Carbon dioxide insufflation can significantly reduce toilet use after colonoscopy: a double-blind randomized controlled trial

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Background and study aims: Carbon dioxide (CO_2) insufflation during colonoscopy can significantly decrease abdominal pain and bloating after the procedure, but its impact on the frequency and duration of toilet use remains unknown. The aim of this study was to assess the impact of CO_2 insufflation on toilet use after screening colonoscopy.

Methods: From 138 average-risk individuals who underwent screening colonoscopy during March to August 2013, 120 were enrolled and randomized to receive either CO_2 or air insufflation at colonoscopy. Both the colonoscopist and participant were blinded to the type of gas used. Abdominal pain and distension were assessed using a visual analog scoring system. The frequency and duration of toilet visits during a 2-hour postcolonoscopy period were recorded using a radiofrequency identification system.

Results: Baseline characteristics were similar in both groups in terms of age, sex, and procedure time. In the 2 hours after colonoscopy, 50 participants (83 %) in the air group and 18 participants (30 %) in the CO_2 group ($P<0.001$) used the toilet at least once. The mean (± SD) duration of each toilet visit was 5.93 ± 4.65 minutes in the air group and 1.53 ± 2.84 minutes in the CO_2 group ($P<0.001$). The abdominal discomfort score was lower in the CO_2 group than in the air group both at the end of the colonoscopy ($P<0.001$) and 2 hours later ($P<0.001$).

Conclusion: Insufflation with CO_2 can significantly reduce abdominal discomfort and toilet use after colonoscopy. Use of this technique may help reduce patient burden and allow more efficient use of space in the endoscopy unit.

Introduction

Colonoscopy can detect both invasive cancers and precancerous neoplasms and has proven to be effective in reducing both the incidence of and the mortality from colorectal cancer (CRC) [1,2]. According to a population study from Canada, every 1 % increment in the complete colonoscopy rate may reduce the hazard of CRC death by 3 %, and the rate of participation has a significant impact on the effectiveness of this screening program [3]. However, about 25 % of individuals experience bloating and 11 % experience abdominal pain after colonoscopy, and these effects may reduce individual's willingness to undergo the next screening or surveillance procedure [4]. Previous studies have shown that although colonoscopy has higher sensitivity for detecting colorectal neoplasms, its use is significantly lower than the use of a fecal test that has a comparable detection rate for invasive cancers [5,6]. However, even in programs that use fecal tests, colonoscopy is the standard tool used for confirmatory diagnosis, and therefore the discomfort after colonoscopy plays a pivotal role in determining adherence to the screening program. Additional disadvantages of abdominal discomfort after colonoscopy are that it may increase the possibility of a prolonged hospital stay, cause inconvenience on the way home, delay the return to work, and may even result in an emergency service visit [7]. This may put a further burden on medical care systems and associated resources.

Many studies have been conducted to identify the factors that affect discomfort during or after colonoscopy by using various approaches to reduce postprocedural abdominal discomfort either in screening or therapeutic colonoscopy [8–13]. In several randomized trials, CO_2 insufflation has been shown to be safe and effective in reducing postcolonoscopy abdominal discomfort [10,14–17]. In these studies, questionnaires using a linear analog scale were often used to evaluate patient discomfort. Moreover, unlike abdominal pain and distension, anal incontinence after colonoscopy often leaves patients feeling embarrassed

and dissatisfied with the procedure. Hoff et al. reported that incontinence was significantly less frequent in patients undergoing colonoscopy with CO_2 insufflation than those receiving air insufflation [18]. Current European guidelines therefore strongly recommend the use of CO_2 insufflation for colonic endoscopic procedures [19]. However, despite the abovementioned clinical evidence, the impact of CO_2 insufflation on the frequency and duration of toilet use remains unknown.

The aim of the current randomized controlled trial (RCT) was to assess the impact of CO_2 insufflation on toilet use after colonoscopy. Radiofrequency identification (RFID) technology was used to monitor the activity of participants after the procedure and to objectively measure the number and duration of visits to the toilet. It was hypothesized that CO_2 insufflation would reduce not only discomfort after the procedure but also the frequency and duration of toilet visits.

Patients and methods

Patient enrollment and randomization

This study was designed as a randomized, double-blind, and controlled trial. From March to August 2013, individuals who underwent a screening colonoscopy as part of a thorough health check-up were evaluated for eligibility and recruited for the study at the Heath Management Center of the National Taiwan University Hospital, Hsin-Chu branch. Individuals were considered eligible if they were between the age of 40 and 80 years. Individuals with chronic lung disease and severe heart disease were excluded.

