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Polyp detection at colonoscopy: Endoscopist and technical factors

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A B S T R A C T

The adenoma detection rate (ADR) has emerged as the most important quality measure in colonoscopy, as it predicts the risk of interval cancer after colonoscopy. Measuring and improving ADR is the central focus of the current quality movement in colonoscopy. High ADRs can be achieved by a colonoscopist with a thorough understanding of the wide range of endoscopic appearances of precancerous lesions in the colorectum, effective bowel preparation, and meticulous technique using high definition colonoscopes. The knowledgeable and effective examiner needs no adjunctive devices or techniques to achieve master level ADRs. However, measurement reveals that many colonoscopists have ADRs that are below recommended minimum thresholds or below master levels. These colonoscopists, and even master level performers, can choose from a variety of adjunctive tools to improve ADR. This review describes these tools according to whether they are non-device methods (e.g. double right colon examination, patient position change, water exchange), mucosal exposure devices (wide angle colonoscopy, fold flattening devices), and lesion highlighting techniques (e.g. chromoendoscopy, electronic chromoendoscopy).

Introduction to variable detection

The current worldwide movement to improve the quality of colonoscopy is based on observations made 2 decades ago of variable polyp and cancer detection by colonoscopists [1,2] and consolidated in the past decade by evidence of variable cancer protection by colonoscopists [3,4]. What is stunning about variable detection in colonoscopy is its magnitude. The adenoma detection rate (ADR), proposed in 2002 [5], has emerged as the primary measure of the quality of mucosal inspection by individual colonoscopists. Studies of colonoscopists in the same gastroenterology groups consistently demonstrate variation in the adenoma detection rate of 3–6 fold between the best and the worst performers [6–8]. When detection is expressed as adenomas per colonoscopy (APC), the differences between top and bottom performers can exceed tenfold [6]. This means that colonoscopy is done so badly by some colonoscopists that they miss more than 90% of the precancerous lesions in the colon. Variation in detection of serrated class lesions is even greater than for conventional adenomas [9,10]. With regard to operator dependence of performance, colonoscopy is to gastroenterology what ultrasound is to radiology, except even more so. The goal of the modern colonoscopy quality improvement movement is to reduce this operator dependence, and generally to move low-level performers toward high-end performance as rapidly as possible.

Which colonoscopists are the problem in detection? Multiple lines of evidence suggest that gastroenterologists on average are better at detection of polyps than general surgeons [11], and better at cancer prevention [12–14]. Differences between gastroenterologists and surgeons are identifiable even during training [15], which may reflect inferior training or personality differences between the groups of endoscopists. However, the dramatic differences between gastroenterologists noted above indicate that poor performance occurs within all specialties and can only be identified through measurement. To perform screening and surveillance colonoscopy without measurement of ADR is no longer acceptable. The first step toward reducing operator dependence is to identify colonoscopists with low ADRs.

Training

It seems obvious that adequate training is essential to optimal detection, but demonstration that training can improve detection has only been recent [16,17]. Training should emphasize the proven value of high-level detection in cancer prevention, and should then

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cover the broad areas of lesion recognition and mucosal exposure technique. A critical concept is that a large fraction of precancerous colorectal lesions are endoscopically subtle [18]. This concept is nicely conveyed by the Paris classification, which divides precancerous lesions into type I (polyps) and type II (flat and depressed lesions) (Fig. 1). The distribution of pedunculated (primarily left colon), sessile (evenly distributed), and flat and depressed (primarily right colon) conventional adenomas must be understood. Within the serrated class, the sessile serrated polyps are nearly always flat or sessile, located with a more proximal colon distribution, and have a unique endoscopic appearance compared to conventional adenomas [19,20]. Table 1 summarizes the precancerous colorectal lesions according to their histology, tendency toward advanced histology, typical Paris shape and colon distribution, and frequency in the colorectum. The trained endoscopist approaches colonoscopy with awareness of this distribution and determination to expose and recognize even the most subtle lesions. In the EQUIP training program developed by Wallace and colleagues at the Mayo Clinic, training also includes polyp differentiation skill [16,17]. It is quite possible, though unproven, that differentiation skills enhance detection, since they increase awareness of color, texture, and other clues that signal the presence of a subtle lesion.

In addition to lesion recognition skills, training in basic mucosal exposure technique is essential [21].

