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Adenoma detection rate is not influenced by the time of day in computer-aided detection colonoscopy

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Abstract

Because of endoscopist fatigue, the time of colonoscopy have been shown to influence adenoma detection rate (ADR). Computer-aided detection (CADe) provides simultaneous visual alerts on polyps during colonoscopy and thus to increase adenoma detection rate. This is attributable to the strengthening of endoscopists diagnostic level and alleviation of fatigue. The aim of the study was to investigate whether CADe colonoscopy could eliminate the influence of the afternoon fatigue on ADR.

We retrospectively analyzed the recorded data of patients who were performed CADe colonoscopy from September 2017 to February 2019 in Endoscopy Center of Sichuan Provincial People's Hospital. Patients demographic as well as baseline data recorded during colonoscopy were used for the analysis. Morning colonoscopy was defined as colonoscopic procedures starting between 8:00 AM and 12:00 noon. Afternoon colonoscopy was defined as procedures starting at 2:00 PM and thereafter. The primary outcome was ADR. Univariate analysis and multivariate regression analysis were also performed.

A total of 484 CADe colonoscopies were performed by 4 endoscopists in the study. The overall polyp detection rate was 52% and overall ADR was 35.5%. The mean number of adenomas detected per colonoscopy (0.62 vs 0.61, $P > .05$) and ADR (0.36 vs 0.35, $P > .05$) were similar in the AM and PM group. Multivariable analysis shows that the ADR of CADe colonoscopy was influenced by the age ($P < .001$), gender ($P = .004$) and withdrawal time ($P < .001$), no correlation was found regarding bowel preparation ($P = .993$) and endoscopist experience ($P = .804$).

CADe colonoscopy could eliminate the influence of the afternoon fatigue on ADR. The ADR during CADe colonoscopy is significantly affected by age, gender and withdrawal time.

Abbreviations: ADR = adenoma detection rate, AM = morning, BBPS = Boston Bowel Preparation Score, BMI = body mass index, CADe = computer-aided detection, CRC = colorectal cancer, IBD = inflammatory bowel disease, iCRC = interval colorectal cancer, PM = afternoon.

Keywords: adenoma detection rate, afternoon, colonoscopy, computer-aided detection, morning

1. Introduction

Colorectal cancer (CRC) is the third most commonly diagnosed cancer in male and the second most cancer in females worldwide, and the fifth leading cause of cancer-related deaths in China.[1,2] Colonoscopy is considered the gold standard for screening CRC via detection and removal of adenomatous polyps.[3–5] Adenoma detection rate (ADR) was recommended as an important quality indicator for screening colonoscopy.[6] High-quality clinical evidence shows that interval CRC (iCRC) rate was inversely correlated with provider ADR.[7] In addition, ADR itself would be affected by not only age, gender, withdrawal time, quality of bowel preparation, but also the time of colonoscopy and endoscopists fatigue.[8–11] Recent studies have shown that a higher ADR could be attained during colonoscopy performed in the morning, which was due to longer withdrawal time, better bowel preparation and full attention of endoscopists.[11,12]

Over the years, computer-aided detection (CADe), particularly based on deep learning algorithm, in colonoscopy draws increasing attention. CADe allows automated detection of a given target, mostly colorectal polyps, during real-time colonoscopy.[13,14] Such a CADe system could assist endoscopists in real time to avoid miss diagnosis of polyps by means of providing visual alerts on polyps that endoscopist might have missed due to inexperience or distraction caused by fatigue.[15] The CADe system showed high sensitivity and accuracy even when been compared to expert human endoscopists.[16] We have developed a polyp detection CADe system and demonstrated its positive impact in increasing ADR during colonoscopy through random-

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All data generated or analyzed during this study are included in this published article [and its supplementary information files].

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ized clinical trials.[17–19] However, whether CADe system could help to eliminate ADR gap in afternoon colonoscopy due to endoscopists fatigue has not been analyzed. Hence, the aim of this study was to evaluate whether ADR differs by the timing (morning vs afternoon) of colonoscopy with CADe system, and to investigate the relevant factors for ADR in CADe colonoscopy.