All participants gave written informed consent at enrollment. The trial was approved by the institutional review board of the ethics committee and was registered on the clinical trial website http://www.clinicaltrials.gov (NCT01807312). Participants were randomly assigned using a computer-generated number list to either the air or CO_2 insufflation group.

Bowel preparation, endoscopic procedure, and blinding

Study participants were asked to begin a low-residue diet 3 days before colonoscopy. On the day of the procedure, all participants were asked to ingest 2 L of polyethylene glycol (PEG) solution (Niflec powder, 131.75 g; China Chemical and Pharmaceutical Co., Ltd., Hsin-Chu, Taiwan; containing 21.3 g sodium chloride, 10.8 g potassium chloride, 24.5 g sodium bicarbonate, 82.9 g sodium sulfate anhydrous) 6 hours prior to colonoscopy. This reduced-volume PEG-electrolyte lavage solution has demonstrated effectiveness, producing high rates of excellent and good cleansing effect in previous studies including from our group [20 – 23]. All participants were asked to urinate before colonoscopy in order to minimize the influence of urination on the frequency and duration of postcolonoscopic toilet visits.

The Olympus CF-Q260AI colonoscope (Olympus, Optical Co., Ltd., Tokyo, Japan) was used for all colonoscopy examinations. In the CO_2 insufflation group, CO_2 was insufflated during colonoscopy using the Olympus UCR endoscopic CO_2 regulation unit. In the air insufflation group, air was insufflated using an ordinary air-inlet system. All colonoscopies were performed by experienced gastroenterologists who had performed at least 2000 procedures. Sedation was administered by an anesthesiologist using propofol (20 – 150 mg), midazolam (2.5 mg), and fentanyl (50 – 100 µg). The cecal intubation time, total procedure time, and endoscopic treatment performed during colonoscopy were all recorded.

Before colonoscopy, the gas generator system was covered by drapes, and one dedicated study nurse in the endoscopy suite controlled the gas selection according to the results of the allocation. The study participants, endoscopists, assistant nurses, and nurses in the recovery room were all blinded to the insufflation gas used both during and after the procedure.

Recording participant activity after procedure

Recently, radiofrequency identification (RFID) technology, a "wireless automatic identification and data capture" technology, has emerged as a multidimensional innovation that can accelerate the transformation of healthcare processes and offers a better means of patient identification, tracking, and tracing [24]. In the current study, all participants were confined to a closed area at the Health Management Center from their arrival at the Center until they left after all health check-up examinations had been completed. Because colonoscopy was scheduled for the morning, the RFID technique enabled the activity of the participants to be recorded after colonoscopy, and allowed the frequency and duration of toilet visits to be measured in an objective and accurate way.

An RFID reader (Cimtrac CW401 UHF Reader, WistronNeWeb Corp., Hsin-Chu, Taiwan) was positioned and set at the entrance of every toilet in the screening center. After the colonoscopy procedure, an individual RFID tag was attached to the clothing of each participant in order to trace his or her activity. The frequency and overall duration of toilet visits were recorded for 2 hours after colonoscopy.

Assessment of abdominal pain and bloating

To assess abdominal pain and bloating after the procedure, participants were assessed in the recovery room by nursing staff who were blinded to the allocation. A questionnaire incorporating a visual analog scale (VAS) was used for assessment. The score was graded from 0 (no pain at all; no bloating at all) to 10 (extremely painful, completely intolerable; extremely bloating). Participants were asked to select the score at two times: at the end of the colonoscopy (defined as when participants awoke and returned to an ordinary state in the recovery room) and at 2 hours after the endoscopist had completed the procedure.

Study end points

The primary outcome was the number of toilet visits and the duration of these visits after the procedure. The secondary outcomes were the severity of abdominal pain and bloating, both of which were assessed using the VAS.

