World Journal of Gastroenterology

Online Submissions: http://www.wjgnet.com/esps/
wjg@wjgnet.com
doi:10.3748/wjg.v18.i37.5231

World J Gastroenterol 2012 October 7; 18(37): 5231-5239
ISSN 1007-9327 (print) ISSN 2219-2840 (online)

BRIEF ARTICLE

High-definition colonoscopy with i-Scan: Better diagnosis for small polyps and flat adenomas

Pier Alberto Testoni, Chiara Notaristefano, Cristian Vailati, Milena Di Leo, Edi Viale

Pier Alberto Testoni, Chiara Notaristefano, Cristian Vailati, Milena Di Leo, Edi Viale, Division of Gastroenterology and Gastrointestinal Endoscopy, Vita-Salute San Raffaele University, Scientific Institute San Raffaele, 20132 Milan, Italy
Author contributions: Testoni PA was responsible for the conception and design; Notaristefano C, Di Leo M and Vailati C contributed to the analysis and interpretation of the data; Testoni PA and Notaristefano C drafted the article; Testoni PA and Viale E contributed to critical revision of the article for important intellectual content; Testoni PA and Viale E contributed to final approval of the article.
Correspondence to: Pier Alberto Testoni, MD, Division of Gastroenterology and Gastrointestinal Endoscopy, Vita-Salute San Raffaele University, Scientific Institute San Raffaele, Via Olgettina 60, 20132 Milan, Italy. testoni.pieralberto@hsr.it
Telephone: +39-2-26432756 Fax: +39-2-26435609
Received: February 27, 2012 Revised: May 2, 2012
Accepted: May 5, 2012
Published online: October 7, 2012

Abstract

AIM: To investigate if high-definition (HD) colonoscope with i-Scan gave a higher detection rate of mucosal lesions *vs* standard white-light instruments.

METHODS: Data were collected from the computerized database of the endoscopy unit of our tertiary referral center. We retrospectively analyzed 1101 consecutive colonoscopies that were performed over 1 year with standard white-light (n = 849) or HD+ with i-Scan (n = 252) instruments by four endoscopists, in an outpatient setting. Colonoscopy records included patients' main details and family history for colorectal cancer, indication for colonoscopy (screening, diagnostic or surveillance), type of instrument used (standard white-light or HD+ plus i-Scan), name of endoscopist and bowel preparation. Records for each procedure included whether the cecum was reached or not and the reason for failure, complications during or immediately after the procedure, and number, size, location and characteristics of the lesions. Polyps or protruding lesions were defined as sessile or pedunculated, and nonprotruding lesions were defined according to Paris classification. For each lesion, histological diagnosis was recorded.

RESULTS: Eight hundred and forty-nine colonoscopies were carried with the standard white-light video colonoscope and 252 with the HD+ plus i-Scan video colonoscope. The four endoscopists did 264, 300, 276 and 261 procedures, respectively; 21.6%, 24.0%, 21.7% and 24.1% of them with the HD+ plus i-Scan technique. There were no significant differences between the four endoscopists in either the number of procedures done or the proportions of each imaging technique used. Both techniques detected one or more mucosal lesions in 522/1101 procedures (47.4%). The overall number of lesions recognized was 1266; 645 in the right colon and 621 in the left. A significantly higher number of colonoscopies recognized lesions in the HD+ plus i-Scan mode (171/252 = 67.9%) than with the standard white-light technique (408/849 = 48.1%) (P < 0.0001). HD+ with i-Scan colonoscopies identified more lesions than standard white-light imaging (459/252 and 807/849, P < 0.0001), in the right or left colon (mean ± SD, 1.62 ± 1.36 *vs* 1.33 ± 0.73, P < 0.003 and 1.55 ± 0.98 *vs* 1.17 ± 0.93, P = 0.033), more lesions < 10 mm (P < 0.0001) or nonprotruding (P < 0.022), and flat polyps (P = 0.04). The cumulative mean number of lesions per procedure detected by the four endoscopists was significantly higher with HD+ with i-Scan than with standard white-light imaging (1.82 ± 2.89 *vs* 0.95 ± 1.35, P < 0.0001).

CONCLUSION: HD imaging with i-Scan during the withdrawal phase of colonoscopy significantly increased the detection of colonic mucosal lesions, particularly small and nonprotruding polyps.

Key words: Colonoscopy; High-definition+ with i-Scan colonoscopy; White-light colonoscopy; Colonic polyps;

Nonprotruding lesions; Adenoma detection rate; Withdrawal time; Surface enhancement; Contrast enhancement; Tone enhancement

Peer reviewer: Dr. Jeff Butterworth, MB, FRCP, Department of Gastroenterology, Shrewsbury and Telford Hospitals NHS Trust, 102 The Mount, Shrewsbury SY3 8PH, United Kingdom

Testoni PA, Notaristefano C, Vailati C, Di Leo M, Viale E. High-definition colonoscopy with i-Scan: Better diagnosis for small polyps and flat adenomas. *World J Gastroenterol* 2012; 18(37): 5231-5239 Available from: URL: http://www.wjgnet.com/1007-9327/full/v18/i37/5231.htm DOI: http://dx.doi.org/10.3748/wjg.v18.i37.5231

INTRODUCTION

Screening colonoscopy is widely considered the gold standard for detection of colonic neoplasia and adenomatous lesions[1]; however, there are several reports of failure to detect small and flat neoplastic lesions[1-10], meaning that in these cases, colonoscopy does not provide adequate protection against colorectal cancer. This inadequacy results in up to 6% of new or missed cancer 3 years after colonoscopy[11,12]. In a recent study, colonoscopy in the preceding 10 years was associated with an overall 77% lower risk for colorectal cancer and approximately 50% lower risk for right-sided cancer[13].

Major factors affecting this polyp miss rate are the presence of blind segments in the colon, poor colon cleaning, and the fact that standard white light may be unable to recognize some small or flat lesions, which are particularly frequent in the right colon. The operator's experience and a longer withdrawal time, permitting closer observation, can only partly overcome these limitations. Even experienced endoscopists may miss up to 6% of adenomas larger than 1 cm and 30% of all adenomas[2,14,15].