Basic mucosal exposure technique

The first step in effective mucosal exposure is bowel preparation. The most important advance in bowel preparation science of the past 2 decades is recognition of the gains generated by split dosing, defined as taking half the preparation the day before colonoscopy and half the preparation on the day of the colonoscopy (Fig. 2), typically starting 4 to 5 h before the scheduled procedure time. Any commercially available bowel preparation given in split dosing is likely to defeat any other commercial preparation given entirely the evening before. Split dosing is also better tolerated than evening before dosing and is probably safer because it allows patients more opportunity to recover from any preparation induced electrolyte disturbances. Entire same-day dosing is as effective as split dose preparations. In randomized controlled trials [22], and historically controlled studies [23], split dosing improves the adenoma detection rate compared to evening before dosing. Split dosing provides its greatest relative advantages in the cecum and ascending colon, the same area where flat and depressed lesions are most common (Table 1).

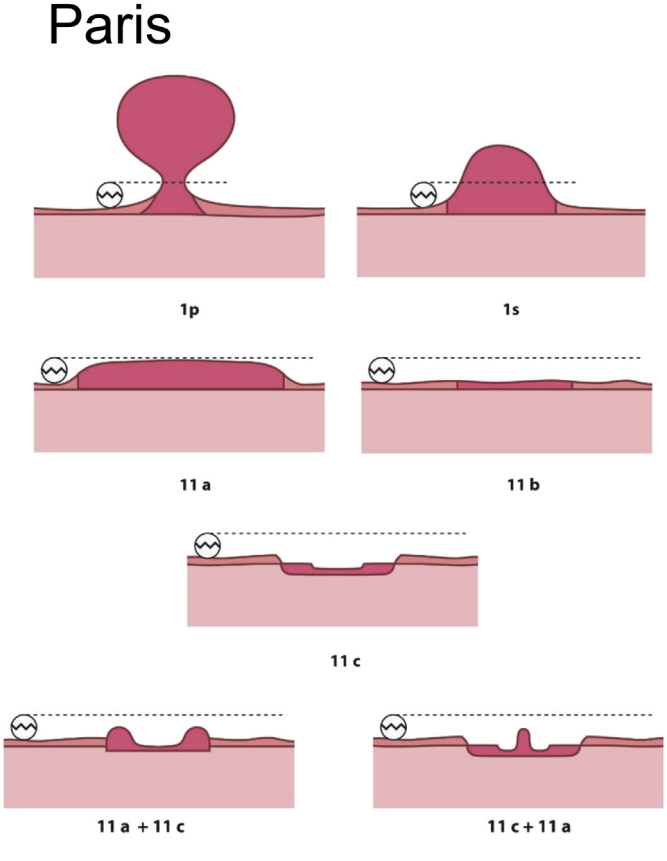

Fig. 1. The Paris classification of lesion shapes in the colorectum. Type I lesions are polyps (Ip: pedunculated and Is: sessile). Type IIa lesions are flat slightly elevated and IIb is completely flat. IIc and its variants are depressed.

Basic withdrawal technique is straightforward, and was associated in 2000 with improved detection [21]. The basic components of effective mucosal exposure are;

- A detailed effort to probe and expose the proximal sides of bowels, haustral folds, and flexures.
- Wash and clean areas of residual debris.
- Adequate distention.

A study of videotaping trained endoscopists without their knowledge, followed by videotaping after announcing that examinations would be recorded, but without informing endoscopists that they had already been recorded, showed that video recording induced better quality withdrawals, and longer examinations(24). This finding suggests that trained endoscopists know how to perform meticulous technique, but often do not utilize careful technique. Undoubtedly, personality factors underlie such behavior, and obsessive-compulsive tendencies and low-risk taking probably characterize the best colonoscopy examiners.

Withdrawal time

The appropriate place of withdrawal time in the quality movement and quality measurements is often misunderstood. When the US Multi-Society Task Force on Colorectal Cancer first proposed the ADR in 2002(5), it also recommended that colonoscopies performed for screening and surveillance in persons with intact colon and without biopsies or polypectomies performed should average at least 6 to 10 min. Withdrawal time was proposed as a secondary measure of quality, with the ADR being the primary measure of the quality of mucosal inspection [5]. In a landmark study in 2006, Barclay et al. showed that the adenoma detection rate and the withdrawal time were almost linearly correlated, and that a 6-min withdrawal time separated low and high level detectors nicely [6]. Unfortunately, many colonoscopists and endoscopy units interpreted this finding to mean that instituting a policy of forced withdrawals greater than 6 min would improve detection. Prospective studies of forcing withdrawal time were unsuccessful [25], unless they were accompanied by an education program and forcing withdrawal time by colonic segments [26]. Specifically, an education program combined with a targeted 8-min total withdrawal, with a timer set to force at least 2 min of withdrawal in each of 4 colon sections, was a successful strategy for improving ADR [26]. Retrospective studies have consistently shown a strong association of detection with withdrawal time, and recently this association was extended to the serrated lesions [27] and colorectal cancer prevention [28].