Sample size estimation and statistical analysis

The sample size calculation was based on a previous unpublished pilot study using air and CO_2 insufflations at colonoscopy, which we conducted during May and June 2012 prior to the current study. In the pilot study, 10/13 participants (76.9 %) in the air group used the toilet after colonoscopy compared with only 4/17 participants (23.5 %) in the CO_2 group. The mean frequency of toilet visits was 1.3 times in the air group and 0.29 times in the CO_2 group. The mean duration of each toilet visit was 6.61 minutes in the air group and 1.47 minutes in the CO_2 group. The sample size was calculated to be 20 per group based on the frequency of toilet visits and 15 per group based on the duration of toilet visits in order to detect a significant difference in the two groups with a two-sided 5 % significance level and a power of 90 %. Because participants would be required to remain in the Health

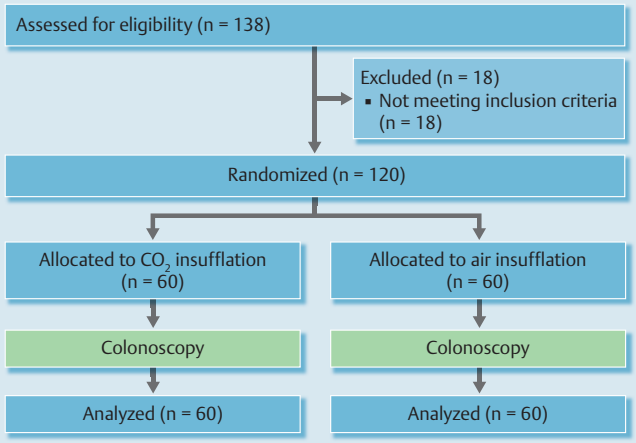

Fig. 1 CONSORT diagram of participants through the study.

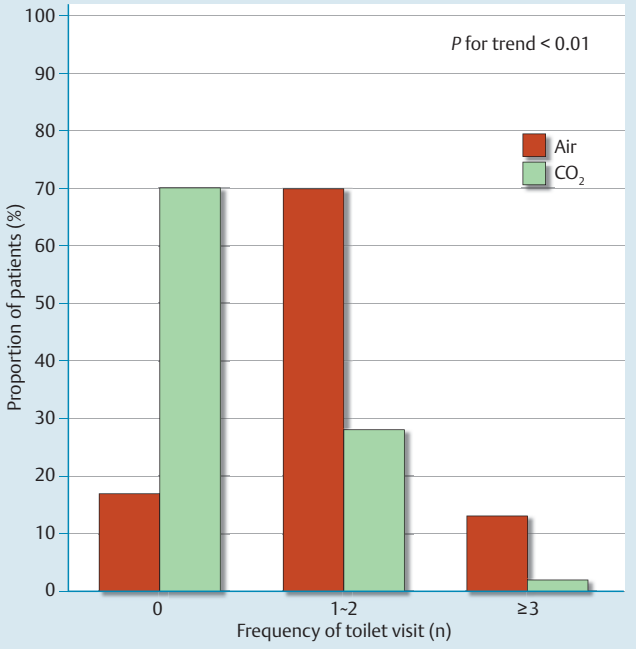

Fig. 2 The frequency of toilet visits after colonoscopy in the air and CO_2 groups ($P<0.001$ by chi-squared test).

Management Center for 2 hours after the colonoscopy, the refusal rate was not expected to be low. Based on the above calculations, the likely drop-out rate (i.e. those leaving the Center soon after the procedure), skewing from the pilot study results, and the possibility of the RFID missing visits, it was finally decided to extend the sample size to 60 participants per group.

Numeric variables were reported as mean (±SD) and categorical variables were reported as percentages. The two-sided *t* test was used to compare the means of numeric variables between the two groups, and the chi-squared test was used for categorical variables. For the number of toilet visits, the frequency was trichotomized into three groups: 0, 1–2, ≥3, and compared using the Cochrane–Armitage trend test. A *P* value of <0.05 was considered to be statistically significant. Statistical analysis was performed using SPSS statistical software, version 20.0 (IBM Corp., Armonk, New York, USA).

Tab. 1 Demographic characteristics of study participants in both groups.

	Air (n=60)	CO_2 (n=60)	*P* value
Age, mean ± SD, years	56.3 ± 9.6	54.7 ± 8.9	0.33
Male sex, n (%)	31 (52)	37 (62)	0.36
BMI, mean ± SD, kg/m^2	23.7 ± 3.1	24.5 ± 4.5	0.28
Procedure time, mean ± SD, minutes			
Time to cecal intubation	7.6 ± 5.4	7.0 ± 4.9	0.47
Total procedure time	14.5 ± 5.9	14.2 ± 6.1	0.76
Polypectomy, n (%)	14 (23)	17 (28)	0.68

BMI, body mass index.

