Carbon dioxide insufflation is associated with increased serrated polyp detection rate when compared to room air insufflation during screening colonoscopy

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ABSTRACT
Background and study aims Sessile serrated adenomas (SSA) and traditional serrated adenomas (TSA) have been increasingly recognized as precursors of colorectal cancer. The aim of this study was to compare the effect of carbon dioxide insufflation (CO2I) vs. room air insufflation (AI) on serrated polyp detection rate (SPDR) and to identify factors associated with SPDR.

Patients and methods Single-center retrospective cohort study of 2083 screening colonoscopies performed with AI (November 2011 through January 2013) or CO2I (February 2013 to June 2015). Data on demographics, procedure characteristics and histology results were obtained from a prospectively maintained endoscopy database and chart review. SPDR was defined as proportion of colonoscopies in which ≥1 SSA, TSA or hyperplastic polyp (HP) ≥10 mm in the right colon was detected. Multi-variate analysis (MVA) was performed to identify predictors of SPDR.

Results A total of 131 histologically confirmed serrated polyps (129 SSA, 2 TSA and 0 HP ≥10 mm) were detected. SPDR was higher with CO2I vs. AI (4.8% vs. 1.4%; P < 0.0001). On MVA, CO2I was associated with higher SPDR when compared to AI (OR: 9.52; 95% CI: 3.05–30.3). Both higher body mass index (OR 1.05; 95% CI: 1.02–1.09) and longer colonoscope withdrawal time (OR 1.11; 95% CI: 1.07–1.16) were also associated with higher SPDR.

Conclusion CO2I is associated with higher SPDR when compared to AI during screening colonoscopy. While the mechanism remains unknown, we speculate that the favorable gas characteristics of CO2 compared to room air results in improved polyp detection by optimizing bowel insufflation. These findings suggest an additional reason to prefer the use of CO2 over AI during colonoscopy.
rates ranging from 1% to 22% [14–17]. Both patient- and endoscopist-related factors have been associated with serrated polyp detection rate (SPDR). Intuitively, adequate luminal distention during screening colonoscopy should be of utmost importance in the identification of these premalignant lesions. Recently, carbon dioxide insufflation (CO2I) has become increasingly utilized for colonoscopy due to its favorable patient-related outcomes, such as reduced post-procedural bloating and discomfort when compared to standard room air insufflation (AI) [18]. The recently published ESGE colorectal polypectomy and EMR guideline suggested the use of CO2I for colonoscopy and polypectomy, and recommended the use of CO2 for colorectal EMR [19,20]. However, there is limited data on the impact of CO2I on the detection of premalignant lesions during screening colonoscopy. The aims of this study were to compare SPDR in patients undergoing screening colonoscopy with CO2I versus AI and to identify factors influencing SPDR in an average CRC risk population.

Patients and methods

Study design and patient population

The study was approved by the institutional review board (IRB) of the University of Florida in which a waiver for informed consent was obtained. The prospectively maintained endoscopic database at the University of Florida Health (UF Health) was retrospectively reviewed to search for patients who had undergone a screening colonoscopy between November 2011 and June 2015. Eligible patients included those ≥50 years with an average CRC risk. Patients were excluded if they had a personal or first-degree relative family history of CRC, history of colon polyps, inflammatory bowel disease, gastrointestinal bleeding, history of partial colon resection, incomplete/aborted procedures, and any colonoscopy performed for an indication other than CRC screening. Informed procedural consents were obtained from all patients. AI was used for luminal distention in all procedures performed before January 21, 2013. Following this date, the routine use of CO2I was adopted universally for all endoscopic procedures at UF Health.