Despite these strong associations of withdrawal time with positive outcomes in retrospective studies, the above results suggest that focusing quality improvements on withdrawal time are

Table 1
Paris shapes, colonic distribution, and precancerous potential of the major lesions in the conventional adenoma and serrated class encountered during colonoscopy.

Lesion	Paris shape	Distribution in colon	Frequency	Malignant potential	Correct management during colonoscopy
Pedunculated adenomas	Ip	Mostly left	Low – about 5% of all polyps	Low but increasing with lesion size	Resect completely
Sessile adenomas	Is	Throughout colon	Very common	Low but increased in granular lateral spreading tumors with large discrete nodules	Resect completely
Flat adenomas	IIa	Skewed toward right	Very common	Generally low but increased in non-granular lateral spreading tumors	Resect completely
Depressed adenomas	IIc and its variants	Skewed toward right	Rare	Very high	Resect completely; en bloc when possible
Sessile serrated polyp	IIa, Is	Skewed toward right	Common – 8–9% of screening exams	Significant; may be low per lesion but increased if dysplastic component; patients with multiple large lesions at high risk	Resect completely
Traditional serrated adenoma	1s, 1p	Skewed toward left	Rare	Significant	Resect completely
Hyperplastic polyps	Is, IIa	Skewed toward rectum and sigmoid	Very common	Insignificant	Resect if > 5 mm or proximal to sigmoid; leave in place or sample if ≤ 5 mm and in rectum or sigmoid