Results

Demographics

A total of 138 individuals were screened for eligibility, 18 of whom were excluded due to being either older than 80 years or younger than 40 years (**Fig. 1**). The remaining 120 individuals were then randomly assigned to receive insufflation with either CO_2 (n=60) or room air (n=60). All 120 participants completed the study. Demographic characteristics of participants are shown in **Table 1**. There were no significant differences in terms of age, sex, and body mass index (BMI). There was also no statistical difference between the two groups regarding insertion time, total procedure time, and the proportion that underwent polypectomy. No significant adverse events (perforation, bleeding, and cardiopulmonary events) occurred during the period up to 2 weeks after colonoscopy.

Primary outcome – frequency and duration of toilet visits

The primary outcome of the study was the frequency and duration of toilet visits after colonoscopy, and these results are shown in **Fig. 2**. During the 2 hours after colonoscopy, 50 participants (83%) in the air group and 18 (30%) in the CO_2 group visited the toilet at least once ($P<0.001$) (**Fig. 2**). The mean duration of each toilet visit within 2 hours after colonoscopy was significantly shorter in the CO_2 group than in the air group (1.53 ± 2.84 minutes vs. 5.93 ± 4.65 minutes; $P<0.001$) (**Fig. 3**). The timing and duration of toilet visits in each group are shown in **Fig. 4**.

Secondary outcome – abdominal symptoms

The results of secondary outcomes are summarized in **Table 2**. All patients answered the questionnaire at the end of colonoscopy and 2 hours after the procedure. At the end of colonoscopy, there was a significant difference in the proportion of pain-free participants and those without bloating between the air and CO_2 groups (no pain: 27% vs. 48%, $P=0.023$; no bloating: 7% vs. 35%, $P<0.001$, respectively). The difference in the mean pain scores and bloating scores between the air and CO_2 group was also significant (pain score: 2.68 ± 2.36 vs. 1.38 ± 1.63, $P<0.001$; bloating score: 4.1 ± 2.53 vs. 1.95 ± 2.00, $P<0.001$, respectively]. These trends were similar when evaluated at 2 hours after colonoscopy.

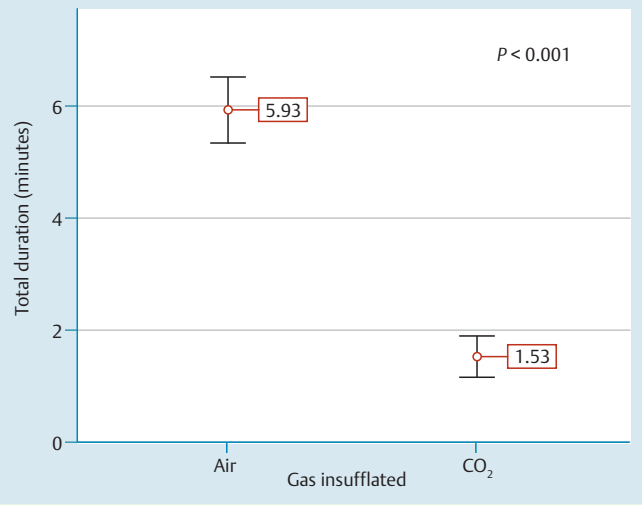

Fig. 3 Comparison of mean total duration of toilet visits after colonoscopy in the air and CO_2 groups. White dots are means, and bars are 95% confidence intervals.

Tab. 2 Abdominal pain and distension scores at the end of the procedure and 2 hours after colonoscopy.

	Air (n = 60)	CO_2 (n = 60)	*P* value
End of colonoscopy			
No pain, n (%)	16 (27)	29 (48)	0.023
Pain score, mean ± SD	2.68 ± 2.36	1.38 ± 1.63	< 0.001
No bloating, n (%)	4 (7)	21 (35)	< 0.001
Bloating score, mean ± SD	4.10 ± 2.53	1.95 ± 2.00	< 0.001
2 hours after colonoscopy			
No pain, n (%)	19 (32)	44 (73)	< 0.001
Pain score, mean ± SD	2.18 ± 2.18	0.55 ± 1.06	< 0.001
No bloating, n (%)	11 (18)	35 (58)	< 0.001
Bloating scores, mean ± SD	2.73 ± 2.25	0.82 ± 1.23	< 0.001

Discussion

This randomized trial showed that insufflation with CO_2 as a replacement for air resulted in not only less abdominal discomfort after colonoscopy, but also decreased the frequency and total duration of toilet use after the procedure. The finding of a rapid decrease in frequency and duration of toilet use in the first 20 minutes after colonoscopy with CO_2 insufflation indicates a potential role in shortening the toilet queue and allowing early discharge from endoscopy suites. This result will not only impact on the adherence of participants to the screening/surveillance program, but may also influence the space planning and toilet facilities required in the endoscopy suite, and thus indirectly influence both the length of time patients have to wait in the unit for their screening procedure and, ultimately, the waiting time to an appointment date. This study is actually the first RCT to demonstrate a reduction in the frequency and total duration of toilet use after colonoscopy with CO_2 insufflation.

