

Original Article

Feasibility and outcomes of colonoscopy with combined carbon dioxide insufflation and water infusion for resection of colonic polyps

Zhiqiang Du, Shancheng Luo, Fei Wang

Department of Gastroenterology, Jianyang People's Hospital, Jianyang 641400, Sichuan, China

Received November 16, 2017; Accepted May 3, 2018; Epub July 15, 2018; Published July 30, 2018

Abstract: *Objective:* Traditional air insufflation colonoscopy (AIC) induces pain, discomfort, and even intolerance during insertion of the scope into the cecum. Although sedation/analgesia suppresses abdominal pain and intolerance, sedation-associated complications are possible in some patients. This perspective study assessed the feasibility of colonoscopies that combine carbon dioxide insufflation with water infusion during colonic polypectomy. *Methods:* Between December 2015 and December 2016, 102 patients were randomly allocated to undergo resection of colonic polyps by either water-aided colonoscopy (WAC) ($n = 50$) or conventional AIC ($n = 52$). Patients were assessed for pain, cecal intubation, on-demand sedation/analgesia, satisfaction, post-procedural complications, and other outcomes. *Results:* WAC significantly attenuated procedure-related pain, discomfort, and intolerance, compared with AIC. Rates of cecal intubation during WAC and AIC were 100% and 94.2%, respectively. Patients undergoing WAC made no requests for on-demand sedation. Patients given AIC displayed significant increases in heart rate and blood pressure during the procedure, but the WAC group experienced no significant alterations. The rate of postprocedural complications was higher in the AIC group than the WAC group. *Conclusion:* WAC is superior to conventional AIC for colonic polypectomy. WAC is highly recommended for resection of colonic polyps.

Keywords: Colonoscopy, colonic polyp, polypectomy, water-aided colonoscopy, air insufflation colonoscopy

Introduction

Colonoscopy is primarily used for screening, detection, and early diagnosis of colorectal lesions (e.g., polyps, adenoma, colorectal cancer, and ulceration). In addition to examining the entire colon, colonoscopy also allows for removal of colonic polyps and adenoma, benign lesions that may become malignant [1-4]. In fact, colonoscopic polypectomy has become the gold standard for patients with polyps in the colorectum [2].

Recently, the demand for therapeutic colonoscopy has risen in many parts of the world, due to increased rates of colonic polyps. However, conventional colonoscopy has a number of drawbacks and disadvantages. These drawbacks include patient pain or discomfort and poor tolerance for discomfort induced by air insufflation to distend the lumen during the insertion phase. These problems have been frequently reported by individuals undergoing

the procedure and appear to adversely affect the diagnostic and therapeutic performance of the colonoscopy.

Currently, sedated colonoscopy is preferred due to improved patient comfort and reduced abdominal pain. It is used in many hospitals worldwide. However, sedation increases patient recovery time, medical costs related to drugs, and requires additional care and monitoring [5-10]. Alternative techniques have been developed to overcome the limitations and challenges of conventional air insufflation colonoscopy (AIC), including carbon dioxide (CO₂) insufflation or water-aided methods [11-14]. Insufflation colonoscopy with CO₂ has a number of benefits, since CO₂ is more rapidly absorbed by the mucosa into blood circulation and is easily eliminated through respiration [11]. Extensive studies comparing CO₂ insufflation with air insufflation in conventional colonoscopy have shown that CO₂ insufflation causes fewer colonic spasms and contractions. This, in turn, mini-

WAC for colonic polyp resection

Table 1. Baseline demographic characteristics of patients that underwent colonoscopy for resection of colonic polyps

	Water-aided	Air insufflation	P
Subjects, <i>n</i>	50	52	-
Male, <i>n</i>	30 (60%)	38 (73%)	0.53
Female, <i>n</i>	20 (40%)	14 (27%)	
Age, <i>y</i>	48.5 ± 14.18	45.02 ± 13.09	0.60

mizes pain and discomfort for patients and decreases the number of on-demand requests for sedation.