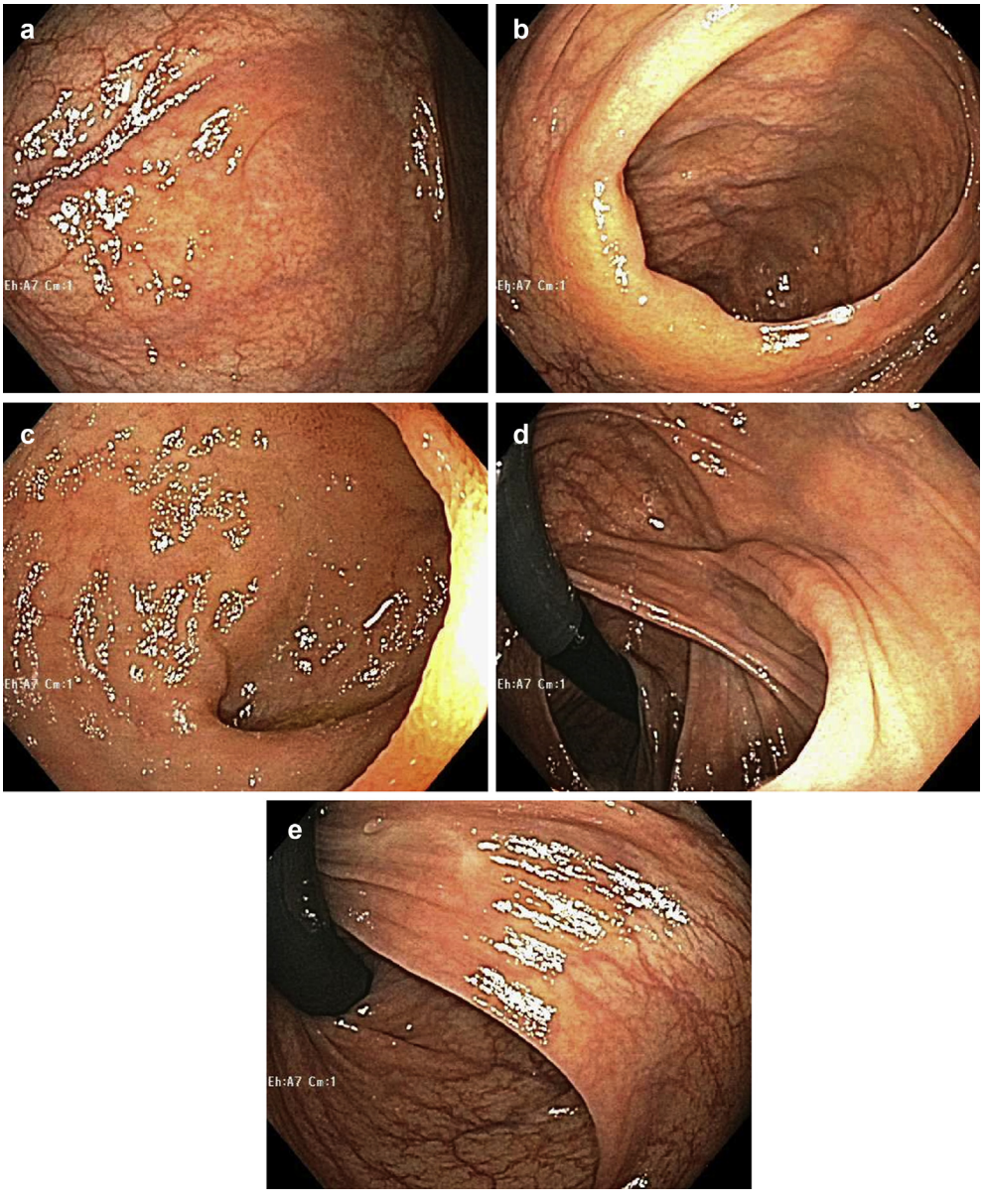

Fig. 2. Photographic documentation of a high quality split dose right colon preparation and examination a) the appendiceal orifice b) the cecum from just distal to the ileocecal valve c) the terminal ileum d) retroflexion in the proximal ascending colon e) the distal ascending colon in retroflexion.

misplaced. Rather, quality improvement should be focused on lesion recognition and effective mucosal exposure technique. The process of effective mucosal exposure technique is inevitably time consuming and laborious, and typically results in average withdrawal times in normal colons of 8–10 min rather than 6 min. This is not to say that withdrawal time should not be recorded. Recording withdrawal time is essential, since if the adenoma detection rate is low, a short withdrawal time is certain to mean ineffective technique. Withdrawal time has also become an important parameter in medical-legal actions alleging negligent examination prior to development of interval cancer [29].

To characterize "basic withdrawal technique" as "basic" suggests that effective technique is easy and can be taken for granted among experienced colonoscopists. Any such assumption is entirely incorrect. The differences in detection between best and worst performers in gastroenterology groups when they are using identical equipment and performing colonoscopy in identical populations far exceed the gains in detection that can be achieved by adjunctive tools that improve mucosal exposure or highlight flat lesions (see below). Thus, the potential gains in detection for low-level performers through acquisition of the lesion recognition skills and dedication to detailed mucosal exposure cannot be overestimated.

Practice points

- The adenoma detection rate (ADR) is the primary measure of the quality of mucosal inspection during colonoscopy
- Training in colonoscopic detection should emphasize knowledge of the spectrum of endoscopic appearances of adenomas and serrated lesions
- The Paris classification provides a useful vocabulary for describing and discussing the morphology of precancerous colorectal lesions
- Split or same day bowel preparation is essential to effective detection
- Sound basic inspection technique consists of carefully probing the proximal sides of folds and flexures, cleaning the mucosal surfaces, and adequately distending the colon
- Withdrawal times above recommended thresholds are a natural consequence of using effective technique. Withdrawal time is a secondary measure of mucosal inspection technique. In an individual with low ADR, short mean withdrawal times indicate probable ineffective technique.

Medical-legal issues and interval cancer

Colorectal perforation and missed cancer remain the two most common allegations in malpractice issues involving colonoscopy. The arguments are similar across cases [29]. The plaintiff argues that at the time of the colonoscopy, a precancerous lesion or a malignancy of earlier stage must have been present, and should have been detected by careful technique. The defense argues that colonoscopy is imperfect even when performed carefully, and if a lesion was present at the time of colonoscopy, its shape and location could reasonably have defied detection. In the absence of a video recording, the actual quality of the examination will remain uncertain. The available evidence is usually the quality of the bowel preparation, photographic and landmark documentation of cecal intubation (Fig. 1), the procedure duration and the withdrawal time. If the procedure duration is recorded and the withdrawal time is not, the withdrawal time becomes a source of speculation. Whether the doctor has measured the ADR, and the level of the doctor's the ADR are, increasingly brought into play. Although these data may seem like an inadequate summary of the examination, they are generally the only available points to estimate the quality of any given colonoscopy.

Adjuncts to mucosal exposure

Non-device measures

Several non-device measures could potentially improve ADR and/or APC. One is simply measuring ADR. Measurement and feedback to physicians has been unsuccessful in some instances [30] and successful in others [31]. Use of a report card may stimulate improved performance through competition, fear of embarrassment, or fear of penalty. Public reporting of ADR [32] could produce additional gains in performance. Systematic video recording of examinations [24] needs further testing of its impact on ADR.