Colonoscopy procedure

Screening colonoscopies were performed by 1 of the 20 experienced, board-certified gastroenterologists at the University of Florida. Each endoscopist had an experience of over 1000 colonoscopies. All participating gastroenterology (GI) trainees (first to third year of fellowship training) were under the direct supervision of one of these endoscopists. The bowel preparation agent most commonly used was 4 liters of polyethylene glycol solution. Bowel preparation quality was rated as excellent, good, fair, or poor based on the Aronchick scale [21]. All procedures were performed under provider or anesthesiologist administered conscious sedation (fentanyl and midazolam) or propofol sedation. Cecal intubation was confirmed by the identification of landmarks (i.e. ileocecal valve and/or appendiceal orifice). Total procedure time (defined as the time interval between scope insertion to removal from the patient) and withdrawal time (defined as the amount of time spent examining the mucosa as the colonoscope is withdrawn from the cecum to the rectum) were prospectively documented in the electronic report by the assisting nurses. High-definition monitors (NDS Radiance SC-WX32-A1511, NDS Radiance G2, or FSN FSL3202D) were used for all colonoscopies during the study period.

Data collection

Patient demographics and histopathology of polyps were obtained from chart review. Demographic data included age, gender, body mass index (BMI) and the American Society of Anesthesiology (ASA) physical status grade. Polyps were classified according to the revised Vienna criteria and World Health Organization classification system [22,23]. Polyp histopathology was divided into adenomatous (classified as tubular, tubulovillous, villous or adenocarcinoma) and serrated (classified as sessile, traditionally serrated or hyperplastic). Dysplasia was defined as either low grade or high grade.

Procedural characteristics were obtained from the prospective maintained report generating database. These included: type of sedation (conscious vs. propofol), grading of bowel preparation, trainee participation, procedural times, cecal intubation, and if polyps were detected and removed. Adverse events were defined as per the American Society of Gastrointestinal Endoscopy (ASGE) established criteria [24] and were identified by reviewing the colonoscopy report and the post-procedural note in the electronic record.

Definitions and study outcomes

Colonoscopy data were analyzed to calculate the polyp detection rate (PDR) (proportion of colonoscopies in which ≥1 polyp was detected), ADR (proportion of colonoscopies in which ≥1 histologically confirmed adenoma was detected) and the SPDR (proportion of colonoscopies in which ≥1 histologically confirmed SSA, TSA or HP ≥10 mm in the right colon was detected). The right colon was defined as the cecum, ascending colon, transverse colon and splenic flexure whereas the left colon included the descending colon, sigmoid colon and rectum.

The primary aim of this study was to compare the SPDR in patients undergoing screening colonoscopy with AI versus CO2I. A secondary aim was to identify variables associated SPDR in our cohort.

Statistical methods

Baseline characteristics between the two cohorts (AI and CO2I) were compared by (a) the t-test with the Satterthwaite correction for unequal variances for quantitative variables (age, BMI,
Univariate analysis was conducted by univariate and multiple logistic regression. The odds ratios for quantitative independent variables reflect the ratio of odds, for 2 subjects with 1 with a value 1 unit higher than the other, but otherwise equivalent on other covariates in the model—if any—higher value to lower value. The multivariate model estimates the odds ratio (and compares it to the null value of 1.00) adjusting for all other variables in the model. Significance in the multiple regression model means that the variable has independent significant prognostic value that cannot be accounted for by the other variables in the model. All P-values are 2-sided. SAS (Statistical Analysis Systems) version 9.4 was used in all of the analyses.

Results
Baseline characteristics
A total of 2083 screening colonoscopies were performed from November 2011 until June 2015. Overall, mean age was 59 ± 8.7 years and 46% were men. Of these colonoscopies, 634 (30.4%) were performed with AI compared to 1449 (69.6%) with CO₂I (Table 1). There were no significant differences in age, gender, BMI or ASA grade between the AI vs. CO₂I groups.

Both the total procedural and withdrawal time were slightly longer in patients undergoing colonoscopy with AI vs. CO₂I. Cecal intubation rate was similarly high in both groups (99.1% with AI vs. 98.1% with CO₂I; \(P = 0.1\)). GI trainees were more commonly involved in colonoscopies with AI (49.1%) vs. CO₂I (38%) (\(P < 0.001\)). In aggregate, quality of the bowel preparation was rated better in patients undergoing colonoscopy with AI vs. CO₂I (\(P = 0.002\)).

