

Research Article

Carbon dioxide versus room air insufflation in colonoscopy: a comparative study

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Abstract

Background: The uptake of colonoscopy by patients is often limited by the pain and discomfort associated with the procedure. Initial studies demonstrate that carbon dioxide may diminish this discomfort. The objective of this study was to compare carbon dioxide and room air insufflation in colonoscopy with respect to endoscopy time, sedation used, oxygen requirement, post-procedure pain and recovery time.

Methods: Patients who underwent complete colonoscopies by any physician at our facility from November 28, 2014-May 29, 2015, using carbon dioxide or room air were selected. Patient charts were reviewed for patient demographics (BMI, age, gender). Intra-procedure measurements included medication utilized, oxygen requirement and endoscopy time; post-procedure data analyzed was recovery time and presence of pain. Data was analyzed utilizing unpaired t-tests.

Results: Endoscopy time was not increased with the use of CO₂ (CO₂ 21.5mins, RA 23.0mins, p=0.081, 95% confidence interval). Oxygen requirement was not significantly changed with the use of CO₂. Post procedure recovery time remained unchanged with CO₂ compared to air insufflation (59.3mins(RA), 61.2mins (CO₂), p-value 0.225, 95% confidence interval), recovery was also not impacted by the procedure (biopsy vs. polypectomy: RA: p-value 0.571; CO₂: p-value 0.138, 95% confidence interval). Post-procedure pain was significantly reduced overall, 15% of patients in the CO₂ group compared to 36% in the RA group (p<0.05, 95% confidence interval).

Conclusion: Carbon dioxide for insufflation reduces the number of patients experiencing post-colonoscopy pain, but does not significantly alter endoscopy time or recovery time for patients.

Introduction

With increasing awareness for colon cancer screening, colonoscopy has become the mainstay in detecting precancerous and cancerous lesions [1]. Currently there are two widely accepted means of insufflation, room air (RA) and carbon dioxide (CO₂). CO₂ as a means of insufflation in laparoscopic surgery has been used for decades [2]. In endoscopy, the use of CO₂ has not been widely used. Majority of the endoscopists continue to utilize RA as supplied by the manufacturer. CO₂ insufflation requires additional equipment for its utilization. In a study by Janssens *et al.* in 2009, less than 5% of their study respondents utilized CO₂ for luminal distention [3], lower than a previous study conducted in the United States, which reported that only 13% of colonoscopies applied CO₂ [4]. A large proportion of those respondents stated that they were either not aware of the ability to use CO₂, while others stated challenges in the implementation of equipment [3].

One of the major sources of discomfort for patients undergoing colonoscopy is the volume of gas, leading to abdominal distention and increased pain. Air absorption within the colonic lumen is poor. However, the use of CO₂ can lead to quick absorption intraluminally into the blood stream and exhaled [5]. Due to its rapid absorption, it might be logical to assume that a larger volume of CO₂ would be required, which may mitigate some of its advantages, yet a study conducted by Bretthauer *et al.* (2003) indicated that similar volumes of RA and CO₂ were utilized by experienced endoscopists [6]. Many studies have demonstrated that the ability of CO₂ to be absorbed by the body reduces intra and post procedural abdominal distention [7]

and pain [8], which is important for patient compliance in follow up procedures.

The intent of the study was to analyze the effects of CO₂ compared to RA insufflation amongst endoscopists at our centre with respect to endoscopy time, sedation required, post-procedure pain and recovery time.

Materials and methods

Study arms

Four study arms were utilized for this study. The first of the groupings (scenario 1) compared the cases of the primary endoscopist at our centre (physician A) prior to January 29th (n=112), to the other 6 physicians (physicians B-G) practicing at our facility utilizing RA (n=114). The objective of this arm was to assess the baseline results of all physicians prior to the universal implementation of CO₂; this allowed for the detection of inter-practitioner variabilities that may influence the results. The second grouping (scenario 2) consisted

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of a comparison between all cases conducted by physician A (prior to Jan 29th & after Jan 29th) (n=209) and all cases conducted by the other 6 physicians (utilizing RA and CO₂) (n=211). Similarly, this scenario was utilized to detect differences in practice between the main endoscopist and the remainder of the physicians, and thus allowed for the assessment of inter-practitioner variability. The third grouping (scenario 3) compared cases of the other 6 physicians utilizing RA (n=112) versus those that employed CO₂ (n=118); this was used as a direct comparison of RA and CO₂ in practitioners who are new to its use. Scenario 3, allowed for the detection of differences, specifically in those who are new to utilizing CO₂. The last grouping (scenario 4) compared all cases utilizing CO₂ (n=333) versus all those that utilized RA (n=112), which allowed again for a direct comparison of RA and CO₂. However, this scenario was utilized to detect differences between the methods that could be generalized to a broader range of physicians and practices.

