Chromoendoscopy for Dysplasia Surveillance in Inflammatory Bowel Disease

Ann D. Flynn, MD, and John F. Valentine, MD**

Long-standing ulcerative colitis (UC) and extensive Crohn's colitis confer increased risk for development of colorectal cancer. Screening and surveillance colonoscopy programs aim to identify, resect, or detect dysplasia or colorectal cancer. Dysplastic lesions can be removed by endoscopic resection and patients with unresectable lesions can be referred for colectomy at an earlier stage, with the goal of reducing overall morbidity and mortality from colorectal cancer. Surveillance colonoscopy for patients with inflammatory bowel disease (IBD) is endorsed by multiple specialty societies. High-definition endoscopy systems provide improved image resolution, and application of dilute indigo carmine or methylene blue for chromoendoscopy can provide increased contrast. International specialty society guidelines differ in their recommendations regarding use of chromoendoscopy for dysplasia surveillance, with some guidelines advocating a risk-stratified surveillance strategy. In this review, we discuss chromoendoscopy technique, training, implementation, yield as compared with standard-definition and high-definition white light colonoscopy, and positioning of this technique in clinical practice.

Key Words: chromoendoscopy, dysplasia, inflammatory bowel disease, surveillance, high definition

INTRODUCTION

Individuals with long-standing ulcerative colitis (UC) and extensive Crohn's colitis are at elevated risk for development of colorectal cancer (CRC) as compared with the general population. Population-based studies have demonstrated a standardized incidence ratio (SIR) of 2.3 to 2.75 for CRC among patients with UC.[1, 2] In a meta-analysis of population-based cohort studies, 1.6% of patients with UC were diagnosed with CRC during 14 years of follow-up, with a calculated pooled SIR of 2.4 (95% CI, 2.1 – 2.7).[3] The risk of CRC in patients with Crohn's disease (CD) affecting at least one-third of the colon appears to be the same as that for UC.[1, 2, 4] In a more recent meta-analysis of population-based cohort studies including patients with UC and CD , a pooled SIR for CRC in all patients with inflammatory bowel disease (IBD) was 1.7 (95% CI, 2.9 – 17.8).[5] The cumulative risks of CRC were 1%, 2%, and 5% after 10, 20, and > 20 years of disease. Risk factors for development of CRC in this population include extensive colitis, disease duration, severe inflammation, primary sclerosing cholangitis (PSC), and family history of CRC.[6–11]

Screening and surveillance colonoscopy programs, targeting patients with UC with inflammation proximal to the rectum and patients with CD involving greater than one-third of the colon, aim to identify, resect, or detect dysplasia or CRC. Patients with unresectable dysplasia may be referred for colectomy at an earlier stage, with the goal of reducing morbidity and mortality from CRC . The efficacy of surveillance colonoscopy in patients with IBD has not been evaluated in randomized controlled trials. A Cochrane review concluded that "there is no clear evidence that surveillance colonoscopy prolongs survival in patients with extensive colitis".[12] Cancers tend to be detected at an earlier stage resulting in improved prognosis, but lead-time bias, or earlier diagnosis giving the impression of prolonged survival, could not be excluded as explanation for this benefit. However, the Cochrane review authors identified indirect evidence that surveillance is effective at reducing death from IBD-associated CRC. A reduced odds ratio (OR) for CRC has been demonstrated in retrospective case-control studies.[11, 13, 14] A subsequent retrospective population-based cohort study found 5-year CRC-related survival of 100% in a surveillance group compared with 74% in a nonsurveillance group (P = 0.042).[15] Additionally, in a retrospective cohort study, a colonoscopy within 36 months was associated with reduced incidence of CRC and lower mortality among those diagnosed with CRC.[16]

Surveillance Colonoscopy Programs

Surveillance colonoscopy for patients with IBD is endorsed by multiple specialty societies.[17–26] Detailed recommendations of various societies have been recently

Received for publications July 19, 2017; Editorial Decision November 6, 2017.
*University of Utah, Division of Gastroenterology, Hepatology, and Nutrition, 30 North 1900 East SOM 4R118, Salt Lake City, UT 84132

Conflicts of Interest:There are no conflicts of interst to declare.

Supported by: There is no funding source to report.