Endoscopes have now been designed to improve mucosal visualization, with a wide angle of view and high-resolution, high-definition imaging. Despite these technical improvements, however, there is still debate about the value of high-definition colonoscopy in clinical practice. Out of 11 studies published so far evaluating the capacity of high-definition imaging to improve the lesion detection rate during colonoscopy, five have concluded that it gave no significant advantage over standard white-light colonoscopy[16-26]. A recent meta-analysis evaluating five studies involving 4422 patients and comparing high-definition *vs* standard white-light colonoscopy showed that there were marginal differences between the two imaging technologies for detection of colonic polyps and no advantages of high-definition in the detection of high-risk adenomas[27]. The introduction of instantaneous non-white-light imaging that mimics chromoendoscopy (Narrow-band, Olympus Ltd. and FICE, Fujinon Ltd.) makes it possible to enhance contrast and potentially to improve the detection of mucosal lesions; these filter techniques significantly raised the polyp detection rate in all but three of 13 studies to date[16,28-39]. However, two meta-analyses gave conflicting results[38,40].

A newly developed post-processing filter technology, the i-Scan (Pentax Ltd., Tokyo, Japan), combined and integrated into a high-definition processor (EPKi) that generates images above the high-definition television standard (HD+ resolution), highlights the mucosal surface and architecture by surface enhancement (SE), contrast enhancement (CE), and tone enhancement (TE) modes. So far, in all reports but one, retrospective, it permitted significantly better recognition and characterization of the mucosal lesions during colonoscopy[41-45]. In one recent study, narrow-band imaging and i-Scan significantly improved the polyp detection rate and showed similar efficacy[46].

However, most of the studies using these new post-processing filter techniques are based on prospective, controlled clinical trials in a limited number of patients, in which endoscopists are likely to do the colonoscopy more diligently than in routine practice, with adequate bowel preparation, so it is not clear whether the better polyp detection rates reported can be maintained in routine practice.

The aim of the present study was therefore to determine whether the routine use of colonoscopes equipped with high-definition combined with i-Scan technology (HD+ plus i-Scan) gave a higher rate of detection of overall mucosal lesions, particularly of flat adenomas, than standard white-light video colonoscopes, in a consecutive series of patients undergoing screening, diagnostic or surveillance colonoscopy by different endoscopists with similar expertise, in an outpatient clinical practice setting.

MATERIALS AND METHODS

Data for the study were collected from the computerized database of the endoscopy unit of our tertiary referral center. Colonoscopy records included patients' main details and family history for colorectal cancer, indication for colonoscopy (screening, diagnostic or surveillance), type of instrument used (standard white-light or HD+ plus i-Scan), name of endoscopist, and bowel preparation, defined on the basis of a modified Ottawa scale[47].

Records for each procedure included whether the cecum was reached or not and the reason for failure (inadequate cleaning, strictures, and pain during the procedure), complications during or immediately after the procedure, and number, location and characteristics of the lesions. Polyps or protruding lesions were defined as sessile (Ⅰs) or pedunculated (Ⅰp), and nonprotruding lesions as elevated (Ⅱa), flat (Ⅱb), and depressed (Ⅱc), according to Paris classification[48]. For each lesion, histological diagnosis was recorded. Size and location of the lesions were classified as follows: 0-5 mm, 6-10 mm, 11-15 mm, 16-20 mm, 21-30 mm, > 30 mm; right and left colon. Withdrawal time was recorded for all screening colonoscopies, being

these procedures the object of other studies. Images of each lesion were stored in the database. For each patient, pO_2, heart rate, and blood pressure were measured and recorded before, during and at the end of the procedure.

Data collection

Over a 1-year period, all consecutive screening, diagnostic and surveillance colonoscopies in outpatients done by four expert endoscopists, each of whom had done 200-400 colonoscopies/year for at least 15 years and at least 50 procedures with HD+ plus i-Scan definition equipped instruments were evaluated. The four endoscopists used the two endoscopy techniques in a random fashion, depending of the availability of the instruments. Colonoscopies in subjects younger than 18 years, with genetic-associated colon cancer risk conditions, acute gastrointestinal bleeding, or inflammatory bowel disease were excluded. Procedures with insufficient bowel cleansing, patients in whom residual stool could not be removed by endoluminal washing and suctioning, and patients in whom the cecum was not reached were also excluded.

All patients gave informed consent for the procedures, diagnostic or therapeutic, and for data management for scientific purposes. The retrospective, observational study was approved by the institutional ethics committee.

Examination technique

The bowel was prepared in all cases with polyethylene glycol: 4 L SELG (Promefarm S.r.l, Milan, Italy) or 3 L Moviprep (Norgine GmbH, Marburg, Germany), divided into two parts, were taken the day before the procedure. All patients received conscious sedation with midazolam (Ipnovel, Roche SPA, Basel, Switzerland) and fentanyl (Fentanest, Pfizer, New York, United States) or deep sedation with propofol (Diprivan, AstraZeneca, Zug, Switzerland); 20 mg Butylscopolamin (Buscopan, Boehringer Ingelheim Pharma GmbH, Ingelheim, Germany) were administered if necessary, unless contraindicated.

Standard white-light video colonoscopy was carried out with Pentax colonoscopes EC-3870FZK, EC 3885F, EC 3885L (Pentax Ltd., Tokyo, Japan) and an EPM 3500 or EPK 1000 processor. The colon was inspected during withdrawal of the instrument and lesions were identified and characterized with light imaging only. Magnification was not possible with these endoscopes.

HD+ plus i-Scan video colonoscopy was carried out with Pentax colonoscopes EC-3890FI and EC 3870FZK, using the EPKi processor. The i-Scan technology is a digital contrast method using a light filter that uses different software algorithms with real-time image mapping embedded in the EPKi processor. It enhances mucosal imaging by activating three distinct functions-one for SE mode, the second for CE mode, and the third for TE mode. For SE and CE, there are three enhancement levels (low, medium and high); TE mode can be specifically tailored for the esophagus, stomach, or colon. SE mode enhances the structure through recognition of the edges; compared to normal images, SE images do not differ in brightness and differ little in color, but allow easier recognition of minute glandular structures, which makes it simpler to check changes on the basis of structural differences. With CE mode, areas with lower luminance intensity than surrounding pixels are identified on the basis of pixel-wise luminance intensity data. Processing images with CE does not change the image brightness but enhances minute irregularities and depressed areas of the mucosal surface with a slight bluish-white stain. With TE mode, the RGB components of an ordinary endoscope image are broken down into their parts, and each one is then converted independently along the tone curve, followed by resynthesis of the three components to yield a reconstructed image[43].