Patient selection

Patients selected underwent complete colonoscopies utilizing either CO₂ or RA insufflation in the gastrointestinal department at the Brandon Regional Health Centre, a regional referral centre in Brandon, Manitoba, Canada. Patients completed a standard patient consent form for colonoscopy. The study was reviewed and approved by the Gastrointestinal Endoscopy department administration at Brandon Regional Health Centre. All colonoscopies were scheduled and were performed between November 28, 2014 and May 29, 2015. This regional referral site conducts over 3800 colonoscopies each year; the main endoscopist at this site implemented CO₂ into his practice several years ago, however the other physicians only recently began utilizing it for luminal distention on January 29th. Physicians included in this study were either general surgeons or gastroenterologists. Physician A and D have greater than 25 years' experience in colonoscopy; physicians' B and G have greater than 20 years' experience; physician F has greater than 15 years, physician C has greater than 10 years and physician E has 3 years' experience in colonoscopy. Consecutive patients were chosen from each of the study arms, defined above, to be representative of the number of patients scoped by each of the physicians over a 1-year period. Table 1 outlines the percentage of total colonoscopies performed by each of the physicians at our site over the most recent year.

Exclusion criteria

Patients were excluded from the study due to the following: previous large bowel resection, scheduled for endoscopic mucosal resection, incomplete colonoscopy, incomplete recording of data parameters, addition of gastroscopy and those done on an emergent basis.

Parameters assessed

The charts of all patients selected were reviewed and the required data was extracted and recorded. Patient demographic data was obtained to ensure that all groups were similar with respect to age, gender (male: female ratio) and body mass index (BMI) (calculated utilizing the formula mass/height², where mass is in kilograms and height is in centimeters) (Table 2). It should be noted that both height and weight were self-reported by the patient and were not directly measured by the nurse upon patient admission to the Gastrointestinal Department.

Table 1. Percentage of colonoscopies performed by each of the physicians at our site from April 1, 2014-March 31, 2015.

| Physician | A | B | C | D | E | F | G |
|-----------------------|------|-----|-----|-----|-----|-----|-----|
| # Colonoscopies /year | 1023 | 780 | 524 | 156 | 488 | 516 | 319 |
| % of total | 27% | 20% | 14% | 4% | 13% | 14% | 8% |

Intra-procedure measurements assessed included amount of sedation utilized, oxygen (O₂) requirement by nasal prong and endoscopy time. Within the test facility the two medications that are employed for patient sedation during colonoscopies are fentanyl and midazolam. Endoscopy time was measured from the time the scope was introduced, to the time the scope was completely withdrawn.

Post-procedure the patients were assessed for the length of the recovery time and the presence of post procedure pain. For this study, recovery time was defined as the time from admission to the recovery area to time of discharge. The requirements that patients needed to meet prior to discharge were return to pre-procedural baseline of vital signs and sedation/responsiveness. Post-procedure pain was assessed by the nursing staff at three intervals, on admission to recovery, 15 and 30 minutes after admission to recovery. Due to variation in nurse interpretation of pain, for the purposes of this study pain was noted only as present or absent at the intervals.

Data analysis

Data from all three of the previously mentioned scenarios was analyzed utilizing 2 sample unpaired t-tests on Minitab statistical analysis software by the authors to assess for any differences in means between the two samples involved in each scenario. For each of the scenarios the following parameters were assessed utilizing 2 sample unpaired t-tests: age, gender, BMI, amount of fentanyl and midazolam, O₂ requirement, endoscopy time, and recovery time. Post-procedure pain was assessed more thoroughly for each of the scenarios. Pain was assessed in the following ways: overall difference in pain experienced by patients, difference in pain experienced by gender, as well as difference in pain at the assessed time intervals, both overall and by gender.