Polyp characteristics and detection rate
A total of 1835 polyps were detected in this study, of which 1120 were adenomas, 131 were serrated polyps (129 SSAs, 2 TSAs and 0 HP\(\geq 1\) cm in right colon) and 584 HPs. The median number of colonoscopies performed per endoscopist was 46 (range: 3–496). The overall PDR was 45% (range 0–69.2), ADR was 30.9% (range 0–60), and SPDR 3.7% (0–12.3). The colonoscopy performance characteristics per endoscopist are summarized in Table 2.

Detection rates between patients undergoing screening colonoscopy with AI vs. CO₂I are shown in Fig. 1. The PDR was significantly higher in the CO₂I group vs. AI group (46.5% vs. 41.6%; \(P = 0.02\)). Similarly, SPDR was also significantly higher in patients undergoing colonoscopy with CO₂I vs. AI (4.8% vs. 1.4%; \(p < 0.0001\)). There was no statistically significant difference in ADR between the two groups. In aggregate, there were no HPs \(\geq 10\) mm detected. Most of the HPs removed (95.3%) were...
located in the left colon. There was no statistically difference in the detection rate of HPs in the CO2I and AI groups (16.2% vs. 13.7%; \( P = 0.17 \)).

We also examined whether SPDR varied during different time intervals of the study period. For AI, the SPDR was 1.82% (11/2011 through 6/2012) and 0.83% (7/2012 through 12/2014), and 5.44% (1/2015 through 6/2015). There was no statistically significant difference in SPDR between the time intervals evaluated.

### Variables associated with SPDR

Univariate and multiple logistic regression analyses were performed to identify variables associated with SPDR (Table 3). Patient characteristics such as higher BMI was positively associated with SPDR on both univariate (OR 1.04; 95% CI: 1.02 – 1.06; \( P = 0.0008 \)) and multivariate (OR 1.05; 95% CI: 1.02 – 1.09; \( P = 0.0004 \)) analyses. While both scope withdrawal time and total procedure time correlated positively with SPDR on univariate analysis, only scope withdrawal time (OR 1.11; 95% CI: 1.07 – 1.16; \( P < 0.0001 \)) was found to positively impact SPDR on multivariate analysis. CO2I was associated with a higher SPDR when compared to AI on both univariate (OR: 3.91; 95% CI: 1.87 – 8.20; \( P = 0.0003 \)) and multivariate analysis (OR: 9.52; 95% CI: 3.05 – 30.3; \( P = 0.0001 \)). Other covariates, including quality of bowel preparation, trainee involvement, and method of sedation (conscious sedation vs. propofol) were not significantly associated with SPDR.

The type of colonoscope (standard vs. high-definition) was not readily available for all procedures; consequently, this data was not included in the multivariate analysis. Overall, there was no difference in SPDR in the CO2I group based on the type of colonoscope (4.72% with standard vs. 4.5% with high-definition; \( P = 0.97 \)). Similarly, the type of colonoscope did not affect the SPDR in patients undergoing colonoscopy with air insufflation (1% with standard vs. 1.4% with high-definition; \( P = 0.77 \)).

### Adverse events

There were no procedural or sedation-related adverse events reported on either the prospective colonoscopy database or on the post-procedural note on chart review. A total of 6 cases were aborted prematurely due to patient discomfort/intolerance. Out of these, 4 cases were in the AI vs 2 in the CO2I group (\( P = 0.07 \)).