Correspondence address: E-mail: john.valentine@hsc.utah.edu;

© 2018 Crohn's & Colitis Foundation. Published by Oxford University Press. All rights reserved. For permissions, please e-mail: journals.permissions@oup.com.

doi: 10.1093/ibd/izy043
Published online 13 April 2018

Downloaded from https://academic.oup.com/ibdjournal/article/24/7/1440/4969996 by Columbia University Libraries user on 10 March 2026

summarized.[27, 28] All societies recommend initiation of a surveillance colonoscopy program after no later than 8 years of disease, and at the time of diagnosis in patients with PSC. Early initiation of a surveillance program may be considered in patients with a first-degree relative diagnosed with CRC r before the age of 50.[10] A screening examination with segmental colon biopsies is recommended to reassess the maximal endoscopic and histologic extent of disease.[17, 28, 29] Surveillance should be offered for patients with UC and endoscopic or histologic evidence of inflammation extending proximal to the rectum, or CD with inflammation involving more than one-third of the colon.

Surveillance Colonoscopy Equipment and Technique

Dysplasia was previously felt to be detected through visual examination of the mucosa, targeted biopsy of visible lesions, and random biopsy to identify invisible dysplasia.[17, 19] For an adequate surveillance examination, it was recommended that a minimum of 33 random biopsy specimens be obtained to have a 90% chance of detecting the highest grade of dysplasia present.[30] However, it is estimated that this random biopsy strategy detects approximately 1 case of dysplasia per 1505 random biopsies obtained.[31] This technique is expensive, adherence by endoscopists is poor, and it has been suggested that the need for random biopsy may detract attention from meticulous inspection of the mucosa.[30–32]

A high-definition (HD) endoscopy system, which includes HD endoscope, processor, transmission cabling, and HD monitor provides higher pixel density as compared with the standard-definition (SD) endoscope, with image resolution of more than 1 million pixels.[33] HD monitors display faster line scanning, producing fewer artifacts. HD white light endoscopy (WLE) is superior to SDWLE for dysplasia surveillance.[17, 34] As use of HD systems has become widespread, it has become clear that the majority of dysplasia noted on surveillance examination is visible.[35, 36] The quality of a surveillance examination is improved by optimal bowel preparation and longer withdrawal time.[37, 38] Longer procedure duration may improve dysplasia detection.[39]

Chromoendoscopy (CE) using dilute indigo carmine or methylene blue can provide increased contrast that enhances the mucosal topography, delineating the border and highlighting the surface pit pattern of subtly raised or depressed lesions. Whereas HD equipment provides increased image resolution, use of CE serves to increase contrast to identify, target, and characterize suspicious lesions[40] (Fig. 1). Presently, specialty society guidelines differ in their recommendations regarding use of CE for dysplasia surveillance (Table 1).

The SCENIC international consensus statement, endorsed by the American Society for Gastrointestinal Endoscopy (ASGE) and the American Gastroenterological Association (AGA), states that when performing surveillance with SD colonoscopy, CE is *recommended* rather than WLE, based on moderate-quality evidence.[17, 18] When performing surveillance with HD colonoscopy, CE is *suggested* rather than WLE, based on low-quality evidence. The SCENIC international consensus statement was also reviewed and endorsed by the Asian Pacific Association of Gastroenterology (APAGE), British Society of Gastroenterology (BSG), Canadian Association of Gastroenterology, European Society of Gastrointestinal Endoscopy (ESGE), and Japan Gastroenterological Endoscopy Society. The ASGE, in a subsequent guideline, states that "surface chromoendoscopy with resection or targeted biopsy of visible lesions is the preferred surveillance technique, based on the currently available literature".[28] Use of CE is endorsed by guidelines of the BSG, National Institute for Health and Care Excellence (NICE), European Crohn's and Colitis Organization (ECCO), and Cancer Council of Australia by trained endoscopists.