The three modes are arranged in series, so two or more can be applied at one time. The modes of enhancement and their levels can be switched on a real-time basis, permitting efficient endoscopic observation.

In all cases, colonoscopy was done using the SE (low) + CE (low) modes; the TE mode for the colon was routinely activated during withdrawal of the instrument once the cecum had been reached, so the whole retrieval phase of the procedure was done using the i-Scan technique with TE mode set for the colon.

Statistical analysis

Data were analyzed using SPSS version 17.0 software (Chicago, IL, United States). Continuous data were described by mean and standard deviation or compared with the Mann-Whitney test. Statistical differences in categorical variables were analyzed using two-sided Fisher's exact tests or χ^2 tests, as appropriate. All differences were considered significant at two-sided P value < 0.05.

RESULTS

A total of 1101 colonoscopy records with images obtained by the four endoscopists were eligible for the study: 849 with the standard white-light video colonoscope and 252 with the HD+ plus i-Scan video colonoscope. The four endoscopists did 264, 300, 276 and 261 procedures, respectively; 21.6%, 24.0%, 21.7% and 24.1% of them with the HD+ plus i-Scan technique. The number of colonoscopies carried out for screening, diagnosis, and surveillance with standard white-light and HD+ plus i-Scan technology by the four endoscopists are reported in Table 1. There were no significant differences between the four endoscopists in either the number of procedures done or the proportions of each imaging technique used.

Both techniques detected one or more mucosal lesions in 522/1101 procedures (47.4%). The overall number of lesions recognized was 1266: 645 in the right colon and 621 in the left. A significantly higher number of colonoscopies recognized lesions in the HD+ plus i-Scan mode (171/252 = 67.9%) than with the standard white-light technique (408/849 = 48.1%) ($P < 0.0001$). The number of mucosal lesions recognized by the two imaging tech-

Table 1 Colonoscopies carried out for screening, diagnosis and surveillance *n* (%)

Indications	HD+ with i-Scan	Standard white light	Total
Screening	69 (23.9)	219 (76.1)	288
Diagnosis	156 (22.1)	552 (77.9)	708
Follow-up	27 (25.7)	78 (74.3)	105
Total	252	849	1101

HD: High-definition.

Table 2 High-definition+ with i-Scan and standard white-light colonoscopy detection rates of mucosal lesions

Indications	HD+ with i-Scan[1]	Standard white light[1]	*P* value
Screening	179/69 (2.59)	207/219 (0.94)	< 0.0001
Diagnosis	203/156 (1.3)	524/552 (0.94)	0.0105
Follow-up	77/27 (2.8)	76/78 (0.97)	< 0.0001
Total	459/252 (1.82)	807/849 (0.95)	< 0.0001

[1]Number of lesion/procedure (mean). HD: High-definition.

Table 3 Number and size of protruding and nonprotruding lesions found with high-definition+ with i-Scan and standard white-light colonoscopy

	HD+ with i-Scan	Standard white light	Total	*P* value
0-10 mm				< 0.0001
Protruding	341	636	977	
Nonprotruding	43	31	74	
11-20 mm				0.83
Protruding	30	67	97	
Nonprotruding	12	23	35	
21-30 mm				0.36
Protruding	9	8	17	
Nonprotruding	12	21	33	
> 30 mm				
Protruding	9	12	21	0.46
Nonprotruding	3	9	12	

HD: High-definition.

niques and the mean numbers detected by each procedure were significantly higher for HD+ plus i-Scan than with standard white light, for screening, diagnostic, and surveillance colonoscopies (Table 2). In both the right and left colon, HD+ plus i-Scan colonscopy recognized a larger mean number of lesions than standard white light (mean ± SD 1.62 ± 1.36 *vs* 1.33 ± 0.73, $P < 0.003$ and 1.55 ± 0.98 *vs* 1.17 ± 0.93, $P = 0.033$).

Overall, 154 nonprotruding lesions were identified and removed: 70 with the HD+ plus i-Scan mode (27.8%) and 84 with the standard white-light technique (9.9%). The HD+ plus i-Scan mode recognized a significantly higher number of nonprotruding lesions than the standard white-light technique ($P = 0.04$) (Figures 1 and 2).

The overall number and size of the lesions, protruding or nonprotruding, found with HD+ plus i-Scan and standard white light are shown in Table 3. The HD+ plus i-Scan technique identified a significantly larger number of lesions smaller than 10 mm, either protruding or nonprotruding, than standard white light ($P < 0.0001$); the difference was not significant for lesions measuring 11-20 mm, 21-30 mm, and > 30 mm. Colonoscopies performed with HD+ with i-Scan technique also identified a significantly larger number of overall lesions and nonprotruding lesions smaller than 10 mm than did standard white light ($P < 0.0001$ and $P < 0.022$, respectively), while the difference was not different for larger lesions, either protruding or nonprotruding. The differences were not significant considering screening, diagnostic, and surveillance colonoscopies.

Among the 154 nonprotruding lesions, histological report was available for 133 lesions, because in 21 cases, resected specimens were missed during colonoscopy (Table 4). Adenoma detection rate was significantly higher with HD+ plus i-Scan mode than with standard white light only for lesions smaller than 10 mm (32/35 *vs* 19/27, $P = 0.05$), while the difference was not significant for larger adenomas.

The number of procedures managed by the four endoscopists and the distribution of HD+ plus i-Scan and standard white-light colonoscopies, with the mean numbers of lesions found by each one. The lesion detection rates were very similar for all four. The cumulative mean number of lesions per procedure detected with the two techniques was significantly higher with the HD+ plus i-Scan than with standard white-light imaging (mean ± SD, 1.82 ± 2.89 *vs* 0.95 ± 1.35, $P < 0.0001$). In fact, each of the four endoscopists identified twice as many lesions with the HD+ plus i-Scan as with standard white-light imaging.