### Discussion

The effectiveness of screening colonoscopy at reducing the morbidity and mortality associated with CRC is invariably dependent on the optimal detection and resection of premalignant cancerous lesions. Serrated polyps, particularly sessile serrated adenomas, can be difficult to detect endoscopically and may be in part responsible for the decreased performance of colonoscopy in the right colon and a significant proportion of interval CRCs. In this study, CO2I during screening colonoscopy was shown to be associated with a higher SPDR when compared to AI. Furthermore, both higher BMI and longer colonoscope withdrawal time positively correlated with SPDR. CO2I has been increasingly advocated as an alternate method for luminal distention to AI. Several studies have reported that CO2I compared to AI is associated with decreased bloating and pain in patients undergoing routine colonoscopy [25 – 27]. Yet, the available data on the effect of CO2I on the detection of precancerous lesions during screening colonoscopy is limited. In this study, we demonstrate that SPDR was significantly higher during screening colonoscopy with CO2I vs. AI (4.8% vs 1.4%; \( P < 0.0001 \)). The SPDR in this study is congruent to those previously reported, including a multicenter study by Payne et al demonstrating a cumulative SPDR of 2.8% (range 0 – 9.8%) [28]. Our results indicate that method of insufflation during screening colonoscopy was strongly correlated with SPDR, with CO2I associated with almost a ten-fold higher SPDR when compared to AI (OR 9.52; 95% CI: 3.05 – 30.3; \( P < 0.0001 \)). We speculate that differences in SPDR between CO2I and AI may be related to their gas characteristics. CO2 is absorbed across stomach and liver and is eliminated via exhalation, whereas CO2I is absorbed by the colon without the need for this process.

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**Table 2** Colonoscopy performance per endoscopist.

| Endoscopist | Colonoscopies (n) | PDR (%) | ADR (%) | SPDR (%) |
|-------------|-------------------|---------|---------|----------|
| 1           | 3                 | 0       | 0       | 0        |
| 2           | 10                | 60      | 60      | 0        |
| 3           | 9                 | 66.7    | 55.6    | 0        |
| 4           | 13                | 69.2    | 53.9    | 0        |
| 5           | 86                | 56.7    | 34.9    | 3.5      |
| 6           | 8                 | 25      | 0       | 0        |
| 7           | 24                | 50      | 45.8    | 4.2      |
| 8           | 26                | 46.2    | 26.9    | 3.9      |
| 9           | 45                | 44.4    | 35.6    | 0        |
| 10          | 31                | 61.3    | 48.4    | 6.5      |
| 11          | 46                | 39.1    | 23.9    | 0        |
| 12          | 65                | 47.7    | 35.4    | 12.3     |
| 13          | 14                | 35.7    | 28.6    | 0        |
| 14          | 48                | 39.6    | 31.3    | 4.2      |
| 15          | 198               | 38.4    | 28.8    | 3.5      |
| 16          | 317               | 48.3    | 27.4    | 3.2      |
| 17          | 208               | 48.1    | 36.5    | 3.9      |
| 18          | 199               | 43.7    | 34.7    | 3.5      |
| 19          | 237               | 44.7    | 24.1    | 2.5      |
| 20          | 496               | 41.9    | 29.6    | 4.4      |
| Overall     | 2083              | 45      | 30.9    | 3.7      |

ADR, adenoma detection rate; PDF, polyp detection rate; SPDR, serrated polyp detection rate
Polyp detection rate (%)  Adenoma detection rate (%)
Serrated polyp detection rate (%)  Hyperplastic polyp detection rate (%)

Carbon dioxide insufflation (n = 1449)
Room air insufflation (n = 634)

Carbon dioxide insufflation (n = 1449)
Room air insufflation (n = 634)

Carbon dioxide insufflation (n = 1449)
Room air insufflation (n = 634)

Carbon dioxide insufflation (n = 1449)
Room air insufflation (n = 634)

P = 0.02
P = 0.2
P < 0.001
P = 0.17

Fig. 1 Detection rates between patients undergoing screening colonoscopy with AI vs. CO2I.