A risk-stratified surveillance program is endorsed by the ECCO, NICE, BSG, and Cancer Council of Australia (Table 1). Patients are grouped into high, intermediate, and low risk groups, with surveillance colonoscopy recommended at one-, three-, and five-year intervals, respectively.[21, 22, 25] The ASGE guideline continues to endorse surveillance at 1- to 3-year intervals, with annual surveillance favored in patients with active inflammation, anatomic abnormalities such as strictures and multiple pseudopolyps, history of dysplasia, family history of CRC in first-degree relative, and PSC .[28]

CE Technique

CE involves application of a contrast agent to the colonic mucosal surface. Indigo carmine, a contrast dye, is not absorbed and does not react with the mucosa. Indigo carmine coats the colon surface, pooling in pits and innominate grooves.[41] Mucosal lesions that disrupt the normal surface topography are highlighted by the contrast dye. Indigo carmine is available in ampule form, but use of a compounded, powdered form also is described. Methylene blue is absorbed by the colonic epithelium. Normal mucosa is stained a diffuse, homogenous dark blue. Inflamed or dysplastic areas appear light blue, pink (unstained). or heterogeneously stained due to decreased stain uptake. Heterogeneously stained or unstained areas should be targeted. Methylene blue requires approximately 60 seconds at the mucosal surface to achieve adequate staining.

Methylene blue induces cellular DNA damage in vitro when singlet oxygen is generated by photoexcitation from white light.[42] Oxidative DNA damage has been detected in esophageal cells following methylene blue CE .[43] Colonic mucosal biopsy samples were evaluated using an assay for oxidative damage before and after application of 2 mL of 0.1% methylene blue.[44] The biopsy samples were found to have greater DNA damage after methylene blue dye spray. These changes were not seen following application of indigo carmine dye spray. However, the magnitude of this effect is not felt to be clinically significant.

Downloaded from https://academic.oup.com/ibdjournal/article/24/7/1440/4969996 by Columbia University Libraries user on 10 March 2026

