI: [for mean difference] –5, 0.2]; p = 0.07). The total duration of the examination was similar: mean 34.6 (13) minutes in the air group versus 34.3 (13) minutes in the CO_2 group (p = 0.7).

Gas volumes were measured successfully in 218 patients (87%); 109 in the CO_2 and 109 in the air group. Measurement was inadequate in 31 patients because of gas leakage from the gas/water valves used in the trial. The mean and minimum/maximum volumes of gas used, together with volumes of gas insufflated per minute (readings for volume of inflated gas during each examination divided by examination duration in minutes) are given in Table 2. The volumes of gas insufflated by the different endoscopists are shown in Table 1. The difference between the CO_2 and air groups and between endoscopists, with regard to the volume of gas insufflated, was analyzed by an ANOVA model, including both main effects and their interaction. No statistically significant differences between gas groups (p = 0.49) or endoscopists (p = 0.96) were found. Although the differences between volume of CO_2 and air insufflated seemed to vary among endoscopists, the interaction was not statistically significant (p = 0.06). The corresponding analysis of volume per minute showed no difference between gas groups (p = 0.41), but there was a statistically significant difference among endoscopists (p = 0.002). After a Bonferroni adjustment for multiple pairwise comparisons of the endoscopists, the only statistically significant difference observed was the mean volume of gas insufflated per minute between Endoscopist 4 and Endoscopist 3 (p = 0.006). No significant interaction between endoscopists and type of gas was found (p = 0.46). Detailed results of the ANOVA are shown in Table 3.

The limited service time of the rubber rings of the gas/water valves, which led to gas leakage, was the only reason for failure to obtain measurements. Leakage occurred during 31 examinations (13%) and was easily detectable on the flowmeter. These examinations were excluded from further analysis. All other equipment worked well during the study.

DISCUSSION

To our knowledge, no study has investigated the volume of gas insufflated into the colon during colonoscopy. In the present trial, a mean of 8 L was insufflated during each examination. Because the duration of colonoscopic examinations varies widely (dependent on therapeutic procedures performed, technical difficulty, and other factors), it would have

been of limited value to focus only on total volumes of gas insufflated without taking into account the time required for the examination. Therefore, the volumes of gas insufflated per minute were also estimated; approximately 250 mL were insufflated per minute. No difference was observed between the CO_2 and air groups. However, statistically significant differences in the volumes of gas insufflated per minute were observed among 2 of the 4 endoscopists participating in the trial. All were experienced, each having performed more than 1000 procedures before entering the study. The differences observed may represent differences in colonoscopic technique. This interendoscopist difference might be even larger when comparing experienced with less experienced endoscopists.

Comparable cecal intubation ratios (89%, 90%, and 93%, respectively) were observed for 3 of the trial endoscopists (numbers 2,3,4). Endoscopist 1 reached the cecum in only 70% of his patients (Table 1). However, the number of colonoscopies performed by this endoscopist in the trial was small (17). Thus, no conclusions concerning individual performance can be drawn from this particular result. As the NORCCAP study progressed and Endoscopist 1 performed numerous procedures, he was found to have a cecal intubation ratio similar to the other 3 endoscopists.

Because CO_2 is rapidly absorbed from the colon,[11] it might be expected that larger volumes of CO_2 compared with air would be required to secure adequate visualization at colonoscopy. For technical reasons, however, it was not possible to register the volume of gas removed by suction. Thus, no statement can be made about the volume of gas present in the colon at any particular moment. For this reason, no correlation analysis was performed on interendoscopist variation in gas volume used and pain experienced by the patient. More information on the use of gas during colonoscopy, including gas volumes removed from the colon, could contribute to a better understanding of the physiologic mechanisms whereby patients experience pain and discomfort during and after colonoscopy. It then could be possible to link gas volume in the colon at any point in time to pain and discomfort experienced by patients.

It has been shown that a substantial number of patients have abdominal pain after colonoscopy when air insufflation is used during the procedure.[6-8] Despite the use of similar volumes for air and CO_2 insufflation, the use of CO_2 has been shown to substantially reduce postprocedure pain.[6-8]

In conclusion, a method for measuring the volume of gas insufflated during colonoscopy has been developed. Use of this method in future studies may contribute to a better understanding of the physical mechanisms and physiologic responses to colonoscopy.

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