Table 3 Variables associated with SPDR.

| Clinical variable                          | Univariate analysis | P value | Multivariate analysis | P value |
|-------------------------------------------|---------------------|---------|-----------------------|---------|
| Age (years)                               | 1.0 (0.97 – 1.03)   | 0.93    | 1.02 (0.99 – 1.05)    | 0.293   |
| Gender (male vs female)                   | 0.828 (0.52 – 1.31) | 0.42    | 1.23 (0.70 – 2.16)    | 0.47    |
| BMI (kg/m²)                               | 1.04 (1.02 – 1.06)  | 0.0008  | 1.05 (1.02 – 1.09)    | 0.0004  |
| ASA score (1 vs 2/3/4)                    | 2.87 (0.39 – 20.9)  | 0.30    | 4.03 (0.44 – 36.6)    | 0.22    |
| Trainee involvement (yes vs no)           | 1.26 (0.80 – 1.98)  | 0.33    | 0.71 (0.39 – 1.30)    | 0.27    |
| Cecal intubation (yes vs no)              | 1.27 (0.17 – 9.41)  | 0.82    | –                     | –       |
| Scope withdrawal time (per minute)        | 1.10 (1.07 – 1.13)  | <.0001  | 1.11 (1.07 – 1.16)    | <0.0001 |
| Total procedure time (per minute)         | 1.05 (1.03 – 1.07)  | <.0001  | 1.01 (0.98 – 1.05)    | 0.59    |
| Quality of bowel preparation (Excellent/good vs fair/poor) | 1.08 (0.65 – 1.77)  | 0.77    | 0.70 (0.35 – 1.42)    | 0.32    |
| Type of scope (high-definition vs standard) | 1.64 (0.39 – 6.83)  | 0.50    | –                     | –       |
| Type of sedation (conscious vs moderate anesthesia care) | 2.13 (0.92 – 4.95)  | 0.08    | 1.14 (0.38 – 3.42)    | 0.82    |
| Method of insufflation (CO2 I vs AI)      | 3.91 (1.87 – 8.20)  | 0.0003  | 9.52 (3.05 – 30.3)    | 0.0001  |

AI, air insufflation; ASA, American Society of Anesthesiologists; BMI, body mass index; SPDR, serrated polyp detection rate
the intestines approximately 150 times faster than room air which accounts for its favorable profile in terms of patient discomfort and bloating [29, 30]. Endoscopists are commonly aware of the deleterious effects associated with room air reten-
tion in the colon and thereby gas aspiration is performed regular-
ly during scope withdrawal. Aggressive gas aspiration may adversely collapse the lumen and impede adequate visualization. We theorize that CO2 may have been aspirated less than room air by endoscopists during withdrawal which in turn resulted in better colon insufflation, yet without overly distending the lumen as to miss low-profile lesions. While this potential difference in insufflation did not affect ADR between the two groups, it may have played a larger role in the effective detection of subtle low-profile lesions and plausibly account for the higher SPDR with CO2I in this study.

Our study demonstrates that withdrawal time positively correlates with SPDR (OR 1.11; 95% CI: 1.07–1.16; P<0.0001). These results are consistent with those previously reported in the literature. In a prospective study of 1354 colonoscopies, de Wijkerslooth et al examined the impact of patient and endoscopist factors on proximal serrated polyph detection [16]. The authors observed that only withdrawal time was associated with a higher proximal serrated polyp detection rate on multi-

The authors included 43 studies of serrated polyp risk associated with obesity and the metabolic syndrome have been strongly correlated with obesity, particularly during scope withdrawal which in turn resulted in better colon insufflation, yet without overly distending the lumen as to miss low-profile lesions. While this potential difference in insufflation did not affect ADR between the two groups, it may have played a larger role in the effective detection of subtle low-profile lesions and plausibly account for the higher SPDR with CO2I in this study.

Original article

This study has several strengths. We performed a comprehensive and detailed assessment of SPDR in 2083 consecutive screening colonoscopies at our institution. Similar to the study by Payne et al [28], SPDR was calculated by the proportion of subjects with at least one histologically proven SSA, TSA or hyperplastic polyp > 10 mm in the right colon. This definition accounts for the probability of misdiagnosing SSA/TSA (as large HPs) and excludes clinically insignificant small HPs in the left colon that may cause an overestimation of SPDR. Furthermore, multiple established quality metrics were prospectively collected over a 4-year period and included in our analysis. Patient (age, gender, BMI, quality of bowel preparation), endoscopist (cecal intubation rate, total procedural and withdrawal time, GI trainee participation) and procedural (type of sedation, type of colonoscope) characteristics were all evaluated for their association with SPDR. Our results demonstrating that both higher BMI and scope withdrawal time positively correlate with SPDR, which is consistent with prior studies. Most importantly, this is the first study suggesting that CO2I is associated with a higher SPDR when compared to AI even after adjusting for potential confounding factors. The results from this study may provide the background for future prospective comparative trials evaluating the effect of different methods of luminal distention (i.e. AI, CO2I, water immersion) on SPDR during screening colonoscopy.