The overall withdrawal time, reported only for screening colonoscopies, did not significantly differ between procedures performed with the HD+ plus i-Scan and standard white light (8.4 ± 1.2 min *vs* 8.3 ± 1.4 min, respectively) (Table 5).

DISCUSSION

To date, only one study has evaluated the impact of the routine use of i-Scan with TE mode and HD+ imaging in the detection of mucosal lesion during the withdrawal phase of colonoscopy, compared to standard white-light imaging, in a large series of patients in clinical practice[45]. The study was retrospective and did not improve adenoma detection rate in a population with mixed risk for colorectal cancer.

In our retrospective study, with the HD+ plus i-Scan imaging routinely activated during the withdrawal phase of colonoscopy, once the cecum had been reached, a significantly larger number of examinations identified some mucosal lesion and adenomas, either protruding or flat, and there were also significant improvements in the overall detection rate of lesions and the mean number of lesions recognized for each colonoscopy, compared with standard white-light imaging. The rate was most markedly higher for lesions not bigger than 10 mm and nonprotruding ones. Although the rates of detection of

Table 4 Histological report of nonprotruding lesions

	0-10 mm		11-20 mm		21-30 mm		> 30 mm		Total
	HD + with i-Scan	Standard white light	HD + with i-Scan	Standard white light	HD + with i-Scan	Standard white light	HD + with i-Scan	Standard white light	
Missing	8	4	0	3	0	3	0	3	21
Hyperplastic	3	8	3	2	3	0	0	0	19
Serrated	29	16	6	18	9	18	0	0	96
LGIN	3	3	0	0	0	0	3	6	15
Adenocarcinoma	0	0	3	0	0	0	0	0	3
Total	43	31	12	23	12	21	3	9	154

HD: High-definition; LGIN: Low grade intraepithelial neoplasia.

Table 5 Procedures performed by the four endoscopists using the two techniques

Operator	Procedures	HD+ with i-Scan	Standard white light	Lesions	No. of lesions (mean number of lesions/procedure)		*P* value
					HD+ with i-Scan	Standard white light	
1	264	57	207	330	117 (2.05)	213 (1.02)	< 0.0001
2	300	72	228	375	132 (1.83)	243 (1.07)	0.089
3	276	60	216	294	114 (1.9)	180 (0.83)	< 0.0001
4	261	63	198	267	96 (1.52)	171 (0.86)	0.71
Total	1101	252	849	1266	459 (1.82)	807 (0.95)	< 0.0001

HD: High-definition.

lesions larger than 10 mm did not differ with the two imaging techniques, protruding and nonprotruding lesions smaller than 10 mm were recognized significantly more frequently using the HD+ plus i-Scan technology. In particular, HD+ plus i-Scan technology identified flat polyps smaller than 10 mm three times more than the white-light technique.

The cumulative mean number of lesions per colonoscopy recognized by the four colonoscopists was significantly higher with HD+ plus i-Scan than with standard white-light imaging, while the withdrawal time, when recorded, did not differ between the two techniques.

Only two studies published so far have assessed the combined use of HD+ plus i-Scan for colonoscopy; they have reported similar results in favor of this technique but they were obtained in a prospective trial setting and in a smaller number of selected patients[42,44].

Identifying more polyps by colonoscopy in clinical practice, including small (< 10 mm) and flat ones, may have an important impact for colorectal cancer prevention. The polyp miss rate is probably the main factor accounting for a persistent risk of colorectal cancer reported in 10%-24% of cases after screening colonoscopy[49].

A systematic review of six tandem colonoscopy studies using standard white-light imaging showed an overall polyp miss rate of 22%. The rate rose with smaller lesions, ranging from 2.1% for lesions bigger than 10 mm, to 13% for those between 5 and 10 mm, and up to 26% for those smaller than 5 mm[8]. A prospective multicenter study of back-to-back colonoscopies with white-light imaging reported 9% and 27% miss rates for adenomas > 5 mm and < 5 mm, respectively, and 11% for advanced adenomas[9]. This means that small and flat mucosal lesions, mostly in the right colon, are the ones that may frequently be missed during colonoscopy.

A limited number of studies have compared the efficacy of HD+ colonoscopy with standard white-light colonoscopy, and the findings are far from clear: four of the nine studies concluded that high-definition imaging gave no benefit compared to standard resolution[17,18,21,24]. The addition of electronic filters, such NBI and FICE, to the high-definition imaging did improve the polyp detection rate for small/flat lesions but some results were still disappointing for this end-point[16,30].

Even though there is a general belief that detecting and removing small lesions (1-5 mm) in the colon may not have any significant clinical impact, a number of studies have found that small lesions, mainly flat ones, may have unfavorable histology. One reported that small depressed colorectal lesions had up to a 40% chance of submucosal invasion[49]; two found that 3.9% and 16% of adenomas between 6 and 10 mm had high-grade dysplasia[50,51], and 0.5% of adenomas measuring 6-9 mm were actually cancer[51]. These data might explain the reported occurrence of colorectal cancer after negative screening colonoscopy and support the need for detecting and removing all protruding lesions of the colon, regardless of the size, and selecting the most appropriate techniques to ensure maximum recognition of lesions at colonoscopy.

HD+ plus i-Scan can also differentiate diminutive adenomas and hyperplastic polyps[52], and a recent study using a Markov simulation model suggested that a resect and discard strategy for very small polyps might improve the cost-effectiveness of colorectal cancer screening[53].