An increasingly common practice to reduce interval cancer is the double or a second right colon examination. Case-control studies from the U.S. and Germany consistently demonstrate that protection by colonoscopy against right-sided colon cancer averages 40% to 60%, and is lower than the 80% protection achieved in the left colon [12,33–35]. Early Canadian studies where colonoscopy is performed largely by surgeons failed to demonstrate any improvement in right colon protection by colonoscopy [36,37], though this effect was subsequently shown to be operator dependent, and to be related to low cecal intubation rates and low polypectomy rates [38]. These findings have heightened awareness among colonoscopists that the high prevalence of right colon serrated lesions, flat and depressed conventional adenomas, and possibly different polyp-cancer biology demand special efforts to reduce interval right colon cancers. Of particular interest is right colon retroflexion, which is usually performed after an initial detailed forward inspection from the appendiceal orifice to the hepatic flexure. The technique involves reinsertion to the cecum, followed by a repeat detailed forward reinspection of the cecum, since when retroflexion is achieved, the colonoscope tip in many instances is already distal to the ileocecal valve. In any case, the entire cecum cannot be easily examined in retroflexion in any patient. The maneuver is most easily achieved when the insertion tube is relatively straight, and when the cecum and ascending colon are also relatively straight and have an adequate diameter. My technique is to place the colonoscope tip in the cecum, moved the up down and right/left controls to the maximum up and maximum left position, and then rotate the insertion tube counterclockwise. Once retroflexion is achieved, the instrument is withdrawn in retroflexion to the hepatic flexure. Retroflexion is reversed by releasing the up/down and right/left controls to the neutral position, and simultaneously withdrawing the insertion tube. The colonoscope tip is then re-advanced to overlap the forward examinations.

Retroflexion can be performed in the right colon in more than 90% of patients [39], though in some patients the maneuver is challenging and requires repeated attempts. Retroflexion is an important tool for colonoscopists to master, since it is a critical adjunct to endoscopic mucosal resection of some lesions [40]. However, randomized controlled trials indicate that a second examination of the right colon in the forward view is just as effective as performing the second examination in retroflexion increasing polyp detection [41,42].

Given the current evidence that achieving right colon protection is more challenging than left colon protection, a second examination of the ascending colon in either the forward or retroflex

positions could be advocated in all patients. As with any second examination, the yield is higher when the prevalence of disease is high. Thus, patients who have already had lesions detected in the right colon in the first forward examination, who are older, male, or who have bleeding indications, particularly a positive fecal occult blood test, are the highest yield candidates for a second right colon examination.

Another non-device tool that may increase ADR is patient rotation during withdrawal. The concept is to put the colon section currently being examined in a non-dependent position, so that it fills better with gas and is more completely distended. Thus, the right colon is examined in the left lateral decubitus position, the transverse colon in the supine position, and left colon in the right lateral decubitus position. The mechanism of improved detection is optimized distention [43]. Results from randomized controlled trials have been mixed [1,43–46]. The most positive studies have been from the United Kingdom, where the use of light and moderate sedation for colonoscopy is common. Patient rotation in the setting of deep sedation is more challenging, since the patient cannot assist with rotation, and because movement to the supine and right lateral decubitus positions in a deeply sedated patient may increase the risk of pulmonary aspiration. Adequate distention in the left lateral decubitus position can generally be achieved by mechanically closing the buttocks over the colonoscope to prevent gas loss, by use of carbon dioxide to remove fears of overdistension, by administration of antispasmodics such as intravenous hyoscyamine, usually or by filling the dependent section of the colon with clean water, which also generally allows an effective examination.

Recent evidence suggests that water exchange (filling the colon with water and exchanging dirty water for clean water) improves adenoma detection, particularly in the proximal colon [47]. The mechanism is improved bowel preparation (Fig. 3). Water exchange prolongs insertion to a variable degree.

Practice points

- Measuring and reporting ADR may result in ADR improvement.
- Colonoscopy is generally less effective in protecting against right-sided compared to left-sided colon cancer. Double right colon examination is an advisable consideration for many patients. Two forward-viewing examinations are as effective as one forward-viewing and one retroflexed right colon examination.
- Data are mixed with regard to the effectiveness of position change during withdrawal and improving detection. Improved distention is the mechanism of any benefit of position change. Other tools such as water filling can be used to effectively distend a dependent segment.
- Water exchange can improve ADR. The mechanism appears to be improved bowel preparation.