This study also has some limitations. First, this was a single-center study at a tertiary care facility and results may not be generalizable to all ambulatory endoscopic units. Furthermore, this was a retrospective study with its inherent limitations, including baseline differences in gastroenterology trainee involvement, quality of bowel preparation, and procedural times between patients undergoing colonoscopy with AI vs. CO2I. Nonetheless, the impact of these variables on SPDR was assessed and adjusted by performing a logistic regression analysis thereby limiting any confounding effect. Second, other factors, including patient position change during colonoscopy or the specific method of bowel prep administration (i.e. split dose vs. day prior) could not be captured in our database and thereby were not included in the analysis. Furthermore, the type of colonoscope (i.e. standard definition vs. high definition) was not readily available for all procedures. On subgroup analysis, there was no difference in SPDR in each group (AI vs. CO2I) based on the type of colonoscope. However, a significant proportion of procedures (11.6% in AI and 34.2% with CO2I) did not specify the type of colonoscope used, which in turn limits any potential inferences from these findings. While we recognize that differences in the type of colonoscope between the 2 groups may affect the interpretability of our findings, its impact on polyp or ade

noma detection rate remains debatable based on the conflicting available literature [35–37]. The association between withdrawal time and SPDR found in this study must also be interpreted with caution as all colonoscopies, and not only negative screening colonoscopies, were included in the withdrawal time analysis. Furthermore, we recognize that the SPDR could have been affected by inter-observer variability among pathologists at our institution and the potential for histological misclassifi-
cation. The concern for this heterogeneity in pathological as-

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essment is to some extent mitigated by the fact that there were no HPs >10 mm detected in our entire cohort which may have been misclassified as SSAs/TSAs. In addition, we included all endoscopists who performed screening colonoscopies during the study period in order to limit selection bias. Consequently, there was significant variation in the number of procedures performed by each endoscopist thereby limiting our ability to evaluate individual performance characteristics and compare them among all endoscopists. We also acknowledge that, in recent years, there has been a heightened awareness of sessile serrated polyps in the endoscopy community and this could possibly have contributed to a higher SPDR in our cohort of patients undergoing colonoscopy more recently with CO2I. Nevertheless, subgroup analysis (evaluating SPDR in each group in 6-month periods) did not reveal an incremental SPDR with later time periods to suggest that higher SPDR with CO2I was necessarily due to increased pathologist awareness of this diagnosis. Finally, while the adequacy of bowel cleansing has been linked to ADR, the impact of quality of the bowel preparation was not a factor for SPDR in our study (OR: 0.70; 95% CI 0.35 – 1.42; P = 0.32). This apparent discrepancy may be in part explained by the bowel cleansing grading used in this cohort (Aronchick scale), which was specifically designed and validated to compare the efficacy of purgatives rather than outcomes such as SPDR. Furthermore, we acknowledge that the effect of bowel preparation in SPDR cannot be conclusively determine in this retrospective study as actual patient adherence to a specific purgative regimen cannot be determined.

Conclusion

In conclusion, this study demonstrates that CO2I was associated with a higher SPDR when compared to AI. In light of its faster spontaneous absorption across the intestine and decreased association with post-procedural discomfort, we speculate that endoscopists may aspirate less CO2 as compared to room air during colonoscope withdrawal. This in turn may result in improved bowel distention facilitating the detection of precancerous lesions, particularly of flat serrated polyps. These findings suggest an additional reason to prefer use of CO2I over AI during colonoscopy. Both BMI and colonoscope withdrawal time were also shown to positively correlate with SPDR in this study, highlighting the importance of further research on modifying patient- and endoscopist-related factors that may ultimately reduce the risk of these precancerous lesions and CRC.