A potential limitation of the present study was its retrospective nature. However, data used for analysis, in-

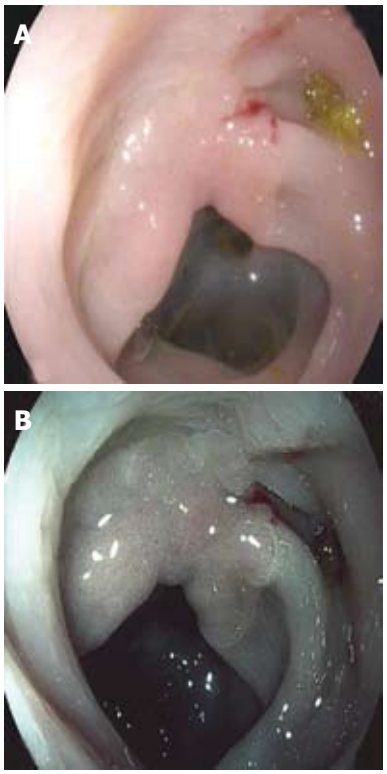

Figure 1 Flat lesion Ⅱb + Ⅱa on left colon examined by high-definition-white light and visualized with i-Scan. A: Flat lesion Ⅱb + Ⅱa of 25 mm × 25 mm on left colon examined by high-definition white light; B: Same lesion visualized with i-Scan.

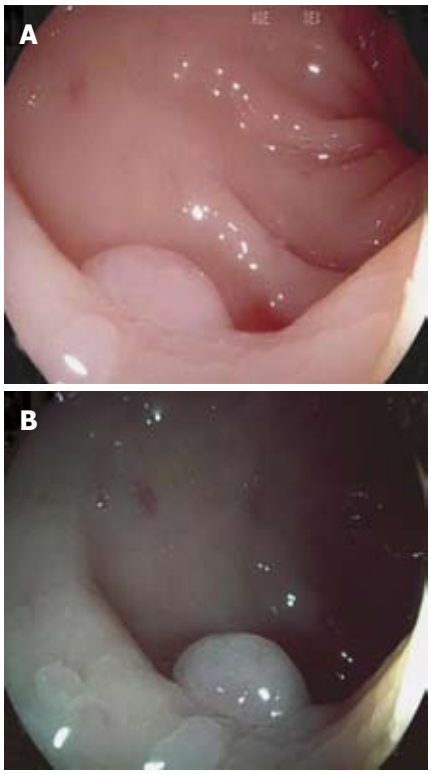

Figure 2 Flat lesion 0-Ⅱa visualized with high-definition white light and surface enhancement and visualized with i-Scan and digital chromoendoscopy. A: Flat lesion 0-Ⅱa visualized with high-definition white light and surface enhancement; B: Same lesion visualized with i-Scan and digital chromoendoscopy.

cluding the adequacy of bowel preparation, were detailed and were collected prospectively for each procedure and stored in a database. Only procedures that included all the data required for the study were considered. As with all nonrandomized trials, potential confounding variables cannot be entirely excluded; however, we examined a large number of colonoscopies and statistical analysis found highly significant differences. Although colonoscopies carried out for different purposes (screening, diagnostic and surveillance) may represent different settings, the differences reported from overall results were also confirmed in the three settings. On the other hand, the retrospective design has the advantage of providing information on the true yield of HD+ plus i-Scan imaging for detecting polyps during colonoscopy in current clinical practice. Prospective trials evaluating new imaging systems could allow the endoscopist to be more attentive during the procedures outside routine practice and very likely give greater accuracy for polyp detection, especially for flat and small lesions, but the good results are not necessarily directly transferable into routine clinical practice.

The lack of documentation of withdrawal time for all colonoscopies is another potential limitation of a retrospective study, compared with prospective ones, because withdrawal time plays an important role in adenoma detection, although here too data are conflicting. In this retrospective evaluation, we were able to assess reliably the withdrawal times only for screening colonoscopies without therapeutic interventions: withdrawal time was comparable by using the two imaging techniques. Besides the imaging technology, probably the endoscopist's technique and experience is perhaps more important than other factors, including withdrawal time, in detecting polyps by colonoscopy[54-56]. The endoscopists in this study were experts, with many colonoscopies behind them and on their current schedules, and adequate experience with HD+ plus i-Scan imaging in the year leading up to the study. In addition, we compared the numbers of colonic lesions recognized by the same endoscopist using the two techniques, thus applying similar expertise and technique, in a similar clinical setting, and found that the four endoscopists using HD+ plus i-Scan imaging detected cumulatively more lesions. Only one other study comparing the diagnostic yield for colonic polyps using standard white-light and HD+ colonoscopy followed a retrospective design, with an adequate number of unselected patients undergoing colonoscopy in routine practice. The findings confirmed the greater accuracy for detecting polyps of HD imaging compared with white light (42.2% *vs* 37.8%)[20]. In our hands, 67.8% and 27.8% of colonoscopies with HD+ plus i-Scan recognized some mucosal lesions and flat small polyps (< 10 mm), respectively, compared to 48.1% and 9.9% for standard white-light imaging. HD+ plus i-Scan thus gave an approximately 30% higher diagnostic yield for mucosal lesions of the colon and increased by three times the diagnostic accuracy for flat polyps smaller than 10 mm.

In conclusion, this retrospective study on a large se-

ries of consecutive outpatients undergoing colonoscopy in different settings by four expert endoscopists showed that the routine addition of i-Scan to HD imaging during the entire withdrawal phase of colonoscopy, once the cecum had been reached, significantly increased the diagnostic yield for detection of mucosal lesions of the colon, particularly small and nonprotruding ones, without affecting the withdrawal time. In colon cancer screening, the routine use of HD+ plus i-Scan can recognize more mucosal lesions without the need to prolong the withdrawal time to allow for closer inspection, as suggested in other studies, and could probably enable less-skilled endoscopists to achieve performances comparable to those of experienced ones in detecting colonic polyps.

COMMENTS

Background

Screening colonoscopy is widely considered the gold standard for detection of colonic neoplasia and adenomatous lesions, however, there are several reports of failure to detect small and flat neoplastic lesions, meaning that in these cases, colonoscopy does not provide adequate protection against colorectal cancer. Besides the operator's experience, withdrawal time, quality of colon cleansing, presence of blind segments in the colon, and quality of imaging provided by endoscopes play an important role in lesion detection. Standard white-light imaging may be unable to recognize some small or flat lesions, which are particularly frequent in the right colon, and it may affect the polyp miss rate during routine colonoscopy. High-definition (HD) imaging and filter technologies have been applied to colonoscopies to improve detection of lesions, but results are conflicting.