In water-aided colonoscopy (WAC), water infusion is used for luminal distention, with several characteristic advantages including less pain and discomfort. Furthermore, WAC allows a higher proportion of resected colonic lesions, improves procedural performance, and decreases posttreatment complications [11, 12, 15, 16]. The potential benefits, feasibility, and clinical outcomes of WAC for removal of colonic polyps have not been extensively investigated.

In this prospective study, we investigated the viability of a modified colonoscopy, using water in conjunction with CO₂ insufflation, relative to conventional AIC without water, for resection of colonic polyps. These methods were compared in terms of pain scales, cecal intubation rates, the proportion of patients requesting on-demand sedation/analgesia, development of post-procedural complications, and other outcomes.

Materials and methods

Patients and study design

The Hospital Review Board for Medical Ethics, at Jianyang People's Hospital, reviewed and approved the protocol of this prospective study. Each patient provided written informed consent at the time of enrollment.

This study was performed at the Endoscopy Center of Jianyang People's Hospital, between December 2015 and December 2016. Patients that underwent conventional colonoscopy and received diagnoses of colonic polyps and adenomas were considered for this study. However, patients having any of the following conditions were eventually excluded from this study: hypertension; cardiac arrhythmia; advanced heart, lung, liver, or kidney disease; medical

history of colorectal surgery; and inability to understand written information or refusal to provide written informed consent. Therefore, 102 individuals (68 men and 34 women; aged 47.6 ± 5.2 y) were finally enrolled and included in this study.

The study subjects were randomly allocated by a computer-generated random list to receive either WAC with CO₂ insufflation (WAC group; *n* = 50) or conventional colonoscopy (AIC group, *n* = 52) for resection of colonic polyps.

Procedures for resection of colonic polyps

All colonoscopies were performed by high definition plus i-Scan (HD i-SCAN) electronic colonoscopy with an EPK-i5000 processor (Pentax, Tokyo, Japan) at the Center for Endoscopy in our hospital. Two well-trained endoscopists, with experience performing > 5000 colonoscopies, were regularly rotated to perform the procedures. Briefly, 2 days prior to the colonoscopies, all patients began eating semifluid food. They were, subsequently, ordered to receive bowel preparation, including 250 mL of polyethylene glycol and 2000 mL of water. Quality of bowel preparation was evaluated, as reported previously [23], and the patients achieved adequate bowel preparation for colonoscopy.

For patients assigned to the WAC group, a water-aided technique for colonoscopy was adopted. Briefly, the CO₂ intraluminal insufflation unit was turned off and a reservoir filled with water (37°C) was used. Warm water (250-300 mL) was, subsequently, infused via an auxiliary channel of the colonoscope to obtain adequate lumen distension during the insertion phase of the procedure, until the cecum was reached. The colonoscopist oversaw the volume, use of warm water, and CO₂ intraluminal insufflation during the insertion phase of the procedure. In the withdrawal phase of the colonoscopy, the water pump was turned off and CO₂ intraluminal insufflation unit was turned on. Water and stool residuals were removed and suctioned from the colonic tract before mucosal inspection and resection of colonic polyps began.

For patients assigned to the conventional AIC group, an intraluminal insufflation unit was used in the insertion phase to obtain adequate lumen distension until the cecum was reached.

WAC for colonic polyp resection

Table 2. Outcomes of colonoscopy for resection of colonic polyps in the WAC and AIC groups*

		WAC	AIC	P
Cecal intubation		50 (100%)	49 (94.2%)	0.65
Time to reach cecum, min		7.68 ± 2.2	8.55 ± 2.6	0.50
Pain scales	0	35	10	0.003
	I	10	25	0.34
	II	5	17	0.002
	III	0	0	-
Colonic polyp resection	Once	50 (100%)	42 (80.7%)	
	Twice	0	10 (19.2%)	
Patient satisfaction	Yes	100%	65%	
	No	0	35%	
Total procedure time, min		14 ± 3.2	17 ± 3.4	
Patients requesting on-demand sedation		0	5	
Colonic polyps newly detected		2	0	
Post procedural complications	Enterobrosis	0	1	
	Post-polypectomy electrocoagulation syndrome	0	1	

*Reported as n, unless otherwise noted.