2. Method

2.1. Study design

We retrospectively collected data of consecutive patients who underwent CADe colonoscopy from September 2017 to February 2019 in the Endoscopy Center of Sichuan Provincial People's Hospital, China and accessed the data at January 2020. All patients were prepared with 2 to 4 L of polyethylene glycol with split-dose. We excluded patients with a history of inflammatory bowel disease (IBD), CRC, colorectal surgery, and patients with a contraindication for biopsy, procedures that cecum were not reached were also excluded. Cecum intubation was defined by visualization of the ileocecal valve and the appendiceal orifice. Colonoscopies were performed with high definition colonoscopies (Fujifilm EC-L590, EC-580, EC-590) (Fujifilm, Tokyo, Japan) and high-definition monitors.

The CADe system (EndoScreener, Shanghai Wision AI Co., Ltd. China) is a real-time automatic polyp detection system developed on a deep learning architecture. In a preliminary study, the system was validated to have a per-image sensitivity of 94.38%, per-image specificity of 95.92% and an area under the receiver operating characteristic curve of 0.984 to detect colon polyps in colonoscopy report images. In addition, the system was also validated to have a per-polyp sensitivity of 100.00% (per-image sensitivity of 91.64%) and a per-image specificity of 95.40% in real-world colonoscopy videos. The system processes >25 frames per second with a latency lesser than 80 ms, an imperceptible latency for most human endoscopists. The CADe system captures and analyzes the video stream from the endoscopy processor and displays alert boxes on an adjacent monitor.[18]

The study was approved by the Institutional Review Board of Sichuan Academy of Medical Sciences & Sichuan Provincial People's Hospital. All data in this study was de-identified.

2.2. Schedule

Morning (AM) colonoscopy was defined as colonoscopic procedures starting between 8:00 AM and 12:00 noon. Afternoon (PM) colonoscopy was defined as procedures from 2:00 PM and thereafter. Data on patient age, sex, body mass index (BMI), insertion time, withdrawal time, biopsy time, indication for procedure, quality of bowel preparation, type of sedation, as well as histology of polyps were obtained from database of our center for this retrospective analysis. The quality of bowel preparation rated by the endoscopists was based on the Boston Bowel Preparation Score (BBPS). Bowel preparation was defined adequate when total score was greater than 6.

2.3. Statistical analysis

Continuous variables were reported as mean with standard deviation, while categorical factors were reported as percentages. As continuous factors, age, BMI, and BBPS were further dichotomized as categories for the further analysis. Continuous variables were compared using the 2-sample *t* test and categorical variables were compared using the chi-square test. ADR was estimated by calculating the percentage of procedures in which at least one adenoma was found, while polyp detection rate (PDR) was the percentage of colonoscopies with any type of polyp found. Univariate analysis was done to identify association between ADR and various other covariates. Multivariate analysis was also performed for ADR, using logistic regression while adjusting for possible extraneous variables. A 2-tailed *P* value of <.05 was considered statistically significant. All statistical analyses were performed in the Statistical Package for the Social Science (SPSS Inc., Chicago, IL, USA) software version 23.0.

3. Result

3.1. Baseline characteristics (Table 1)

A total of 509 consecutive patients were enrolled, among which, 25 patients were excluded during colonoscopy because of meeting exclusion criteria. Finally, 484 were analyzed in the study, 53.93% (261/484) were done in the AM and 46.07% (223/484) were done in the PM. There were averagely 4 cases in AM and 3 cases in PM.

The baseline characteristics are presented in Table 1. Mean age was 49.15 ± 13.19 years, and 50.21% of the patients were female. The overall mean BMI was 23.02 ± 3.20. 82 patients were for screening colonoscopies (16.94%). There were no significant differences in terms of demographic data and indications for colonoscopy between the AM and PM group ($P > .05$).

3.2. Endoscopic characteristics (Table 2)

A total of 4 physicians participated in the study, including 1 senior endoscopist (>10,000 cases experience), 2 mid-level endoscopists and 1 junior endoscopist (<500 cases experience). There were no statistically significant difference between the 2 groups in terms of endoscopic procedures. There were no complications reported. BBPS was 6.89 ± 1.38 in the AM and 6.74 ± 1.44 in the PM, there was no significant difference between the 2 groups in terms of BBPS (6.89 vs 6.74, $P = .232$). Supervised anesthesia (midazolam or propofol) was performed in 478 (98.76%) procedures. The mean insertion time in the AM and PM were 5.93 ± 4.24 minutes and 5.18 ± 3.57 minutes ($P = .037$), while the withdrawal time (7.53 vs 7.39, $P = .42$) and withdrawal time excluding biopsy (7.00 vs 6.85, $P = .335$) were similar between the 2 groups.