Research frontiers

Endoscopes have now been designed to improve mucosal visualization, with a wide angle of view, filter-aided techniques that can enhance characterization of mucosal morphology and surface architecture, and high-resolution/high-definition imaging that can improve endoscopic recognition of mucosal lesions. In this study, the authors demonstrated that the routine use of HD+ plus i-Scan recognized more mucosal lesions without the need to prolong the withdrawal time to allow closer inspection.

Innovations and breakthroughs

Recent studies have analyzed the capacity of high-definition imaging to improve the lesion detection rate during colonoscopy with conflicting results. The value of high-definition colonoscopy in clinical practice is still debated. In this study, the authors showed that the routine addition of i-Scan to HD+ imaging during the entire withdrawal phase of the colonoscopy significantly increased the diagnostic yield for detection of mucosal lesions of the colon, particularly small and nonprotruding ones, without affecting the withdrawal time, and could probably enable less-skilled endoscopists to achieve performances comparable to those of experienced ones in detecting mucosal lesions.

Applications

This study may encourage the utilization of advanced imaging technologies to reduce polyp miss rate and improve colonoscopy performance in the prevention of colorectal cancer.

Terminology

The i-Scan technology is a digital contrast method employing a light filter that uses different software algorithms with real-time image mapping embedded in the Pentax EPKi processor. i-Scan enhances mucosal imaging by activating three distinct functions: one for surface enhancement (SE), the second for contrast enhancement (CE), and the third for tone enhancement (TE), allowing a better recognition and characterization of the mucosal lesions during colonoscopy. SE mode enhances the structure through recognition of the edges, compared to normal images, and allows easier recognition of minute glandular structures which makes it simpler to identify changes on the basis of structural differences. CE mode enhances minute irregularities and depressed areas of the mucosal surface with a slight bluish-white stain. In TE mode, the RGB components of an ordinary endoscope image are broken down into their parts, and each one is then converted independently along the tone curve, followed by resynthesis of the three components to yield a reconstructed image.

Peer review

The authors examined the role of HD+ i-Scan *vs* white-light colonoscopy on polyp detection rates. The research is a significant addition to the literature on the use of contrast technology in improving the quality of colonoscopy in detecting polyps. The results of the study will encourage those regularly involved in performing colonoscopy to consider a lower threshold in utilizing these techniques to improve polyp detection rates. The research novelty is in the fact that the study was conducted in a real clinical practice environment and could be considered to have greater clinical applicability.

REFERENCES

1 **Hixson LJ**, Fennerty MB, Sampliner RE, McGee D, Garewal H. Prospective study of the frequency and size distribution of polyps missed by colonoscopy. *J Natl Cancer Inst* 1990; **82**: 1769-1772

2 **Rex DK**, Cutler CS, Lemmel GT, Rahmani EY, Clark DW, Helper DJ, Lehman GA, Mark DG. Colonoscopic miss rates of adenomas determined by back-to-back colonoscopies. *Gastroenterology* 1997; **112**: 24-28

3 **Matsushita M**, Hajiro K, Okazaki K, Takakuwa H, Tominaga M. Efficacy of total colonoscopy with a transparent cap in comparison with colonoscopy without the cap. *Endoscopy* 1998; **30**: 444-447

4 **Bensen S**, Mott LA, Dain B, Rothstein R, Baron J. The colonoscopic miss rate and true one-year recurrence of colorectal neoplastic polyps. Polyp Prevention Study Group. *Am J Gastroenterol* 1999; **94**: 194-199

5 **Rex DK**, Chadalawada V, Helper DJ. Wide angle colonoscopy with a prototype instrument: impact on miss rates and efficiency as determined by back-to-back colonoscopies. *Am J Gastroenterol* 2003; **98**: 2000-2005

6 **Harrison M**, Singh N, Rex DK. Impact of proximal colon retroflexion on adenoma miss rates. *Am J Gastroenterol* 2004; **99**: 519-522

7 **Kasugai K**, Miyata M, Hashimoto T, Todoroki I, Tsutsui S, Nagase F, WadaY, Sato M, Takahashi K, Tokura Y, Kanazawa T, Kakumu S. Assessment of miss and incidence rates of neoplastic polyps at colonoscopy. *Dig Endosc* 2005; **17**: 44-49

8 **van Rijn JC**, Reitsma JB, Stoker J, Bossuyt PM, van Deventer SJ, Dekker E. Polyp miss rate determined by tandem colonoscopy: a systematic review. *Am J Gastroenterol* 2006; **101**: 343-350

9 **Heresbach D**, Barrioz T, Lapalus MG, Coumaros D, Bauret P, Potier P, Sautereau D, Boustière C, Grimaud JC, Barthélémy C, Sée J, Serraj I, D'Halluin PN, Branger B, Ponchon T. Miss rate for colorectal neoplastic polyps: a prospective multicenter study of back-to-back video colonoscopies. *Endoscopy* 2008; **40**: 284-290

10 **Hewett DG**, Rex DK. Cap-fitted colonoscopy: a randomized, tandem colonoscopy study of adenoma miss rates. *Gastrointest Endosc* 2010; **72**: 775-781

11 **Bressler B**, Paszat LF, Chen Z, Rothwell DM, Vinden C, Rabeneck L. Rates of new or missed colorectal cancers after colonoscopy and their risk factors: a population-based analysis. *Gastroenterology* 2007; **132**: 96-102

12 **Lieberman DA**, Weiss DG, Harford WV, Ahnen DJ, Provenzale D, Sontag SJ, Schnell TG, Chejfec G, Campbell DR, Kidao J, Bond JH, Nelson DB, Triadafilopoulos G, Ramirez FC, Collins JF, Johnston TK, McQuaid KR, Garewal H, Sampliner RE, Esquivel R, Robertson D. Five-year colon surveillance after screening colonoscopy. *Gastroenterology* 2007; **133**: 1077-1085

13 **Brenner H**, Chang-Claude J, Seiler CM, Rickert A, Hoffmeister M. Protection from colorectal cancer after colonoscopy: a population-based, case-control study. *Ann Intern Med* 2011; **154**: 22-30