Results

Scenario 1

Patient demographics (BMI, age and gender) (Table 3), and O₂ requirement (3.0 ± 0.3L vs. 3.1 ± 0.6L, p-value 0.13) were not significantly different at a confidence interval of 95% (physician A n=112; physicians B-G n=114). Endoscopy time was longer in the physician group utilizing RA (23.13 ± 5.96min vs. 18.91 ± 8.00min, p<0.001). Physician A utilized significantly more midazolam in their patients (4.01 ± 1.13mg vs. 3.16 ± 0.82mg, p<0.001), while physicians B-G utilized significantly more fentanyl in their patients (79.9 ± 19.8mcg vs. 57.6 ± 16.9mcg, p<0.001). The amount of time patients required to recover was not significantly altered between the two groups (60.7 ± 13.7mins (physician A) vs. 60.4 ± 16.6mins (physicians B-G), p-value 0.86) and the time for recovery was not significantly shorter for biopsy when compared to more invasive procedures (Physician A: p-value 0.46) (Physicians B-G: p-value 0.39). Patients of physician A overall had less discomfort (13% vs. 35%), upon arrival to the recovery area (13% vs. 31%), or 15 minutes in to the recovery period (4% vs. 12%). Both genders experienced less pain overall (males: 17% vs. 40%) (females: 10% vs. 31%) and at admission to recovery (males: 15% vs. 34%) (females: 10% vs. 28%). At 15 minutes in to the recovery period, males had significantly less pain in the CO₂ group (4% vs. 17%) (Figure 1).

Table 2. Patient characteristics for all patients included in the study

| Characteristics | Total (n=445) |
|---|---------------|
| Age (M [†] ± SD [†]) | 59 ± 14 |
| Female (%) | 222 (50%) |
| Male (%) | 223 (50%) |
| BMI (M ± SD) | 28.7 ± 5.6 |

*M is the mean

†SD is the standard deviation

Table 3. Patient characteristics for scenario 1

| Characteristics | Physician A (before January 29 th (n=112)) | Physicians B-G RA (n=114) | P-value [‡] |
|---|---|---------------------------|----------------------|
| Age (M [†] ± SD [†]) | 58 ± 16 | 59 ± 13 | 0.87 |
| Female (%) | 59 (53%) | 61 (54%) | 0.90 |
| Male (%) | 53 (47%) | 53 (46%) | 0.90 |
| BMI (M ± SD) | 29.1 ± 5.6 | 28.2 ± 5.7 | 0.24 |

*M is the mean

†SD is the standard deviation

‡P-values were calculated utilizing an unpaired t-test

Scenario 2

Patient demographics (BMI, age and gender) (Table 4) and O₂ requirement (3.0 ± 0.2L vs. 3.1 ± 0.5L, p-value 0.07) were not significantly different at a confidence interval of 95%. Endoscopy time was significantly longer in those undergoing evaluations by physicians B-G (24.24 ± 9.43min vs. 19.41 ± 6.26min, p<0.001). Patients who underwent scopes performed by physician A received a statistically significantly higher amount of midazolam (3.92 ± 1.08mg vs. 3.18 ± 0.92mg, p<0.001), while those scoped by physician B-G received significantly more fentanyl (using either RA or CO₂) (79.9 ± 18.8mcg vs. 56.0 ± 17.9mcg, p<0.001). The time patients needed for recovery was not significantly altered between the groups (60.0 ± 12.9mins (Physician A) vs. 61.5 ± 15.8mins (Physicians B-G, CO₂ & RA), p-value 0.28) and when comparing the recovery time for more invasive procedures to biopsy, patients did not require longer recovery time in the more invasive procedures (Physician A: p-value 0.22) (Physicians B-G (CO₂ & RA): p-value 0.12). Patients evaluated by physician A experienced less pain overall (16% vs. 24%), as well as males at 15 minutes after admission to recovery (4% vs. 11%) but no significant difference (at 95% confidence interval) was observed between the two groups at admission to recovery (15% vs. 22%), 15 minutes after admission to recovery (5% vs. 7%) or 30 minutes after admission to recovery (2% vs. 2%). Neither males nor females demonstrated decreased levels of pain overall (males: 18% vs. 27%) (females: 15% vs. 21%), at admission to recovery (males: 16% vs. 24%) (females: 14% vs. 19%), 15 minutes after admission to recovery in females (6% vs. 4%) or 30 minutes after admission to recovery (males: 3% vs. 5%) (females: 2% vs. 0%) (Figure 2).