Colonoscopy is generally considered to be an uncomfortable procedure due to postprocedure abdominal pain and distension. Denters et al. found that individuals who underwent colonoscopy

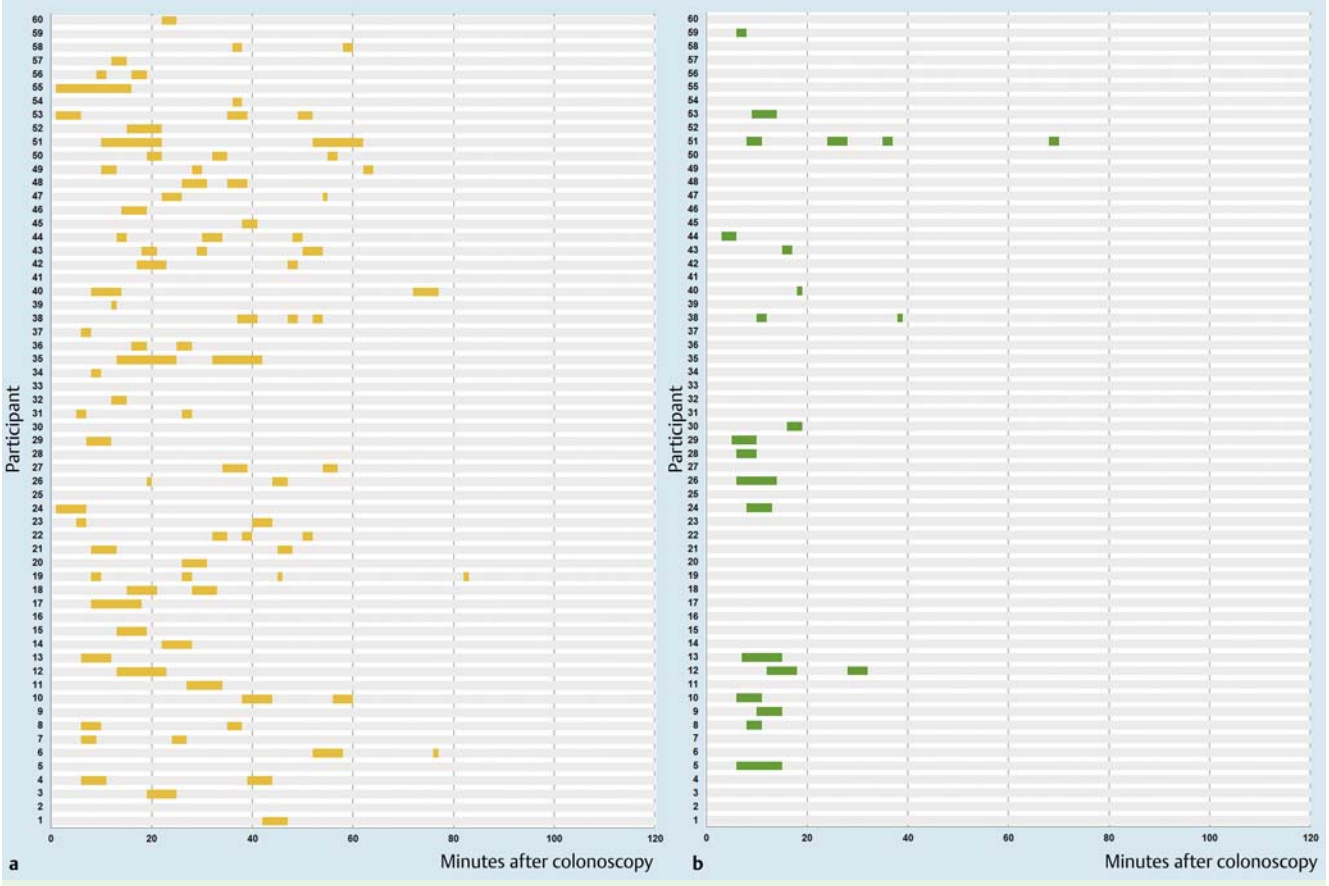

Fig. 4 Plot of the timing and duration of toilet visits according to the radiofrequency identification recording system. **a** Air group. **b** CO_2 group.