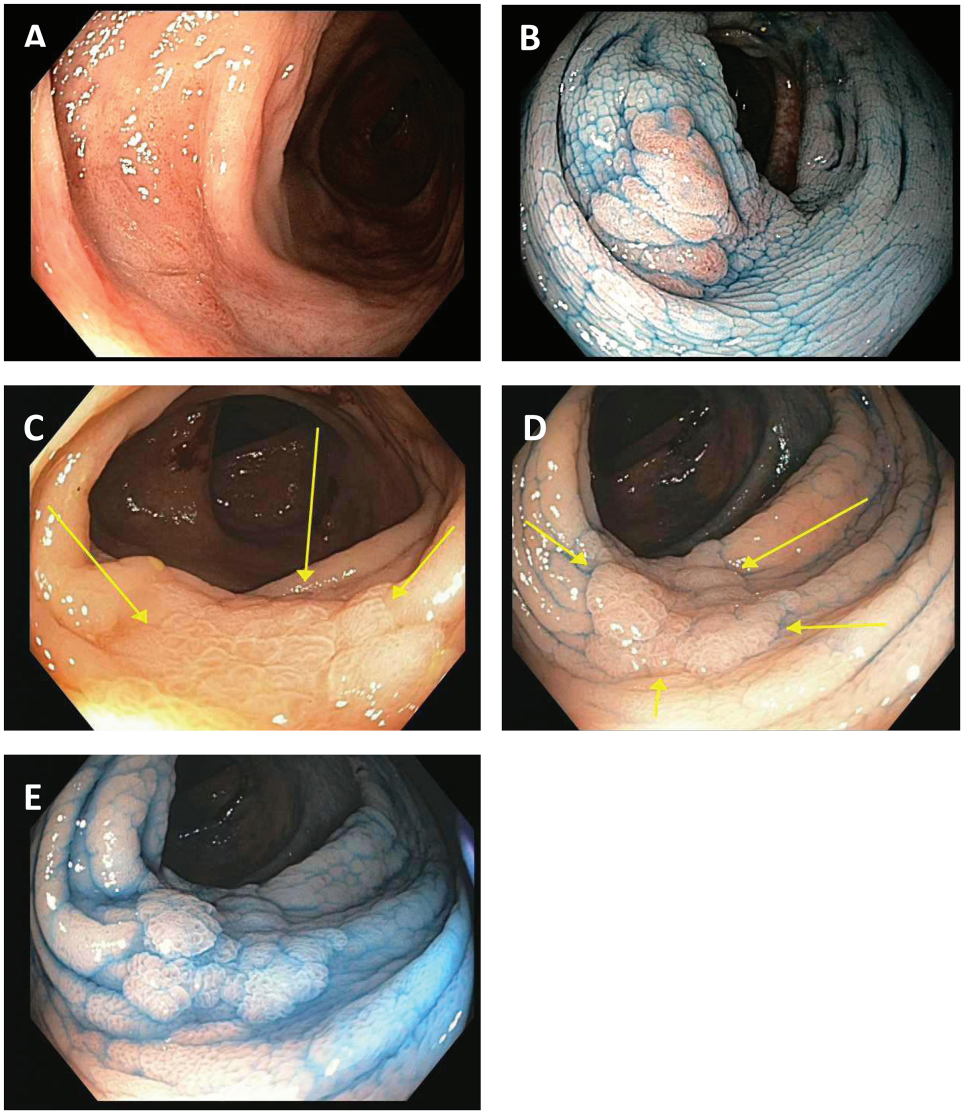

FIGURE 1. A, White light, high-definition image in patient with extensive ulcerative colitis. B, White light, high-definition image after application of indigo carmine. C, White light, high-definition image in patient with extensive ulcerative colitis and primary sclerosing cholangitis. D, White light, high-definition image after low concentration application of indigo carmine. E, White light, high definition image after application of higher concentration indigo carmine.

Surveillance colonoscopy should be performed when IBD is in remission to facilitate endoscopic differentiation between active inflammation and dysplasia. Medical therapy should be optimized before dysplasia surveillance is performed, however, patients with active inflammation are at risk for dysplasia.[41] Endoscopic dysplasia surveillance should not be deferred in patients not responding to therapy, but CE technique will not be optimal for visualization of the mucosa.

An excellent bowel preparation is required, and excess stool, fluid, and mucous residue should be lavaged with clear water during insertion. During withdrawal, the mucosa is coated with a low concentration solution of dye (two 5-mL ampules of 0.8% indigo carmine with 250 mL water or 1 10 mL ampule of 1% methylene blue with 240 mL water) applied with use of the water foot pump or through a spray catheter in a segmental faction.[17] If indigo carmine powder is used, 1-4 grams depending on the concentration desired, can be dissolved in 1 liter of water. The concentration of indigo carmine and methylene blue has varied in previous studies from 0.03%-0.5% mixed in water.[45–47] The mucosa can be coated more efficiently when the dye spray is targeted to the antigravity side of the lumen, permitting fluid to drip down and coat the colon wall.[17] Pools of excess dye are suctioned and the mucosa is carefully visualized. Meticulous mucosal inspection is paramount. The purpose of CE is to highlight and improve lesion detection during the colonoscopy procedure. The application of dye during CE

Downloaded from https://academic.oup.com/ibdjournal/article/24/7/1440/4969996 by Columbia University Libraries user on 10 March 2026

TABLE 1: Recommendations of Specialty Societies Regarding Use of CE for Dysplasia Surveillance