Scenario 3

Patient demographics (BMI, age, gender) (Table 5), O₂ requirement (CO₂ 3.0 ± 0.2L vs RA 3.1 ± 0.6L, p-value 0.08) and endoscopy time (CO₂ 25.3 ± 10.5min vs RA 23.0 ± 8.0min, p-value 0.07) were not found to be significantly different at the 95% confidence interval. The amount of midazolam (3.20 ± 1.02mg (CO₂) vs 3.17 ± 0.82mg (RA), p-value 0.75) or fentanyl (79.9 ± 20.5mcg (CO₂) vs. 80.2 ± 16.8mcg (RA), p-value 0.88) utilized were not statistically different between the two groups. The time patients spent in the recovery room was not significantly altered between the two groups (59.3 ± 14.4mins (RA) vs. 63.2 ± 16.1mins (CO₂), p-value 0.05) and when comparing the recovery time in the more invasive procedures to biopsy, patients did not require

significantly longer recovery time (RA: p-value 0.57) (CO₂: p-value 0.30). Patients who received CO₂ overall had less pain (13% vs. 36%), when arriving to the recovery room (13% vs. 31%), and 15 minutes in to the recovery period (3% vs. 13%). Both genders experienced less pain overall (males: 16% vs. 40%) (females: 10% vs. 32%) and upon arrival to the recovery area (males: 16% vs. 35%) (females: 10% vs. 29%) (Figure 3).

Scenario 4

Patient demographics (BMI, age, gender) (Table 6), O₂ requirement (CO₂ 3.0 ± 0.2L vs. RA 3.1 ± 0.6L, p-value 0.06) and endoscopy time (CO₂ 21.5 ± 8.5mins vs. RA 23.0 ± 8.0mins, p-value 0.08) were not significantly different at a confidence interval of 95%. Patients who underwent scopes with CO₂ received higher amounts of midazolam (3.17 ± 0.82mg vs. 3.67 ± 1.11mg, p<0.001), while those who were scoped utilizing RA received more fentanyl (80.2 ± 16.8mcg vs. 64.5 ± 22.0mcg, p<0.001). The time patients spent in the recovery room was not significantly altered between the two groups (59.3 ± 14.4mins (RA) vs. 61.2 ± 14.2mins (CO₂), p-value 0.23). When comparing the recovery time in more invasive procedures to biopsy, patients did not require significantly longer time for more invasive procedures (RA: p-value 0.57) (CO₂: p-value 0.14). Overall patients scoped with CO₂ had less pain (15% vs. 36%), when arriving in the recovery area (14% vs. 31%), and 15 minutes in to the recovery period (4% vs. 13%). Both genders experienced less pain overall (males: 17% vs. 40%) (females: 13% vs. 32%) and upon arrival to the recovery area (males: 16% vs. 34%) (females: 12% vs. 29%). At 15 minutes in to the recovery period, males had significantly less pain in the CO₂ group (4% vs. 17%) (Figure 4).

Table 4. Patient characteristics for scenario 2

| Characteristics | Physician A (n=215) | Physicians B-G (n=231) | P-value [‡] |
|---|---------------------|------------------------|----------------------|
| Age (M [†] ± SD [†]) | 60 ± 15 | 59 ± 14 | 0.38 |
| Female (%) | 103 (48%) | 120 (52%) | 0.50 |
| Male (%) | 112 (52%) | 111 (48%) | 0.50 |
| BMI (M ± SD) | 29.2 ± 5.8 | 28.4 ± 5.4 | 0.14 |

*M is the mean

†SD is the standard deviation

‡P-values were calculated utilizing an unpaired t-test

Table 5. Patient characteristics for scenario 3

| Characteristics | Physicians B-G: RA (n=112) | Physicians B-G: CO ₂ (n=118) | P-value [‡] |
|---|----------------------------|---|----------------------|
| Age (M [†] ± SD [†]) | 59 ± 13 | 58 ± 15 | 0.86 |
| Female (%) | 59 (53%) | 60 (51%) | 0.78 |
| Male (%) | 53 (47%) | 58 (49%) | 0.78 |
| BMI (M ± SD) | 28.1 ± 5.4 | 28.5 ± 5.2 | 0.54 |

*M is the mean

†SD is the standard deviation

‡P-values were calculated utilizing an unpaired t-test

Table 6. Patient characteristics for scenario 4

| Characteristics | All RA (n=112) | All CO ₂ (n=333) | P-value [‡] |
|---|----------------|-----------------------------|----------------------|
| Age (M [†] ± SD [†]) | 59 ± 13 | 59 ± 15 | 0.71 |
| Female (%) | 59 (53%) | 163 (49%) | 0.50 |
| Male (%) | 53 (47%) | 170 (51%) | 0.50 |
| BMI (M ± SD) | 28.1 ± 5.4 | 29.0 ± 5.6 | 0.15 |