3.3. ADR

A total of 501 polyps were detected, of which 59.68% (299/501) were adenomas. 54.52% adenomas (163/299) were found in the AM and 45.48% (136/299) in the PM. The mean number of adenomas detected per colonoscopy (0.98 AM vs 1.09 PM, $P = .882$) and ADR (0.36 AM vs 0.35 PM, $P = .849$) were equilibrated in the AM and PM group ($P > .05$) (Table 3).

In univariate analysis (Table 4), the age ($P < .001$), gender ($P < .001$), BBPS ($P = .004$), BMI ($P = .041$), withdrawal time ($P < .001$) showed statistically significant determinants of ADR. However, the logistic regression analysis showed that only age ($P < .001$), gender ($P = .003$), withdrawal time ($P < .001$) and withdrawal time excluding biopsy ($P < .001$) have significant influence on ADR (Table 5).

Table 1

Baseline information of patients between AM and PM groups.

Characteristics		All patients (n = 484)	AM (n = 261)	PM (n = 223)	*P* value*
Age (y)	Mean (SD)	49.15 (13.19)	49.67 (13.32)	48.56 (13.05)	.358
Gender	Female, n (%)	243 (50.21)	136 (52.11)	107 (47.98)	.412
	Male, n (%)	241 (49.79)	125 (47.89)	116 (52.02)	
BMI	Mean (SD)	23.02 (3.20)	22.90 (3.30)	23.16 (3.07)	.379
	<25, n (%)	346 (71.49)	191 (73.18)	155 (69.51)	.642
	25≤ BMI≤ 30, n (%)	129 (26.65)	65 (24.90)	64 (28.70)	
	30>, n (%)	9 (1.86)	5 (1.92)	4 (1.79)	
Indication	Symptomatic, n (%)	82 (16.94)	210 (80.46)	192 (86.10)	.114
	Screening, n (%)	402 (83.06)	51 (19.54)	31 (13.90)	
Anesthesia	Yes, n (%)	478 (98.76)	258 (98.85)	220 (98.65)	.846
	No, n (%)	6 (1.24)	3 (1.15)	3 (1.35)	

* *P* value correspond to t-test or Pearson's χ^2.
BMI = body mass index.

Table 2

Endoscopic characteristics between AM and PM groups.

Characteristics		All patients (n = 484)	AM (n = 261)	PM (n = 223)	*P* value*
Anesthesia	Yes, n (%)	478 (98.76)	258 (98.85)	220 (98.65)	.846
	No, n (%)	6 (1.24)	3 (1.15)	3 (1.35)	
BBPS	Mean (SD)	6.82 (1.41)	6.89 (1.38)	6.74 (1.44)	.232
	Inadequate (sum < 6.0 or anyone < 2.0), n (%)	69 (14.26)	31 (11.88)	38 (17.04)	.118
	Adequate (sum ≥ 6.0 and everyone ≥ 2.0), n (%)	415 (85.74)	230 (88.12)	185 (82.96)	
Endoscopist experience	Senior, n (%)	94 (19.42)	47 (18.01)	47 (21.08)	.696
	Midlevel, n (%)	290 (51.24)	159 (60.92)	131 (58.74)	
	Junior, n (%)	142 (29.34)	55 (21.07)	45 (20.18)	
Total time	Mean (SD)	13.05 (4.61)	13.46 (4.83)	12.56 (4.31)	.032
Insertion time	Mean (SD)	5.58 (3.96)	5.93 (4.24)	5.18 (3.57)	.037
Withdrawal time	Mean (SD)	7.47 (2.02)	7.53 (1.98)	7.39 (2.07)	.420
Withdrawal time excluding biopsy	Mean (SD)	6.93 (1.70)	7.00 (1.71)	6.85 (1.70)	.335

* *P* value correspond to t-test or Pearson's χ^2.
BBPS = Boston Bowel Preparation Score.