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Competing interests

None

References

[1] Zauber AG, Winawer SJ, O’Brien MJ et al. Colonoscopic polypectomy and long-term prevention of colorectal-cancer deaths. N Engl J Med 2012; 366: 687 – 696
[2] Siegel R, Desantis C, Jemal A. Colorectal cancer statistics, 2014. CA Cancer J Clin 2014; 64: 104 – 117
[3] Pohl H, Robertson DJ. Colorectal cancers detected after colonoscopy frequently result from missed lesions. Clin Gastroenterol Hepatol 2010; 8: 858 – 864
[4] Snover DC, Jass JR, Fenoglio-Preiser C et al. Serrated polyps of the large intestine: a morphologic and molecular review of an evolving concept. Am J Clin Pathol 2005; 124: 380 – 391
[5] Barret M, Chaussade S, Coriat R. Detection rate of proximal serrated lesions: A new quality indicator for colonoscopy? Dig Liver Dis 2015; 47: 441 – 442
[6] Bettington M, Walker N, Clouston A et al. The serrated pathway to colorectal carcinoma: current concepts and challenges. Histopathology 2013; 62: 367 – 386
[7] Erichsen R, Baron JA, Hamilton-Dutoit SJ et al. Increased risk of colorectal cancer development among patient with serrated polyps. Gastroenterology 2016; 4: 895 – 902
[8] Torlakovic E, Skovlund E, Snover DC et al. Morphologic reappraisal of serrated colorectal polyps. Am J Surg Pathol 2003; 27: 65 – 81
[9] Okamoto K, Kitamura S, Kimura T et al. Clinicopathological characteristics of serrated polyps as precursors to colorectal cancer: current status and management. J Gastroenterol Hepatol 2017; 32: 02358 – 367
[10] Rex DK, Ahnen DJ, Baron JA et al. Serrated lesions of the colorectum: review and recommendations from an expert panel. Am J Gastroenterol 2012; 107: 1315 – 1329; quiz 1314, 1330
[11] Bressler B, Paszat LF, Chen Z et al. Rates of new or missed colorectal cancers after colonoscopy and their risk factors: a population-based analysis. Gastroenterology 2007; 132: 96 – 102
[12] Arain MA, Sawhney M, Sheikh S et al. CIMP status of interval colon cancers: another piece to the puzzle. Am J Gastroenterol 2010; 105: 1189 – 1195
[13] Leggett B, Whitehall V. Role of the serrated pathway in colorectal cancer pathogenesis. Gastroenterology 2010; 138: 2088 – 2100
[14] Kahi CJ, Hewett DG, Norton DL et al. Prevalence and variable detection of proximal colon serrated polyps during screening colonoscopy. Clin Gastroenterol Hepatol 2011; 9: 42 – 46
[15] Hetzel JT, Huang CS, Coulkos JA et al. Variation of proximal colon serrated polyp detection among endoscopists. Gastrointest Endosc 2013; 77: 623 – 629
[16] De Wijkerslooth TR, Stoop EM, Bossuyt PM et al. Differences in proximal serrated polyp detection among endoscopists are associated with variability in withdrawal time. Gastrointest Endosc 2013; 77: 617 – 623
[17] Liang J, Kalady MF, Appau K et al. Serrated polyp detection rate during screening colonoscopy. Colorectal Dis 2012; 14: 1323 – 1327
[18] Wu J, Hu B. The role of carbon dioxide insufflation in colonoscopy: a systematic review and meta-analysis. Endoscopy 2012; 44: 128 – 136
[19] Ferlitsch M, Moss A, Hassan C et al. Colorectal polypectomy and endoscopic mucosal resection (EMR): European Society of Gastrointestinal Endoscopy (ESGE) Clinical Guideline. Endoscopy 2017; 49: 270 – 297
[20] Bassan MS, Holt B, Moss A et al. Carbon dioxide insufflation reduces number of postprocedure admissions after endoscopic resection of large colonic lesions: a prospective cohort study. Gastrointest Endosc 2013; 77: 90 – 95
[21] Aronchick CA, Lipshutz WH, Wright SH et al. A novel tableted purgative for colonoscopic preparation: efficacy and safety comparison with Colyte and Fleet Phospho-Soda. Gastrointest Endosc 2000; 52: 346 – 352