*M is the mean

†SD is the standard deviation

‡P-values were calculated utilizing an unpaired t-test

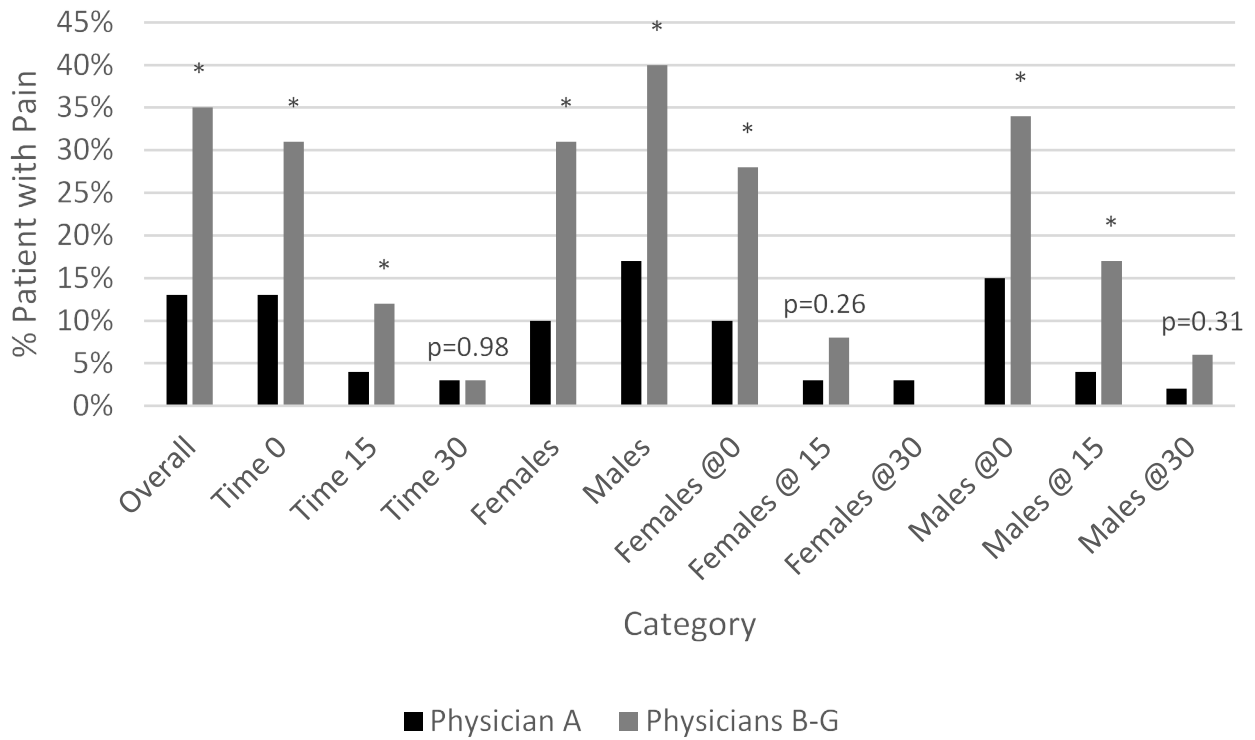


Figure 1. Post-colonoscopy pain experienced by patients at various time points of recovery for scenario 1. * indicates statistical significance at 95% confidence interval ($p < 0.05$) utilizing two sample unpaired t-test.