4. Discussion

CRC is a leading cause of cancer related death worldwide. Thanks to screening colonoscopy and the removal of adenomatous polyps, the mortality and incidence of CRC in adults have significantly decreased by 51% and 32%, respectively in the United States over the past half-century.[20] Conversely, high quality researches have demonstrated failure to detect and remove adenomatous polyps during colonoscopy may increase the risk of interval cancer. Michal et al performed a study of 42 interval cancers identified during a period of 188,788 person-years and showed an inverse correlation between the adenoma detection rate and the risk of interval cancer.[21] Similarly, Douglas AC and members also showed the inversely relationship between the ADR and subsequent risk of colorectal cancer, that is every 1% increase in ADR predicts a 3% reduction in CRC incidence and 5% reduction in mortality.[22] ADR is commonly acknowledged as a major indicator to assess colonoscopy quality.

Table 3

Polyp and adenoma detection.

	AM (n = 261)	PM (n = 223)	*P* value*
PDR	0.51	0.53	.648
ADR	0.36	0.35	.849
Mean Number of Detected Polyp	0.98	1.09	.420
Mean Number of Detected Adenoma	0.62	0.61	.882

* *P* value correspond to t-test or Pearson's χ^2.
ADR = adenoma detection rate, PDR = polyp detection rate.

However, ADR would be affected by a plenty of factors, such as age, gender, BMI which are patient-related and quality of bowel preparation, withdrawal time, endoscopist level which belongs to operator-related factors.[9,23,24] Consistent with previous study,[25] we found ADR was higher in men (OR 2.08, 95%CI 1.28–3.41, $P = .003$) and increased with age (OR 1.03, 95% CI 1.02–1.05, $P < .001$). Moreover, longer pure withdrawal time, withdrawal time excluding biopsy, was also correlated with higher ADR (OR 0.36, 95% CI 0.24–0.53, $P < .001$). However, we found no linear correlation between ADR and the quality of bowel preparation as well as BMI during CADe colonoscopy ($P = .695$ and $P = .0.64$, respectively) based on the enrolled population, which may due to limited sample size.

The timing of colonoscopy was considered as a proxy to endoscopists fatigue. Prior studies reported the timing of colonoscopy may affect polyp detection.[10–12,26] A Korean study showed that compared to non-fatigued endoscopists, the ADR was significantly decreased in fatigued endoscopists (42.6% vs 25.0%, $P = .008$), and the results suggested that endoscopist fatigue may decrease the effectiveness of colonoscopy.[27] Until now, whether colonoscopy was performed in the morning or in

Table 4

Factors associated with adenoma detection: the univariate analysis.

Characteristics		Adenoma (n = 172)	Non-adenoma (n = 312)	*P* value*
Age				$P < .001$
	<50y, n (%)	67 (38.95)	179 (57.37)	
	>50y, n (%)	105 (61.05)	133 (42.63)	
Gender				$P < .001$
	Female, n (%)	65 (37.79)	178 (57.05)	
	male, n (%)	107 (62.21)	134 (42.95)	
BBPS	Mean ± SD	6.57 ± 1.29	6.96 ± 1.45	$P = .004$
	Inadequate (sum < 6.0), n (%)	88 (51.16)	116 (37.18)	$P = .004$
	Adequate (sum ≥ 6.0), n (%)	84 (48.84)	196 (62.82)	
Doctor	Senior, n (%)	40 (23.26)	54 (17.31)	$P = .143$
	Midlevel, n (%)	103 (59.88)	187 (59.94)	
	Junior, n (%)	29 (16.86)	71 (22.75)	
BMI	< 25, n (%)	111 (64.53)	235 (75.32)	$P = .041$
	25≤ BMI≤ 30, n (%)	58 (33.72)	71 (22.76)	
	30>, n (%)	3 (1.75)	6 (1.92)	
Time	AM, n (%)	94 (54.65)	167 (53.53)	$P = .849$
	PM, n (%)	78 (45.35)	145 (46.47)	
Insert time	Mean ± SD	5.43 ± 3.88	5.67 ± 4.01	$P = .520$
Withdrawal time	Mean ± SD	8.73 ± 2.39	6.77 ± 1.36	$P < .001$
Withdrawal time excluding biopsy	Mean ± SD	7.55 ± 2.17	6.59 ± 1.26	$P < .001$

* *P* value correspond to *t* test or Pearson's χ^2.
BBPS = Boston Bowel Preparation Score, BMI = body mass index.