14 **Postic G**, Lewin D, Bickerstaff C, Wallace MB. Colonoscopic miss rates determined by direct comparison of colonoscopy

with colon resection specimens. *Am J Gastroenterol* 2002; **97**: 3182-3185
15 **Bretagne JF**, Hamonic S, Piette C, Manfredi S, Leray E, Durand G, Riou F. Variations between endoscopists in rates of detection of colorectal neoplasia and their impact on a regional screening program based on colonoscopy after fecal occult blood testing. *Gastrointest Endosc* 2010; **71**: 335-341
16 **Rex DK**, Helbig CC. High yields of small and flat adenomas with high-definition colonoscopes using either white light or narrow band imaging. *Gastroenterology* 2007; **133**: 42-47
17 **East JE**, Stavrindis M, Thomas-Gibson S, Guenther T, Tekkis PP, Saunders BP. 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
18 **Pellisé M**, Fernández-Esparrach G, Cárdenas A, Sendino O, Ricart E, Vaquero E, Gimeno-García AZ, de Miguel CR, Zabalza M, Ginès A, Piqué JM, Llach J, Castells A. Impact of wide-angle, high-definition endoscopy in the diagnosis of colorectal neoplasia: a randomized controlled trial. *Gastroenterology* 2008; **135**: 1062-1068
19 **Tribonias G**, Theodoropoulou A, Konstantinidis K, Vardas E, Karmiris K, Chroniaris N, Chlouverakis G, Paspatis GA. Comparison of standard vs high-definition, wide-angle colonoscopy for polyp detection: a randomized controlled trial. *Colorectal Dis* 2010; **12**: e260-e266
20 **Buchner AM**, Shahid MW, Heckman MG, McNeil RB, Cleveland P, Gill KR, Schore A, Ghabril M, Raimondo M, Gross SA, Wallace MB. High-definition colonoscopy detects colorectal polyps at a higher rate than standard white-light colonoscopy. *Clin Gastroenterol Hepatol* 2010; **8**: 364-370
21 **Burke CA**, Choure AG, Sanaka MR, Lopez R. A comparison of high-definition vs conventional colonoscopes for polyp detection. *Dig Dis Sci* 2010; **55**: 1716-1720
22 **Kahi CJ**, Anderson JC, Waxman I, Kessler WR, Imperiale TF, Li X, Rex DK. High-definition chromocolonoscopy vs. high-definition white light colonoscopy for average-risk colorectal cancer screening. *Am J Gastroenterol* 2010; **105**: 1301-1307
23 **De Melo SW**, Wallace MB. Endoscopic colorectal imaging and therapy. *Curr Opin Gastroenterol* 2011; **27:** 54-60
24 **Mönkemüller K**, Fry LC, Zimmermann L, Mania A, Zabielski M, Jovanovic I. Advanced endoscopic imaging methods for colon neoplasia. *Dig Dis* 2010; **28**: 629-640
25 **Rastogi A**, Early DS, Gupta N, Bansal A, Singh V, Ansstas M, Jonnalagadda SS, Hovis CE, Gaddam S, Wani SB, Edmundowicz SA, Sharma P. Randomized, controlled trial of standard-definition white-light, high-definition white-light, and narrow-band imaging colonoscopy for the detection of colon polyps and prediction of polyp histology. *Gastrointest Endosc* 2011; **74**: 593-602
26 **Adler A**, Aminalai A, Aschenbeck J, Drossel R, Mayr M, Scheel M, Schröder A, Yenerim T, Wiedenmann B, Gauger U, Roll S, Rösch T. Latest generation, wide angle, high-definition colonoscopes increase adenoma detection rate. *Clin Gastroenterol Hepatol* 2011; **10:** 155-159
27 **Subramanian V**, Mannath J, Hawkey CJ, Ragunath K. High definition colonoscopy vs. standard video endoscopy for the detection of colonic polyps: a meta-analysis. *Endoscopy* 2011; **43**: 499-505
28 **Sikka S**, Ringold DA, Jonnalagadda S, Banerjee B. Comparison of white light and narrow band high definition images in predicting colon polyp histology, using standard colonoscopes without optical magnification. *Endoscopy* 2008; **40**: 818-822
29 **Adler A**, Pohl H, Papanikolaou IS, Abou-Rebyeh H, Schachschal G, Veltzke-Schlieker W, Khalifa AC, Setka E, Koch M, Wiedenmann B, Rösch T. A prospective randomised study on narrow-band imaging vs conventional colonoscopy for adenoma detection: does narrow-band imaging induce a learning effect? *Gut* 2008; **57**: 59-64
30 **Kaltenbach T**, Friedland S, Soetikno R. A randomised tandem colonoscopy trial of narrow band imaging vs white light examination to compare neoplasia miss rates. *Gut* 2008; **57**: 1406-1412
31 **Inoue T**, Murano M, Murano N, Kuramoto T, Kawakami K, Abe Y, Morita E, Toshina K, Hoshiro H, Egashira Y, Umegaki E, Higuchi K. Comparative study of conventional colonoscopy and pan-colonic narrow-band imaging system in the detection of neoplastic colonic polyps: a randomized, controlled trial. *J Gastroenterol* 2008; **43**: 45-50
32 **Rastogi A**, Keighley J, Singh V, Callahan P, Bansal A, Wani S, Sharma P. High accuracy of narrow band imaging without magnification for the real-time characterization of polyp histology and its comparison with high-definition white light colonoscopy: a prospective study. *Am J Gastroenterol* 2009; **104**: 2422-2430
33 **Chang CC**, Hsieh CR, Lou HY, Fang CL, Tiong C, Wang JJ, Wei IV, Wu SC, Chen JN, Wang YH. Comparative study of conventional colonoscopy, magnifying chromoendoscopy, and magnifying narrow-band imaging systems in the differential diagnosis of small colonic polyps between trainee and experienced endoscopist. *Int J Colorectal Dis* 2009; **24**: 1413-1419
34 **Parra-Blanco A**, Jiménez A, Rembacken B, González N, Nicolás-Pérez D, Gimeno-García AZ, Carrillo-Palau M, Matsuda T, Quintero E. Validation of Fujinon intelligent chromoendoscopy with high definition endoscopes in colonoscopy. *World J Gastroenterol* 2009; **15**: 5266-5273
35 **Adler A**, Aschenbeck J, Yenerim T, Mayr M, Aminalai A, Drossel R, Schröder A, Scheel M, Wiedenmann B, Rösch T. Narrow-band vs white-light high definition television endoscopic imaging for screening colonoscopy: a prospective randomized trial. *Gastroenterology* 2009; **136**: 410-6.e1; quiz 715
36 **Tischendorf JJ**, Schirin-Sokhan R, Streetz K, Gassler N, Hecker HE, Meyer M, Tacke F, Wasmuth HE, Trautwein C, Winograd R. Value of magnifying endoscopy in classifying colorectal polyps based on vascular pattern. *Endoscopy* 2010; **42**: 22-27
37 **Raghavendra M**, Hewett DG, Rex DK. Differentiating adenomas from hyperplastic colorectal polyps: narrow-band imaging can be learned in 20 minutes. *Gastrointest Endosc* 2010; **72**: 572-576
38 **Sabbagh LC**, Reveiz L, Aponte D, de Aguiar S. Narrow-band imaging does not improve detection of colorectal polyps when compared to conventional colonoscopy: a randomized controlled trial and meta-analysis of published studies. *BMC Gastroenterol* 2011; **11**: 100
39 **Gross SA**, Buchner AM, Crook JE, Cangemi JR, Picco MF, Wolfsen HC, DeVault KR, Loeb DS, Raimondo M, Woodward TA, Wallace MB. A comparison of high definition-image enhanced colonoscopy and standard white-light colonoscopy for colorectal polyp detection. *Endoscopy* 2011; **43**: 1045-1051
40 **Jin XF**, Chai TH, Shi JW, Yang XC, Sun QY. A meta-analysis for evaluating the accuracy of endoscopy with narrow-band imaging in detecting colorectal adenomas. *Gastroenterol Hepatol* 2012; **27:** 882-887
41 **Hoffman A**, Basting N, Goetz M, Tresch A, Mudter J, Biesterfeld S, Galle PR, Neurath MF, Kiesslich R. High-definition endoscopy with i-Scan and Lugol's solution for more precise detection of mucosal breaks in patients with reflux symptoms. *Endoscopy* 2009; **41**: 107-112
42 **Hoffman A**, Kagel C, Goetz M, Tresch A, Mudter J, Biesterfeld S, Galle PR, Neurath MF, Kiesslich R. Recognition and characterization of small colonic neoplasia with high-definition colonoscopy using i-Scan is as precise as chromoendoscopy. *Dig Liver Dis* 2010; **42**: 45-50
43 **Kodashima S**, Fujishiro M. Novel image-enhanced endoscopy with i-scan technology. *World J Gastroenterol* 2010; **16**:

1043-1049
44 **Hoffman A**, Sar F, Goetz M, Tresch A, Mudter J, Biesterfeld S, Galle PR, Neurath MF, Kiesslich R. High definition colonoscopy combined with i-Scan is superior in the detection of colorectal neoplasias compared with standard video colonoscopy: a prospective randomized controlled trial. *Endoscopy* 2010; **42**: 827-833
45 **Erim T**, Rivas JM, Velis E, Castro F. Role of high definition colonoscopy in colorectal adenomatous polyp detection. *World J Gastroenterol* 2011; **17**: 4001-4006
46 **Lee CK**, Lee SH, Hwangbo Y. Narrow-band imaging vs i-Scan for the real-time histological prediction of diminutive colonic polyps: a prospective comparative study by using the simple unified endoscopic classification. *Gastrointest Endosc* 2011; **74**: 603-609
47 **Rostom A**, Jolicoeur E. Validation of a new scale for the assessment of bowel preparation quality. *Gastrointest Endosc* 2004; **59**: 482-486
48 The Paris endoscopic classification of superficial neoplastic lesions: esophagus, stomach, and colon: November 30 to December 1, 2002. *Gastrointest Endosc* 2003; **58**: S3-43
49 **Kudo SE**, Kashida H. Flat and depressed lesions of the colorectum. *Clin Gastroenterol Hepatol* 2005; **3**: S33-S36
50 **Read TE**, Read JD, Butterly LF. Importance of adenomas 5 mm or less in diameter that are detected by sigmoidoscopy. *N Engl J Med* 1997; **336**: 8-12
51 **Butterly LF**, Chase MP, Pohl H, Fiarman GS. Prevalence of clinically important histology in small adenomas. *Clin Gastroenterol Hepatol* 2006; **4**: 343-348
52 **Winawer SJ**, Zauber AG, Ho MN, O'Brien MJ, Gottlieb LS, Sternberg SS, Waye JD, Schapiro M, Bond JH, Panish JF. Prevention of colorectal cancer by colonoscopic polypectomy. The National Polyp Study Workgroup. *N Engl J Med* 1993; **329**: 1977-1981
53 **Hassan C**, Pickhardt PJ, Rex DK. A resect and discard strategy would improve cost-effectiveness of colorectal cancer screening. *Clin Gastroenterol Hepatol* 2010; **8**: 865-869, 865-869
54 **Chen SC**, Rex DK. Endoscopist can be more powerful than age and male gender in predicting adenoma detection at colonoscopy. *Am J Gastroenterol* 2007; **102**: 856-861
55 **Lee RH**, Tang RS, Muthusamy VR, Ho SB, Shah NK, Wetzel L, Bain AS, Mackintosh EE, Paek AM, Crissien AM, Saraf LJ, Kalmaz DM, Savides TJ. Quality of colonoscopy withdrawal technique and variability in adenoma detection rates (with videos). *Gastrointest Endosc* 2011; **74**: 128-134
56 **Erim T,** Rivas JM, Velis E, Castro F. Role of high definition colonoscopy in colorectal adenomatous polyp detection. *World J Gastroenterol* 2011; **17:** 4001-4006

S- Editor Gou SX **L- Editor** Kerr C **E- Editor** Xiong L