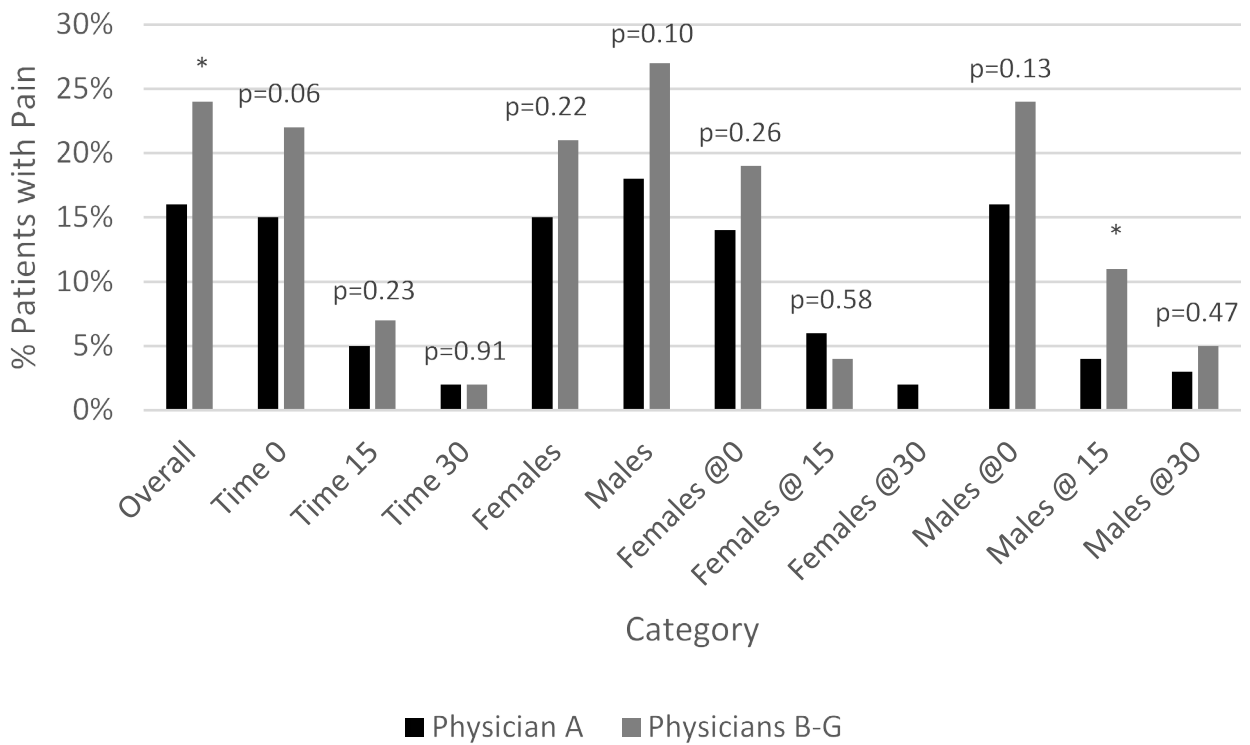


Figure 2. Post-colonoscopy pain experienced by patients at various time points of recovery for scenario 2. * indicates statistical significance at 95% confidence interval ($p < 0.05$) utilizing two sample unpaired t-test.

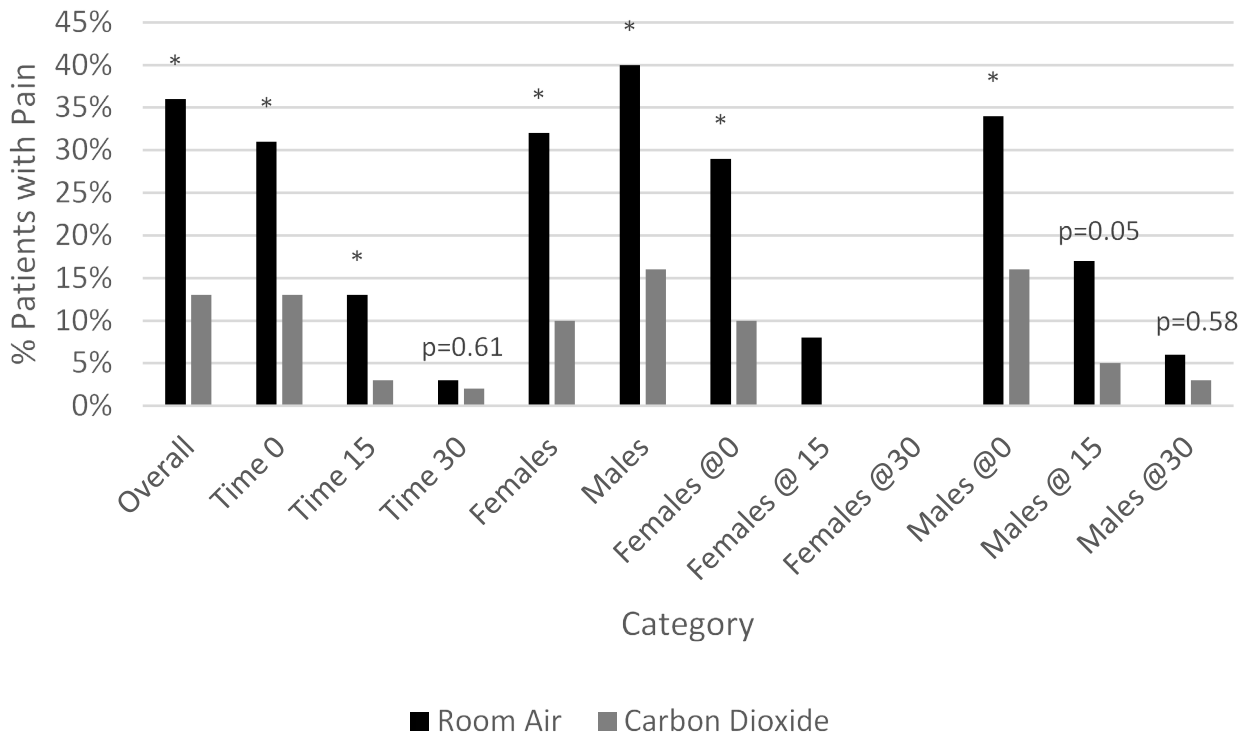


Figure 3. Post-colonoscopy pain experienced by patients at various time points of recovery for scenario 3. * indicates statistical significance at 95% confidence interval ($p < 0.05$) utilizing two sample unpaired t-test.