The time from insertion to reaching the cecum was recorded. In the withdrawal phase, the colonic mucus was inspected properly within each colonoscopic field of view. Once detected, colonic polyps were removed with various polyp removal procedures, according to the size and shape of colonic polyps [17, 18].

Polyps < 0.5 cm in diameter were clamped and removed using electric coagulation biopsy forceps. If large pedunculated colonic polyps were detected (> 0.5 cm diameter), endoscopic polypectomy using high-frequency electrocoagulation resection was undertaken, in which an electronic wire was looped around the base of the colonic polyp and tightened until the lesion was burned off. For large and flat-surfaced polyps, an endoscopic mucosal resection was performed, in which saline was injected beneath the polyp to lift it for removal with a snare. The entire procedural time, defined as the time from insertion to polypectomy and removal of the scope, was measured.

Outcome measures of patients in the two groups

The following outcomes of patients in both groups were assessed: insertion time to the cecum (from insertion of the scope to reaching the cecum) during the insertion phase, depth of insertion, according to the length of the scope as it reached the cecum, and total procedural time from insertion to removal of the scope. Degree of abdominal pain or discomfort was evaluated based on World Health Organization

(WHO) scales, as follows: 0, absence of pain or slight discomfort; I, slight pain; II, tolerable pain; and III, severe, intolerable pain. Heart rate (HR), systolic blood pressure (SBP), diastolic blood pressure (DBP), and peripheral oxygen saturation (SpO₂) were also recorded. Newly detected colonic polyps were recorded and degree of satisfaction was reported by patients.

Statistical analysis

All data are stated as mean ± standard error. Statistical analyses were conducted using SPSS version 17.0 software (Chicago, Illinois, USA). Chi-square (X²) and *t*-tests were applied to compare data between the WAC and AIC groups. For statistical analysis, *P* < 0.05 indicated a statistically significant difference.

Results

Baseline demographic characteristics

Of the 102 patients enrolled in this prospective study, 68 (66.7%) were men and 34 (33.3%) were women. Mean age of the participants was 47.647.6 ± 5.2 years. Baseline demographic data on WAC and AIC groups are shown in **Table 1**. The two groups were comparable with regards to gender and age, with no significant differences between the groups (*P* > 0.05).

Procedural outcomes of colonoscopy for resection of colonic polyps

Cecal intubation was achieved in all 50 patients in the WAC group, as well as 49 of the 52

WAC for colonic polyp resection

Table 3. HR, SBP, DBP, and SpO₂ before, during, and after colonoscopy in the WAC and AIC groups

		WAC	AIC	P
HR, bpm	Before	71.9 ± 10.2	76.2 ± 12.5	0.78
	During	72.7 ± 11.2	87.6 ± 14.1	0.003
	After	73.9 ± 12.1	87.4 ± 15.3*	0.001
SBP, mmHg	Before	112.5 ± 7.3	124.8 ± 6.2	0.65
	During	116.0 ± 8.5	130.6 ± 7.6*	0.002
	After	115.2 ± 6.9	125.4 ± 5.6*	0.001
DBP, mmHg	Before	74.3 ± 4.8	74.8 ± 5.3	0.34
	During	74.1 ± 3.9	85.2 ± 8.3*	0.005
	After	74.9 ± 5.6	79.6 ± 6.3*	0.002
SpO ₂	Before	96.6 ± 9.8	98.1 ± 0.5	0.56
	During	98.6 ± 0.7	94.2 ± 2.5	0.36
	After	98.6 ± 0.3	98.3 ± 0.5	0.21

*Indicates a significant difference relative to the WAC group of $P < 0.01$.

(94.2%) patients in the AIC group. Cecal intubation rates were statistically similar (**Table 2**). Median times to reach the cecum in WAC and AIC groups were 7.9 minutes and 9.0 minutes, respectively.