the afternoon would affect the ADR and colonoscopy quality remains controversial.[28–30] Teng et al[11] showed afternoon colonoscopies led to a significantly reduced ADR, which might due to shorter withdrawal time and insufficient endoscopists attentiveness. Gurudu et al[31] reported the afternoon ADR was significantly lower than the morning ADR only when the endoscopists worked the full-day. The study also showed that afternoon ADR could maintain at high level if colonoscopies were performed in half-day blocks by different endoscopists, it was believed attributable to the decline of physician fatigue. Christopher et al have showed the ADR was higher in the early morning and the number of polyps gradually decreased as the day progressed.[12] The results indicated the decreased ADR and decline of colonoscopy quality in the later of day may due to the endoscopist fatigue, inattention caused by repetitive colonoscopies.[32] Thanks to the breakthrough of artificial intelligence technology in computer vision, computer-aided detection (CADe) of colorectal polyps is now attracting increased attention. Several studies have indicated that CADe could overcome the limitation of human endoscopist regarding diagnostic capability and consistent attentiveness, high-performance CADe has been also demonstrated in clinical trials to increase ADR by indicating the presence and location of polyps during colonoscopy in real time, in order to draw the endoscopists attention to some easy-to-miss polyps that are visible in the screen.[17–19,33–35]

Table 5

Factors associated with adenoma detection: a multivariable logistic regression analysis.

	OR	95% Confidence interval	*P* value*
Age	1.03	1.02–1.05	.000
Male	2.08	1.28–3.41	.003
BMI	1.02	0.95–1.10	.640
BBPS	0.97	0.81–1.15	.695
Withdrawal time	4.12	2.79–6.08	.000
Withdrawal time excluding biopsy	0.36	0.24–0.53	.000

* *P* value correspond to t-test or Pearson's χ^2.
BBPS = Boston Bowel Preparation Score, BMI = body mass index.

Notably, with the assistance of CADe system, we found no significant difference in ADR between afternoon and morning colonoscopies, the ADR was 36% in the morning and 35% in the afternoon ($P = .849$). Furthermore, the mean number of detected adenoma was also stabled between morning and afternoon colonoscopies (0.62 vs 0.61, respectively, $P = .882$). We believe the result is generalizable because the endoscopists worked full-time during the CADe trials with a representative workload, averagely 12 colonoscopy procedures, including 3 to 4 procedures of CADe colonoscopy, were performed per half day.

Moreover, we found the endoscopist experience did not influence the ADR during CADe colonoscopy ($P = .143$). Worth mentioning, there was no decline of withdrawal time in the afternoon, the mean withdrawal time in the AM and PM were 7.53 ± 1.98 minutes and 7.39 ± 2.07 minutes ($P = .420$). This indicates the CADe system may have double advantages, first to overcome the inexperience of junior endoscopist, second to spur all endoscopist to do better, just like the supervision of senior endoscopist,[36] without increasing fatigue level.

Although this study was based on a Chinese population whose average age was younger than 50, the ADR was 36.6% which was beyond the suggestion of guidelines of American Society for Gastrointestinal Endoscopy (ASGE)/American College of Gastroenterology (ACG),[37,38] therefore, the result could be deemed generalizable to other regions with qualified ADR in colonoscopy.

There are some limitations in this study. First is the small sample size and single center data, the result base on a 484 population from 1 endoscopy center may lack external validity. Larger and multi-source samples are needed to further confirm this result. The second is the retrospective design in nature which might have selection bias and introduce imbalance in baseline characteristics in 2 groups, but logistic regression was used to

control known potential confounders to minimize this limitation. Last, the timing of colonoscopy (AM vs PM) was used as an indirect marker to represent physician fatigue, because it is very difficult to directly measure physician fatigue. However, this is a commonly acknowledged methodology.

In conclusion, we found that the time of day (AM vs PM) does not have a significant impact on ADR in CADe colonoscopies, which indicated that CADe colonoscopy could be used as an effective quality assurance that helps to overcome the afternoon fatigue and help endoscoposits to maintain high ADR. Larger-scaled controlled studies as well as cost effective studies on CADe colonoscopy are needed to confirm the effectiveness and cost effectiveness of the CADe system. In addition, we confirmed the ADR of CADe colonocopy was associated with the age, gender, and withdrawal time.

Author contributions

Conceptualization: Shan Lei, Mengtian Tu, Xun Xiao, Liangping Li, Xiaogang Liu, Pu Wang.
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