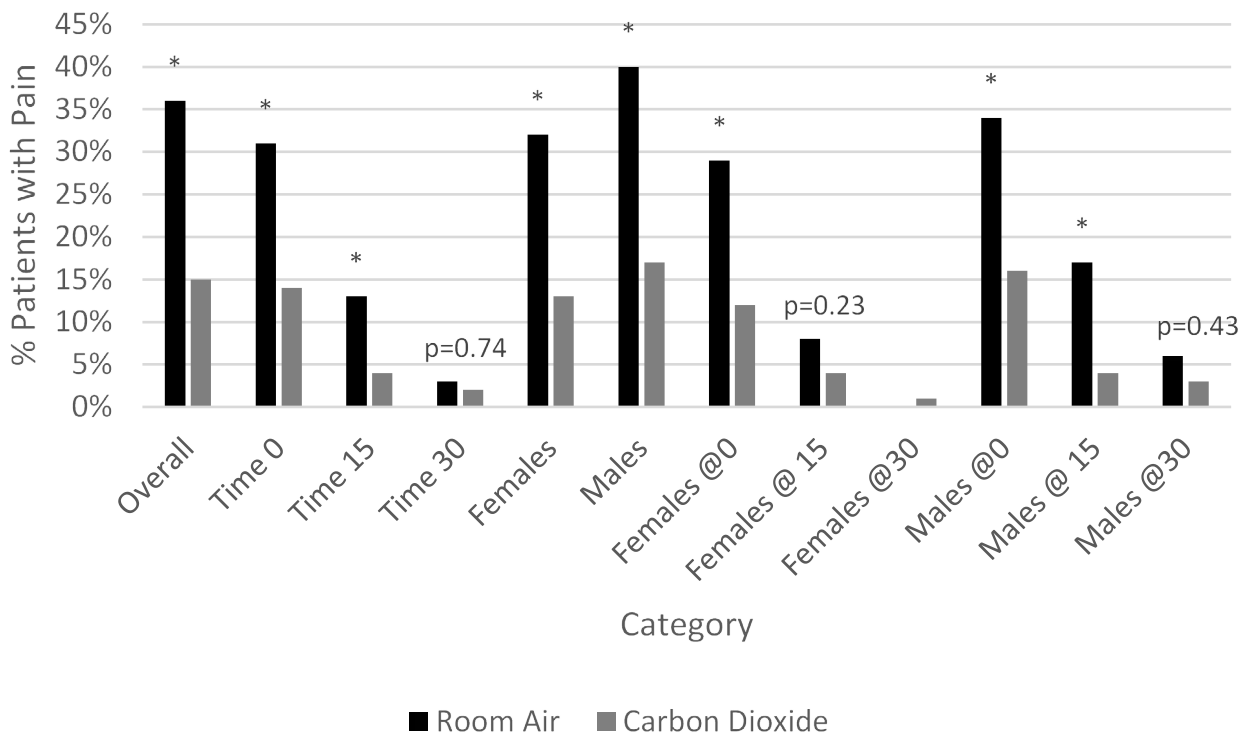


Figure 4. Post-colonoscopy pain experienced by patients at various time points of recovery for scenario 4. * indicates statistical significance at 95% confidence interval ($p < 0.05$) utilizing two sample unpaired t-test.

Discussion

The use of colonoscopy is the main method of detection of colon polyps and cancer. Many individuals are reluctant to undergo colonoscopy due to their perception of pain associated with the procedure. CO₂ has been suggested as a means of reducing patient discomfort for several years [4,5]. A barrier to the implementation of any intervention in health care is the cost of its use. However, CO₂ is relatively inexpensive, in a study conducted by Wong *et al.* in 2008 calculated that its use cost less than 0.84 euros extra per patient when compared to the use of RA [9]. The use of CO₂ has also been found to be safe for use with electrosurgical instruments, as such it is a viable method for use in all colonoscopic procedures [10].