Society	Year	Position on CE	Interval Follow- up
ASGE[28]	2015	❖ CE with pancolonic dye spraying and targeted biopsies is sufficient for surveillance in IBD; consider 2 biopsies from each colon segment for histologic staging, or ❖ Random biopsies with targeted biopsies of any suspicious lesions is a reasonable alternative if CE is not available or if the yield of CE is reduced by significant underlying inflammation, pseudopolyposis, or poor preparation.	✓ Every 1-3 years. ✓ Optimal surveillance interval not defined. ✓ Presence of these risk factors merits annual surveillance: active inflammation, anatomic abnormality (stricture, multiple pseudopolyps), history of dysplasia, family history of CRC in first-degree relative, PSC. ✓ In patients with endoscopically and histologically normal mucosa on ≥ 2 surveillance colonoscopies, the surveillance interval can be lengthened.
AGA, ASGE SCENIC Consensus[17, 18]	2015	❖ When performing surveillance with WLE, HD is recommended rather than SD. ❖ When performing surveillance with SD colonoscopy, CE is *recommended* rather than WLE. ❖ When performing surveillance with HD colonoscopy, CE is *suggested* rather than WLE. ❖ For patients with endoscopically invisible dysplasia (confirmed by a GI pathologist) referral is *suggested* to an endoscopist with expertise in IBD surveillance using CE with HD colonoscopy.	✓ Not addressed
ECCO[21]	2013	❖ Pancolonic methylene blue or indigo carmine CE should be performed during surveillance colonoscopy, with targeted biopsies of any visible lesion. ❖ If appropriate expertise for CE is not available, random biopsies (4 every 10 cm) should be performed; however this is inferior to CE in the detection rate of neoplastic lesions.	✓ *High risk features:* stricture or dysplasia detected within the past 5 years, PSC, extensive colitis with severe active inflammation, or a family history of CRC in a first- degree relative at less than 50 years. Next surveillance colonoscopy in 1 year. ✓ *Intermediate risk factors:* extensive colitis with mild or moderate active inflammation, postinflammatory polyps, or a family history of CRC in a first-degree relative at 50 years and above. Next surveillance colonoscopy in 2 to 3 years. ✓ *Neither intermediate nor high risk:* surveillance colonoscopy in 5 years.
NICE[25]	2011	❖ CE with targeted biopsy preferred over conventional colonoscopy. ❖ High-quality evidence showed that chromoscopy detected statistically significantly more intraepithelial dysplastic lesions in people with extensive colitis (at least 8 years' duration) compared with conventional colonoscopy.	✓ *High risk:* extensive ulcerative or Crohn's colitis with moderate or severe active inflammation that has been confirmed endoscopically or histologically or primary sclerosing cholangitis (including after liver transplant) or colonic stricture in the past 5 years or any grade of dysplasia in the past 5 years or family history of CRC in a first-degree relative aged under 50 years. Next colonoscopy in 1 year. ✓ *Intermediate risk:* extensive ulcerative or Crohn's colitis with mild active inflammation that has been confirmed endoscopically or histologically or postinflammatory polyps or family history of CRC in a first-degree relative aged 50 years or over. Next colonoscopy in 3 years. ✓ *Low risk:* extensive but quiescent UC or extensive but quiescent Crohn's colitis or left-sided UC (but not proctitis alone), or Crohn's colitis of a similar extent. Next colonoscopy in 5 years.

Downloaded from https://academic.oup.com/ibdjournal/article/24/7/1440/4969996 by Columbia University Libraries user on 10 March 2026

TABLE 1: Continued

Society	Year	Position on CE	Interval Follow- up
Cancer Council of Australia[26]	2011	❖ If available, the use of CE/dye spraying where targeted biopsies are obtained from visibly abnormal lesions or strictures is the preferred means to conduct colonoscopic surveillance in IBD. This is especially true for patients at high risk. ❖ If CE is unavailable, or if an endoscopist lacks sufficient expertise with this technique, or if the presence of inflammation interferes with the interpretation of CE, an acceptable alternative practice is using standard WLE with random nontargeted biopsies from each colonic segment and from raised lesions.	✓ *Annual colonoscopic surveillance* is recommended for patients with UC extending proximal to the sigmoid colon or patients with Crohn's colitis affecting more than one-third of the colon and with 1 or more of the following risk factors: active disease, primary sclerosing cholangitis, family history of CRC in first- degree relative < 50 years old, colonic stricture, patients with multiple inflammatory polyps or shortened colon, and/or previous dysplasia. ✓ *3 year follow- up colonoscopy is recommended* for patients with: inactive UC extending proximal to the sigmoid colon without any of the above risk factors patients with Crohn's colitis affecting more than one-third of the colon without any of the above risk factors, IBD patients with a family history of CRC in a first-degree relative > 50 years old. ✓ *5 year follow- up colonoscopy recommended* for patients in whom 2 previous colonoscopies were macroscopically and histologically normal.
ACG[68, 69]	2009 (CD), 2010 (UC), *under revision*	❖ At present, the recommendation to routinely use CE- enhanced surveillance in low-risk patients awaits additional information regarding longer term follow-up. ❖ Given the increased yield of CE, it may be of value in follow-up of the "higher-risk" patient (ie, patients with indefinite or known dysplasia not proceeding to colectomy), and to ensure adequacy of previous resection of polypoid or minimally raised lesions. ❖ Require adequate training in the techniques of endoscopic staining and interpretation of mucosal pit patterns.	✓ Annual or biannual surveillance.
AGA[30]	2010	❖ CE with targeted biopsies is considered an acceptable alternative to WLE for endoscopists who have experience with this technique.	✓ Patients with extensive or left-sided colitis should begin surveillance within 1 to 2 years after the initial screening endoscopy. The optimal surveillance interval has not been clearly defined. ✓ After 2 negative examinations (no dysplasia or cancer), further surveillance examinations should be performed every 1 to 3 years. ✓ Patients with a history of CRC in first-degree relatives, ongoing active endoscopic or histologic inflammation, or anatomic abnormalities such as a foreshortened colon, stricture, or multiple inflammatory pseudopolyps may benefit from more frequent surveillance examinations.