[22] Schlemper RJ. The Vienna classification of gastrointestinal epithelial neoplasia. Gut 2000; 47: 251 – 255

[23] Snover DC, Ahnen DJ, Burt RW et al. Serrated polyps of the colon and rectum and serrated polyposis. In: Bosman T, Carneiro F, Hruban R et al. eds. WHO classification of tumours of the digestive system. Lyon: World Health Organization; 2010: 160 – 165

[24] Cotton PB, Eisen GM, Aabakken L et al. A lexicon for endoscopic adverse events: report of an ASGE workshop. Gastrointest Endosc 2010; 71: 446 – 454

[25] Yamano HO, Yoshikawa K, Kimura T et al. Carbon dioxide insufflation for colonoscopy: evaluation of gas volume, abdominal pain, examination time and transcutaneous partial CO2 pressure. J Gastroenterol 2010; 45: 1235 – 1240

[26] Dellon ES, Hawk JS, Grim IS et al. The use of carbon dioxide for insufflation during GI endoscopy: a systematic review. Gastrointest Endosc 2009; 69: 843 – 849

[27] Geyer M, Guller U, Beglinger C. Carbon dioxide insufflation in routine colonoscopy is safe and more comfortable: results of a randomized controlled double-blinded trial. Diagn Ther Endosc 2011; 2011: 378906

[28] Payne SR, Church TR, Wandell M et al. Endoscopic detection of proximal serrated lesions and pathologic identification of sessile serrated adenomas/polyps vary on the basis of center. Clin Gastroenterol Hepatol 2014; 12: 1119 – 1126

[29] Brandt LJ, Boley SJ, Sammartano R. Carbon dioxide and room air insufflation of the colon. Effects on colonic blood flow and intraluminal pressure in the dog. Gastrointest Endosc 1986; 32: 324 – 329

[30] Hussein AM. Carbon dioxide insufflation for more comfortable colonoscopy. Gastrointest Endosc 1984; 30: 68 – 70

[31] Buttery L, Robinson CM, Anderson JE et al. Serrated and adenomatous polyp detection increases with longer withdrawal time: Results from the New Hampshire Colonoscopy Registry. Am J Gastroenterol 2014; 109: 417 – 426

[32] Feakins RM. Obesity and metabolic syndrome: pathological effects on the gastrointestinal tract. Histopathology 2016; 68: 630 – 640

[33] Platz EA, Willett WC, Colditz GA et al. Proportion of colon cancer risk that might be preventable in a cohort of middle-aged US men. Cancer Causes Control 2000; 11: 579 – 588

[34] Bailie L, Loughrey MB, Coleman HG. Lifestyle risk factors for serrated colorectal polyps: a systematic review and meta-analysis. Gastroenterology 2016; 152: 92 – 104

[35] Burke CA, Choure AG, Sanaka MR et al. A comparison of high-definition versus conventional colonoscopes for polyp detection. Dig Dis Sci 2010; 55: 1716 – 1720

[36] Tribonias G, Theodoropoulou A, Konstantinidis K et al. Comparison of standard vs high-definition, wide-angle colonoscopy for polyp detection: a randomized controlled trial. Colorectal Dis 2010; Oct 12: e260 – 266

[37] East JE, Stavrindis M, Thomas-Gibson S et al. A comparative study of standard vs. high definition colonoscopy for adenoma and hyperplastic polyp detection with optimized withdrawal technique. Aliment Pharmacol Ther 2008; 28: 768 – 776