Within all scenarios, the patient profile was similar between all groups. Intra-procedure O₂ requirement did not change with the introduction of CO₂ insufflation, thus indicating that the respiratory drive of patients did not change. CO₂ is likely safe in all patients, as O₂ requirements were not increased, and patients with chronic lung disease were not excluded. However, the data for end-tidal CO₂ (ETCO₂) was not assessed in this study as it was not readily available on all patients. To confirm these findings, it would be necessary to study the ETCO₂ of patients undergoing colonoscopy. Previous studies assessing ETCO₂ have been mixed with some demonstrating an increase, while others demonstrating no change in levels [11,12].

Endoscopy time was largely dependent on the individual endoscopist. Physicians new to the use of CO₂ did not significantly increase their endoscopy time when compared to their baseline. Physicians adapted quickly to the use of CO₂ method of insufflation.

The amount of administration of medications appear to be largely physician dependent during the procedure. Some physicians prefer to utilize higher amounts of midazolam, while others prefer fentanyl. The use of CO₂ did not alter significantly their prescribing practices, however, the impression by the nursing staff is that physicians utilize less medication with CO₂. At our institution, nursing staff are under the impression that patients who underwent colonoscopy with CO₂ had shorter recovery times. However, the difference was not significant when analyzing the data. Many confounding factors may have skewed the data, including patients waiting for their family to pick them up, lab work that needed to be completed or waiting to speak with their endoscopist. Discharge criteria utilized by the unit was not altered after the implementation of CO₂. Some nursing staff were still waiting for patients to pass flatus and were monitoring for bowel sounds. As CO₂ is readily absorbed into the bloodstream and expired, these criteria may no longer be appropriate. There was no difference in recovery time between patients undergoing colonoscopy with or without biopsy versus polypectomy. A difference in recovery time was also postulated by Belle *et al.*, but they were also unable to detect a difference in their study [7]. They attributed this inconsistency to differences between clinical assessment done by nursing staff and guidelines [7].

Overall, pain was improved with the use of CO₂. This can be explained by the mechanism of clearance of the CO₂, as it can be rapidly absorbed which means less abdominal distention and thus less discomfort. A study conducted by Belle *et al.*, demonstrated less abdominal distention with CO₂ by measuring abdominal girth before and after colonoscopy [7]. Similarly, two randomized control trials demonstrated minimal colonic gas in the large intestine was discovered by abdominal radiograph 1-hour post-procedure with CO₂ (94% CO₂ vs. 2% RA), and minimal residual gas in the small intestine (87% CO₂ vs. 55% RA) [13,14]. In our study, significantly less patients experienced

pain at 15 minutes in to recovery, but at 30 minutes this difference did not reach statistical significance. Studies have demonstrated that the benefits of CO₂ with respect to pain can last from 6 to 24 hours [8,15]. Matyja *et al.* found that CO₂ in unsedated colonoscopy did not reduce pain immediately or 15 minutes after the procedure, but a slightly lower pain intensity was observed 60 minutes after the procedure, although did not reach statistical significance [16]. Procedures conducted in their study were also very short (an average of 11 minutes each), postulating that in shorter procedures the use of CO₂ did not impact the post-procedure pain [16].

Overall decreased pain is seen in both genders in those undergoing colonoscopy with CO₂. The level of physician experience is an important factor in predicting patient discomfort, with patients experiencing less pain during and after the procedure was noted in our study.

Limitations

Due to the small sample size and ability to measure pain, which is subjective in nature, the extent of the benefits of CO₂ over RA insufflation in post-procedure discomfort are difficult to assign a metric especially in a sedated patient with different indications for colonoscopy. Data from multiple endoscopists, with different skill sets and training, were included which may have influenced the outcomes. Lastly, as data was collected from charts, data directly from the patients could not be obtained.

Future directions

Further studies should focus on assessing the extent to which pain is decreased in patients when CO₂ is utilized, as well as to investigate intra-procedure discomfort experienced by patients. The advantage of CO₂ should also be assessed in gastroscopy and endoscopic retrograde cholangiopancreatography.

Conclusion

Data obtained in this study suggests that utilizing CO₂ for insufflation leads to a better overall patient experience, with less discomfort during and after the procedure. With less discomfort, patients may be more likely to present for follow up procedures, furthermore cost saving could be realized with earlier discharge as suggested by clinical impression from nursing staff. It also suggests that physicians do not need to significantly change their practice, with respect to medication administration and endoscopy time.

Author contributions

Both authors contributed equally to following: conception and design; analysis and interpretation of the data; drafting of the article; critical revision and final approval of the article

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Competing interests:

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