should enhance, not detract from, careful visualization of the mucosa. Detailed inspection and careful suction of pools of excess fluid are required.Concerning lesions should be further characterized with use of a higher concentration solution (one 5 mL ampule of 0.8% indigo carmine with 25 mL water or one 10 mL ampule of 1% methylene blue with 40 mL water) pushed with a syringe through the biopsy channel.[17] High concentration CE helps to delineate morphology, surface pit pattern, border, and size of concerning lesions.

The endoscopist should look carefully throughout the examination for changes in color, pattern, or elevation. Subtle findings including uneven redness, nodularity, villous texture, slight elevation or depression, friability, obscured vascular pattern, ulcerated or velvety surface, or disruption of innominate lines may indicate a dysplastic lesion. When a lesion is encountered, the appearance should be characterized as polypoid (pedunculated or sessile) or nonpolypoid (slightly elevated, flat, or depressed), according to the modified Paris classification.[17, 48] The lesion border should be classified as distinct or indistinct. Features such as overlying ulceration, depression, or failure to lift should be noted.[18] The Kudo pit-pattern classification (type I through type V) should be used to predict the histology of neoplastic and nonneoplastic

Downloaded from https://academic.oup.com/ibdjournal/article/24/7/1440/4969996 by Columbia University Libraries user on 10 March 2026

TABLE 1: Continued

Society	Year	Position on CE	Interval Follow- up
BSG[22]	2010	❖ It is recommended that pancolonic dye spraying is adopted as the technique of choice. ❖ A number of studies show improved detection rates for dysplasia and cancer if targeted biopsies are taken rather than random biopsies. In addition, clinician adherence to endoscopic protocols for random biopsies is poor and the endoscopic and pathology staffing costs are high. ❖ If CE is not used, the strategy outlined in the 2002 guidelines should be followed (ie, 2 to 4 random biopsies from every 10 cm of the colon).	✓ *Higher risk:* Extensive colitis (either UC or Crohn's colitis) with moderate or severe endoscopic/histological active inflammation the previous surveillance colonoscopy or stricture within past 5 years or confirmed dysplasia within past 5 years in a patient who declines surgery or primary sclerosing cholangitis/postorthotopic liver transplant for primary sclerosing cholangitis or family history of CRC in a first-degree relative aged <50 years. Yearly colonoscopy is recommended. ✓ *Intermediate risk:* Extensive colitis (either UC or Crohn's colitis) with mild endoscopic/histological active inflammation on the previous surveillance colonoscopy or presence of postinflammatory polyps or family history of CRC in a first-degree relative aged 50 years or over. 3 year follow- up colonoscopy is recommended. ✓ *Lower risk:* Extensive colitis (either UC or Crohn's colitis) with no endoscopic/histological active inflammation on the previou1s colonoscopy (histological chronic or quiescent changes acceptable) or left-sided colitis (any grade of inflammation) or Crohn's colitis affecting <50% of the surface area of the colon (any grade of inflammation). 5 year follow- up colonoscopy is recommended.
APAGE[23, 24]	2010 (UC), 2015 (CD)	❖ High resolution video with methylene blue or indigo carmine CE is superior to traditional random colon biopsies in the detection of neoplastic lesions.	✓ Not addressed.
CCF[19]	2005	❖ For patients with extensive disease, a minimum of 33 biopsies should be performed. This involves taking 4 quadrant biopsies every 10 cm throughout the colon. ❖ CE endorsed for appropriately trained endoscopists.	✓ Patients with extensive colitis or left-sided colitis who have a negative screening colonoscopy should begin surveillance within 1 to 2 years. ✓ With a negative surveillance colonoscopy, subsequent surveillance examinations should be performed every 1 to 2 years. ✓ With 2 negative examinations, the next surveillance examination may be performed in 1 to 3 years until UC has been present for 20 years. At that time, consideration should be given to performing surveillance every 1 to 2 years, based on the concept that CRC risk increases with longer duration of colitis. ✓ Patients with PSC should undergo surveillance yearly. Patients with other risk factors, such as positive family history of CRC, may require shorter surveillance intervals. ✓ Patients with proctosigmoiditis, who have little or no increased risk of CRC compared with the population at large, should be managed according to standard CRC prevention measures as defined in consensus Gastrointestinal Consortium recommendations and guidelines.