Device measures

Mucosal exposure tools

In an unconvincing randomized trial in which the withdrawal times with the device and control group were not equal, the Third-Eye Retroscope TER increased adenoma detection [48]. Unfortunately, the device was unpopular because of its cost and because it filled the working channel of the colonoscope, so that it had to be

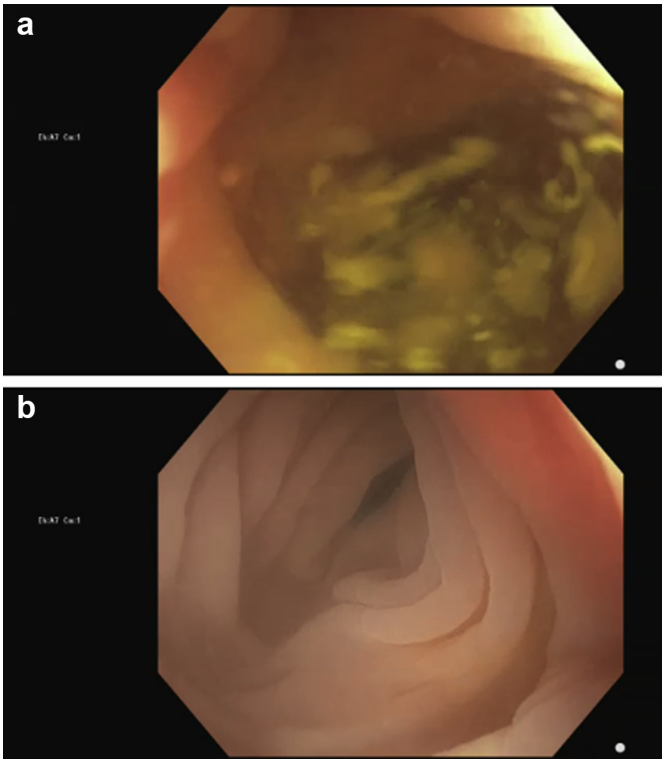

Fig. 3. Effects of water exchange. a) the sigmoid colon filled with water and dispersed mucus. Note the suction channel at 5 o'clock on the image is positioned near the image center to allow continuous suction during simultaneous water installation b) the same segment about 30 s later after continuous water installation and suctioning – the water exchange process.

removed each time a polyp was detected and then replaced after polyp resection and retrieval. The Panoramic Third Eye device has recently received approval from the Food and Drug Administration. This is a reusable device that clips on the colonoscope of all current manufacturers, and provides images to the side that are displayed adjacent to the forward viewing image of the colonoscope, so that a panoramic view similar to the Full Spectrum Endoscopy system is created. No significant size clinical trials with the panoramic device are currently available.

The Full Spectrum Endoscopy (FUSE) system, which utilizes imaging chips on both sides of the colonoscope tip to create a 330-degree field of view in the horizontal direction (120° in the vertical direction) produced a reduction in adenoma miss rates in a tandem study [49] (Fig. 4). The initial version of the instrument was tested in a FIT-positive population in Italy and there was no difference in detection between FUSE and standard Olympus colonoscopes [50]. The main concern about FUSE has been lower image resolution Originally developed in Israel, it was commercialized in the United States by EndoChoice, which was subsequently acquired by Boston Scientific. Currently, the future of the device is uncertain. An Olympus device with very wide angle of view has undergone preliminary testing but is not yet commercially available [51].

Four devices that fit on the scope and are used to flatten haustral folds have been developed. The simplest version is the short cap or hood. In the First North American study, the device improved detection in a tandem study [52]. The G-EYE is a reusable balloon that is built on to Pentax colonoscopies [53]. EndoRings, developed by EndoAid and marketed in the United States by US Endoscopy, has been tested in a tandem study [54] (Fig. 5). The most extensive experience, with multiple randomized controlled trials and one tandem study, is with Endocuff [55]. This device was developed by Arc Medical and originally marketed in the United States by