Abdominal pain scales, as rated and reported by patients during the colonoscopy, were significantly lower in the WAC group than AIC group (**Table 2**). Thirty-five patients in the WAC group reported no pain or slight discomfort (pain scale, 0), significantly more than the 10 patients in the AIC group reporting this. The number of patients in the WAC group reporting slight pain I or tolerable pain II (10 and 5, respectively) was fewer than the AIC group (25 and 17). No patients, in either group, reported severe intolerable pain (III).

It was observed that patients in the WAC group remained calm and made no reports of abdominal pain or discomfort during the procedure. Individuals in the AIC group reported pain from slight/discomfort to severe/intolerable, with abdominal distension and anxiety (**Table 2**). Patient overall satisfaction was 100% in the WAC group but only 65% in AIC group.

Of the 52 patients that underwent AIC traditional colonoscopy, 5 requested on-demand sedation to complete the polypectomy due to intolerance to severe abdominal pain. No patients requested sedation in the WAC group. The 3 individuals that failed cecal intubation expressed unwillingness, anxiety, and even fear

regarding a future follow up colonoscopy examination.

Median total procedural time in the WAC group was 14 minutes, shorter than the AIC group (17 minutes). In the WAC group, new colonic polyps were detected in 2 patients. All detected polyps were removed by techniques mainly based on the size of the polyps: electric coagulation biopsy forceps (< 0.5 cm diameter); high frequency electrocoagulation resection (> 0.5 cm diameter); or endoscopic mucosal resection (large and flat).

HR, SBP, DBP, and SpO₂ before, during, and after colonoscopy

Prior to insertion of the scope, the WAC and AIC groups were comparable regarding HR, SBP, DBP, and SpO₂ (**Table 3**). However, when the scope reached the cecum (or during the procedure for patients that did not complete) and upon completion of the colonoscopy, values of HR, SBP, and DB significantly increased in the AIC group compared to WAC group. There were no significant differences between WAC and AIC groups concerning SpO₂. These changes in HR, SBP, DBP, and SpO₂ seemed to be reflected in the pained or painless facial appearances of patients.

Post-procedural complications

Concerning post-procedural complications, one case of enterobrosis occurred in the AIC group but it was improved by surgical intervention (**Table 2**). Also, in the AIC group, there was one case of post-polypectomy electrocoagulation syndrome, a rare complication of polypectomy featured by a transmural burn in the colon. This adverse event was further treated with ambrosia, fluid infusion, etc.. None of the patients in the WAC group developed enterobrosis or post-polypectomy electrocoagulation syndrome after colonoscopy.

Discussion

Traditional colonoscopy has posed challenges for patients and colonoscopists, regardless of the experience of the colonoscopist. These challenges are mainly due to pain, discomfort,

and even intolerance when the colonoscope is inserted into the cecum [19]. Although sedation/analgesia is available to minimize abdominal pain and intolerance, sedation/analgesia has been associated with complications in some patients. It would be more desirable to make improvements and develop techniques that would avoid provoking these adverse effects [8, 10, 20]. In addition to sedation-associated complications, time required, sedative drugs, and care associated with sedation have acquired a negative image.

This study discovered that, for polypectomy, WAC in adjunction with CO₂ insufflation is superior to conventional AIC without water. The main findings supporting this conclusion are based on the following evidence. Relative to conventional AIC, WAC largely attenuated pain, discomfort, and even patient intolerance during the insertion of the colonoscope into the cecum. The cecal intubation rate of patients receiving WAC was higher than the AIC group. Patients given WAC made no requests for on-demand sedation, significantly fewer than the AIC group. WAC was more effective than AIC in cleaning out the colon, which was responsible, at least in part, for increased detection of new colonic polyps for some patients in the WAC group. Finally, a smaller percentage of patients in the WAC group, compared to AIC patients, experienced postprocedural complications.

The advantages of water infusion, in lieu of air insufflation, during the insertion phase in colonoscopies have been extensively reported in previous studies [12, 13, 15, 16]. Indeed, modified underwater colonoscopy techniques have become increasingly popular. Consistent with previous findings, this present study confirms that colonoscopy, with the help of water during insertion into the cecum, causes less patient pain and discomfort and decreases on-demand requests for sedation. Thus, replication in our center was warranted.