CE, Chromoendoscopy. WLE, white light endoscopy. HD, high definition. SD, standard definition. ASGE, American Society for Gastrointestinal Endoscopy. AGA, American Gastroenterological Association. ECCO, European Crohn's and Colitis Organization. NICE, National Institute for Health and Clinical Excellence. ACG, American College of Gastroenterology. BSG, British Society of Gastroenterology. APAGE, Asian Pacific Association of Gastroenterology. CCF, Crohn's and Colitis Foundation.

lesions.[49, 50] When uncertainty exists regarding the pit pattern or if confidence in the pit-pattern classification is low, biopsy of the lesion for histologic confirmation is recommended.[51] In addition to dysplastic lesions, sessile serrated polyps/adenomas (SSPs/SSAs) are increasingly recognized in patient with IBD. In a series of IBD patients undergoing surveillance colonoscopy, SSAs were detected in 10 (11%) of 87 patients. A type II-O Kudo pit pattern was present 86% and a spiral and irregular vascular pattern was present in 79% of these lesions.[52]

An endoscopically resectable lesion is a lesion with distinct margins, completely removed by visual inspection following endoscopic resection, completely removed on

Downloaded from https://academic.oup.com/ibdjournal/article/24/7/1440/4969996 by Columbia University Libraries user on 10 March 2026

histologic examination, and free of dysplasia on biopsies obtained adjacent to the resection margin.[18, 53] This terminology should be used in place of unclear, nonspecific terms such as dysplasia-associated lesion or mass (DALM), adenoma-like, or nonadenoma-like. Endoscopically resectable lesions should be removed or tattoo should be placed, with referral to an endoscopist with expertise in endoscopic mucosal resection (EMR) and endoscopic submucosal dissection (ESD).

Data on resection of these lesions is largely based on expert consensus and extrapolation from principles of resection in noncolitic patients.[54] Endoscopists should be aware that submucosal scarring in colitic patients will impair submucosal lift. Patients with tubular colon, postinflammatory polyps, loss of vascular pattern, or active inflammation are more likely to have severe submucosal scarring.[54] Dynamic injection technique and use of colloid or viscous injection fluid may be helpful in achieving an adequate submucosal injection plane.[55, 56] Braided or spiral snares, which have an additional wire around the main snare cable, may improve the ability to grip and capture the tissue adequately.[54] If a lesion is felt to be endoscopically resectable, but endoscopic resection is beyond the skill of the performing endoscopist, then referral to a specialized interventional endoscopist or regional center should be considered.[53] Resources including articles, endoscopic atlases, books, and endoscopic videos are available for learning CE technique (Table 2).[57] Literature regarding CE training and evaluation of competency is limited. In a study conducted at 3 Mayo clinic sites, 6 investigators without prior experience with CE received training in CE technique and image interpretation. They performed WLE followed by CE in 75 patients with long-standing UC. The median withdrawal time among endoscopists who had conducted less than 5 procedures was 31 minutes. Withdrawal time stabilized after performance of 15 procedures at median of 19 minutes.[58] In a meta-analysis of 6 unique studies comparing CE with targeted biopsy and WLE with random biopsy, the pooled increase in time for CE over WLE was 10.9 minutes (95% CI 9.1 minutes-12.9 minutes), with mean procedure time of 35.5 minutes to 45 minutes for CE and 22.18 minutes to 35 minutes for WLE.[59] However, nontargeted (random) biopsies were obtained every 10 cm in all studies, in addition to performance of CE. This may have resulted in increased procedure time. In a meta-analysis of tandem studies in which patients underwent SDWLE and CE, performance of CE increased duration of the procedure by 11 minutes (9 minutes to 12 minutes).[17] In a randomized controlled trial using WLE (the majority with HD equipment) for dysplasia surveillance, patients with long-standing UC were randomized to random plus targeted biopsies or targeted biopsies alone. The targeted and targeted plus random biopsy strategies detected similar proportions of neoplasia. Significantly more biopsies were obtained in the random biopsy group and the total examination time was longer in the random biopsy group (41.7 minutes vs 26.6 minutes; $P < .001$).[60] In a prospective study of screening colonoscopy in a community-based practice, the average procedure duration was 19 minutes ± 21.[61] The time required for completion of CE may be particularly relevant when considering introduction of the technique into the workflow of a community-based endoscopy practice however, it is less than a WLE with inspection of the mucosa and 4 quadrant biopsies every 10 cm. The increased procedure time observed with use of CE may be offset by eliminating performance of random biopsies and fewer biopsies also should reduce costs. An increase in scheduled procedure time has been suggested when learning CE technique.