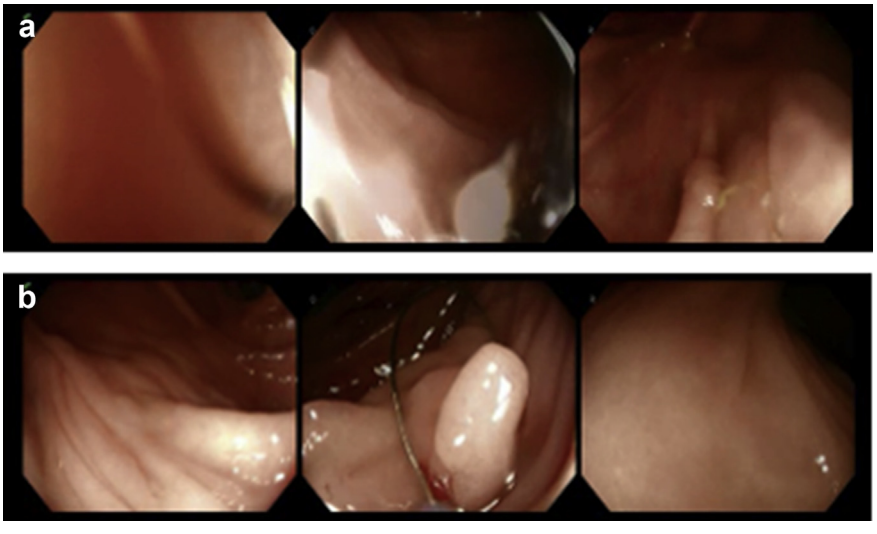

Fig. 4. The Full Spectrum Endoscopy (FUSE) utilizes 3 imagers that provide a 330 right left angle of view. a) a polyp is first visualized in the right image – the left image demonstrates a "red-out") and b) the same lesion brought to the center image for removal

MediVators. Endocuff had 2 rings of fingers that were used to stretch and flatten folds. Endocuff is no longer marketed, and has been replaced by Arc Medical with EndoVision, marketed in the United States by Olympus, and AmplifEYE manufactured and marketed in the US by MediVators. Both EndoVision and AmplifEYE have only one set of fingers at the distal tip. Limited data are available with EndoVision and AmplifEYE, but Endocuff was effective in improving ADR by about 7% in multiple randomized controlled trials [53]. There are no head-to-head data to compare the relative efficacy of FUSE, EndoRings, EndoVision, AmplifEYE, and Endocuff. The profile of EndoRings is larger than Endocuff or EndoVision, making it slightly more difficult to pass in patients with severe sigmoid diverticular disease.

Practice points

- Data are mixed with regard to the efficacy of wide angle instruments, including Full Spectrum Endoscopy (FUSE). FUSE may disappear from the market because of low uptake by colonoscopists
- Devices that are fixed to the colonoscope tip for the purpose of flattening folds, including a short cap or hood, Endocuff, Endocuff Vision, Endorings, and balloon colonoscopy, are all effective in increasing ADR.

Tools for highlighting flat lesions

Pancolonic dye spraying or chromoendoscopy, which has become essential to identification of dysplasia in ulcerative colitis [56], is also effective in detection of adenomas and serrated lesions during routine colonoscopy. Although chromoendoscopy is often considered too tedious for routine use, the largest randomized controlled trials produced significant increases in adenomas and a nearly significant increase in advanced lesions [57,58]. Despite its efficacy, pancolonic dye spraying has not been adopted for routine colonoscopy.

Modern colonoscopy is best performed with high definition instruments. High definition is essential to polyp differentiation, and essential to modern endoscopic mucosal resection as it greatly facilitates all tracking of residual polyp. It also enhances evaluation of post mucosectomy scars at followup. Meta-analysis suggests that high definition produces a 2% to 4% gain in the adenoma detection rate [59].

Auto fluorescence is currently available only in the trimodal imaging system and not in the United States. Both auto fluorescence and electronic chromoendoscopy systems such as the Olympus narrowband imaging, Pentax i-scan, and Fujinon intelligent chromoendoscopy (FICE) have produced uncertain benefits in detection, though they appear beneficial for polyp differentiation. One study suggested that NBI could improve the learning curve for detection

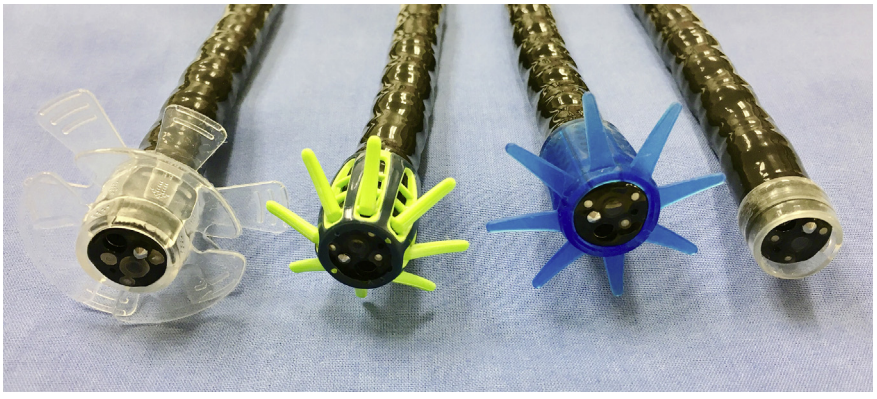

Fig. 5. The fold flattening devices available for use in the United States. From right to left: EndoRings, EndoCuff Vision, Amplifye, and the short cap or hood.

of flat lesions [60]. Brighter versions of electronic chromoendoscopy, including narrow band imaging [61] (Fig. 6), and blue laser imaging [62], have had positive results for detection in initial trials.