There are diverse ways for using water in colonoscopies. According to the time when infused water is removed, WAC can be classified as either water exchange, in which water is suctioned out during the insertion phase, or water immersion, whereby the infused water is removed during the withdrawal phase [5, 12, 15, 21-26]. However, it seems this classification of WAC is equivocal. In the literature, there

is no consensus or clear distinction between exchange and immersion methods.

Aside from the timing of water removal, WAC methods may vary by total volume of water used. Falchuk et al. reported that water volume of no more than 300 mL, infused into the sigmoid colon, was helpful during colonoscopy [27]. In another study performed by Leung et al., a larger amount of water, totaling 1000 mL, given in aliquots (30-60 mL), was infused during the insertion phase of colonoscopy, but a major weakness was the longer intubation time (22.6 min). In the present study, 250-300 mL of warm water was used but the exact amount of water, in each case, was determined by the two experienced colonoscopists. Furthermore, combined water infusion with CO₂ insufflation during the insertion phase was used to obtain adequate lumen distension and achieve full cecal intubation. The timing of turning-on CO₂ insufflation in the insertion phase was determined as needed.

To the best of our knowledge, this study is the first to report on combined colonoscopy while evaluating feasibility and outcomes for resection of colonic polyps. Most previous studies were performed using water infusion combined with air insufflation. WAC combining with CO₂ insufflation could hold significant advantages and benefits for improving patient outcomes, relative to AIC. In 2 patients, polyps in the colon were newly detected during the procedure and there were no post-treatment complications in the WAC group. In contrast, 2 patients in the AIC group did experience, respectively, post-procedural enterobrosis and post-polypectomy electrocoagulation syndrome.

Although WAC has apparent advantages for detection and removal of polyps in the colon, the procedure can be technically challenging. First, an appropriate volume of water should be used to ensure clear visualization during the insertion phase of the procedure. In this prospective study, we used a minimal volume of warm water (250-300 mL), which was subsequently aspirated into a suction bottle together with fecal residual. In fact, excessive water used in colonoscopy has been reported to increase risk of post-procedural complications, including water intoxication, water-electrolyte disturbance, and cardiovascular disease. On the other hand, insufficient water may lead to a

rather vague view and incomplete removal of stool residues, which has been strongly associated with lower detection rates of colonic polyps. Second, the optimal timing of switching from water-infusion to CO₂ insufflation also needs to be judged and determined by a well-trained colonoscopist. Thus, only well-trained professionals are able perform colonoscopy for colonic polypectomy without patient sedation. Third, a proper sequence of events should be adhered to, avoiding adverse events such as suction of the mucosa.

This present study had some limitations. Since this study was performed in a single center, the clinical benefits should be validated by external investigators, although the results have been confirmed internally. In addition, colonoscopists conducting the present investigation were not blinded to randomization. Despite these limitations, there was an increase in the number of newly detected polyps in the WAC group compared with conventional AIC. Therefore, further investigation with a larger sample size for verification is warranted.

In conclusion, colonoscopy with CO₂ insufflation combined with water infusion has demonstrated apparent advantages over traditional AIC for removal of colonic polyps. These advantages include attenuation of procedure-related abdominal pain consequently reducing the proportion of patients requesting on-demand sedation, improved performance, and enhanced acceptance of colonoscopy for screening, diagnosis, and therapy. Thus, colonoscopy with CO₂ insufflation and water infusion is more feasible and a better method than conventional AIC. It is, therefore, highly recommended for colonic polypectomy of polyps or other lesions in the colon.

Acknowledgements

We would like to thank Linda Abraham, editor at Medjaden Bioscience Ltd., for assistance in editing and proofreading the manuscript.

Disclosure of conflict of interest

None.

Address correspondence to: Zhiqiang Du, Department of Gastroenterology, Jianyang People's Hospital, 180 Yiyuan Rd, Jianyang 641400, Si-

chuan, China. Tel: +86 137-3073-8579, E-mail: 1028606063@qq.com

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