were bothered by abdominal complaints for several days following the procedure, and that postcolonoscopy abdominal complaints were deemed as the most burdensome elements together with bowel preparation in a fecal immunochemical test (FIT) screening program [25]. Residual bowel gas is the key cause of abdominal pain. Absorption of CO_2 is more rapid than that of room air and results in less bowel distension [26]. A meta-analysis of nine RCTs by Dellon et al. showed that CO_2 insufflation increases the proportion of pain-free patients at 1 and 6 hours after colonoscopy [13]. Another meta-analysis study by Wang et al. indicated that the CO_2 group had lower pain VAS scores at the end of the procedure and up to 3 hours after colonoscopy compared with the air group [27]. In the current study, 48% and 35% of the participants in the CO_2 group were free from pain and bloating at the end of colonoscopy, and 73% and 58% were free from the complaints at 2 hours. These findings support the observations of previous RCTs that CO_2 insufflation can significantly reduce abdominal discomfort compared with air insufflation [10, 13, 14].

In the USA, many people undergo their colonoscopies in an office-based setting rather than in a hospital [28]. In Canada, a cohort study by Rabeneck et al. reported that about 14% of colonoscopies were performed in private offices [29]. In Taiwan, nationwide CRC screening is performed with FIT-based screening, and about 20% of confirmatory colonoscopy performed after a positive FIT result take place in small hospitals or clinics (unpublished government data). In such settings, sufficient toilet facilities are as important as the endoscopy facility, and may largely impact on the length of time patients have to wait in the unit for their screening procedure and, ultimately, the waiting time to an appointment date. In this respect, use of CO_2 insufflation provides a useful solution and more efficient use of the limited space in the office or endoscopy unit. Though further research is necessary to quantify the workload and resources that are saved by using CO_2 insufflation, the current study paves the way for further investigation.

The study has several strengths. First, an RFID system was used to record the frequency and duration of toilet visits, and thus more accurate information on facility use could be provided compared with the simple assessment of subjective symptoms performed in previous studies [15, 30]. Second, all participants remained in a closed area for at least 2 hours after colonoscopy, and all evaluations were made face-to-face in the same circumstances, resulting in reliable measurements. Third, only average-risk screening individuals were enrolled, thus the results may well represent the target population of most CRC screening programs.

The study is not without limitations, however. First, the impact of urination or hand washing could not be excluded from the results of frequency and duration of toilet visits. To minimize this impact, all participants were asked to urinate before the colonoscopy procedure; in addition, as the study was a randomized trial, the influence of urination should be similar in the two groups. Second, this study was a single-center study and all colonoscopies were performed by experienced physicians. It is possible that the observed outcomes may not be completely generalizable. Third, only abdominal pain and bloating were assessed during the first 2 hours after colonoscopy, and therefore it was not possible to evaluate the discomfort of patients on their way home or beyond this time. However, the data (**Fig. 4**) showed that toilet visits were concentrated within the first 20 minutes in the CO_2 group and only one visit occurred after the 40th minute. Even in the air group, there were only a few visits to the toilet after the first hour and none after the 100th minute. Based on these findings, it may be concluded that the postcolonoscopy course, including during the journey home, would be much more comfortable in the CO_2 group and only a few toilet visits can be anticipated after 2 hours in both groups, although some degree of mild subjective abdominal discomfort may remain. Regarding the cost, the estimate of the cost of CO_2 insufflation is about US$0.8 per examination at our institution, which is almost negligible compared with the overall cost of colonoscopy (US $70), though these costs may vary across different countries. Although formal economic analysis is lacking, use of CO_2 is obviously a cost-effective approach given its significant impact on the limited space in endoscopy units, colonoscopy queues (especially in the office setting), and improved patient experience.

In conclusion, insufflation with CO_2 during colonoscopy results not only in less abdominal pain and distension, but also a decrease in the frequency and total duration of toilet use after the procedure. Use of this technique may result in less space required for toilet facilities, decreased workload in the endoscopy units or recovery rooms, and probably a reduction in emergency service use. Its impact on public acceptance of CRC screening tests and participation rates for subsequent screening and surveillance needs further study.

Competing interests: None

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