The largest paradigm shift in polyp detection may be emergence of computer-assisted detection (CAD). CAD would produce real-time highlighting of images for inspection by colonoscopists.

Practice points

- High definition improves ADR by 2–4%, and is essential to modern colonoscopy
- Pan-colonic dye spraying (chromoendoscopy) is effective for increasing ADR. New oral agents for colonic dye application may increase interest in chromoendoscopy for routine colonoscopy indications
- Electronic chromoendoscopy has been generally ineffective in increasing ADR. However, second generation technologies with brighter illumination, such as the Olympus 190 series narrow band imaging, and the Fujifilm Blue Laser Imaging, have produced ADR increases in initial studies
- Computer aided diagnosis of colorectal polyps during colonoscopy is under development as an adjunct to detection

Summary

Colonoscopy is highly operator dependent with regard to detection of precancerous lesions and prevention of colorectal cancer. The highest levels of detection are achieved by endoscopists using forward viewing high definition colonoscopes, equiped with a detailed understanding of the full spectrum of endoscopic appearances of precancerous lesions in the colorectum, and performing an examination characterized by meticulous exposure of colonic mucosa, thorough mucosal cleaning, and adequate luminal distention. Measurement and reporting of ADR, education in the appearances of flat and depressed adenomas and of serrated lesions, and instruction in effective withdrawal techniques, are the cornerstones of effective detection.

In cases where higher ADR is desirable, a variety of adjuncts to colonoscopy may result in improvements. These include a cap on the colonoscope tip, Endocuff, Endorings and balloon colonoscopy. Chromoendoscopy is effective for highlighting adenomas. Pancolonic dye spraying is well accepted in chronic colonoic inflammatory bowel disease, but has not been adapted for routine colonoscopy. An oral chromoendoscopy agent has undergone testing and may be commercially available soon. Electronic chromoendoscopy techniques have been generally ineffective on improving detection, but newer brighter techniques including for newer version of narrow band imaging and blue laser imaging warrant further study.

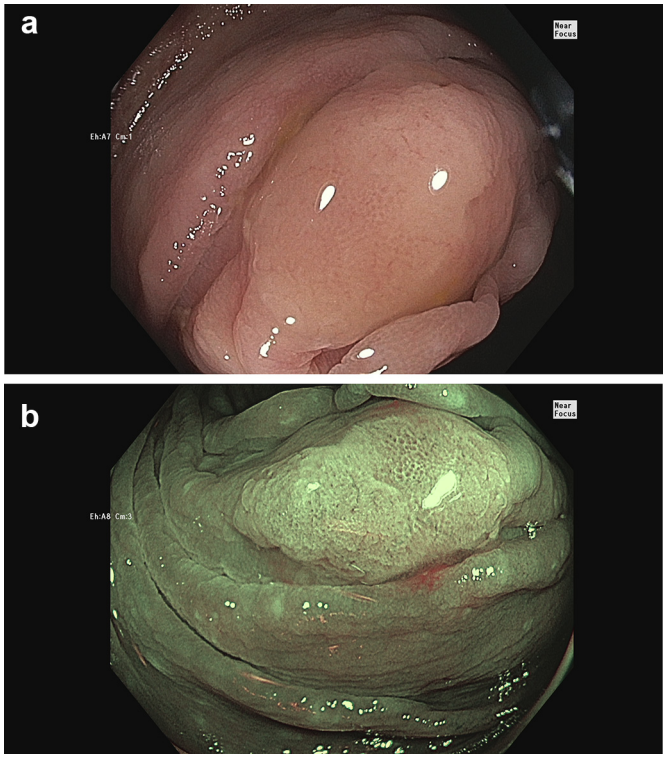

Fig. 6. A flat sessile serrated polyp in a) white light illumination and b) narrow band imaging using the Olympus 190 series colonoscope.

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Conflicts of interest

Dr Rex receives research support from Boston Scientific, Medtronic, Medivators, Colonary Solutions, Braintree Laboratories, Paion Medical, and EndoAid. He is a consultant to Boston Scientific and Olympus Corporation.

Research Agenda

1. Do the benefits for cancer prevention continue indefinitely as ADR rises?
2. Can high level detectors utilize longer screening and surveillance intervals?
3. How do devices and techniques for improved detection perform when compared head to head?
4. Do detection devices and techniques improve detection for all examiners (high and low ADR), or only low ADR?

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