In a prospective multicenter cohort study that included academic and community practice settings, endoscopists with and without expertise in CE performed surveillance examinations.[62] Before study initiation, teaching included a brief learning set of images incorporated into a slideshow with a short explanation of morphological characteristics of lesions. Dysplasia detection rates were evaluated consecutively. The dysplasia detection rate was comparable between expert and nonexpert endoscopists, 12.7% versus 16.2% ($P = 0.46$), with no significant learning curve observed when comparing dysplasia

TABLE 2: Resources for Learning CE

Articles	• Endoscopic and chromoendoscopic atlas featuring dysplastic lesions in surveillance colonoscopy for patients with long-standing ulcerative colitis. Matsumoto T et al. *Inflamm Bowel Dis*. 2008;14:259-64.
	• The detection of non-polypoid (flat and depressed) colorectal neoplasms in patients with inflammatory bowel disease. Soetikno R et al. *Gastroenterology*. 2013;144(7):1349-52, 1352.e1-6.
	• An atlas of the nonpolypoid colorectal neoplasms in inflammatory bowel disease. Soetikno R et al. *Gastrointest Endosc Clin N Am*. 2014;24:483-520.
	• A roadmap to the implementation of chromoendoscopy in inflammatory bowel disease colonoscopy surveillance practice. Sanduleanu S et al. *Gastrointest Endosc*. 2016 Jan;83(1):213-22.
Endoscopic Videos	• ASGE Chromoendoscopy for IBD https://www.youtube.com/watch?v=OARkbgwlObI
	• ASGE Video Tip of the Week: Chromoendoscopy in IBD surveillance https://www.youtube.com/watch?v=uGR4gjxfFjg
	• Chromoendoscopy for Surveillance in Ulcerative Colitis: How to do it and What to Look for https://www.youtube.com/watch?v=gcN_FkXhR-M

Downloaded from https://academic.oup.com/ibdjournal/article/24/7/1440/4969996 by Columbia University Libraries user on 10 March 2026

detection in the first third and last third of procedures, 12.5% versus 18.5% ($P = 0.18$).

Endoscopic image-enhancement technologies are in development and include multiple generations of NBI (Olympus), i-scan (Pentax), and Fuji Intelligent Chromo Endoscopy (FICE, Fujinon). The SCENIC international consensus statement affirms "When performing surveillance with image-enhanced high-definition colonoscopy, narrow-band imaging is not suggested in place of chromoendoscopy. (90% agreement; conditional recommendation; moderate-quality evidence)".[17, 18] Too few studies were available with i-Scan and FICE for an analysis. A more recent meta-analysis of the published literature identified 2 studies that compared NBI to CE in patients with IBD.[63] These authors found that NBI performed as well as CE on a per patient analysis but they did not recommend NBI as equivalent to CE for IBD surveillance. A recent prospective study by Bisschops et al subsequent to the meta-analysis by Har-Noy et al, randomized 131 patients with long-standing UC to surveillance colonoscopy with HDCE and targeted biopsies (n = 66) or NBI with targeted biopsies (n = 65).[64] The per patient dysplasia rate and total dysplastic lesions detected were not significantly different between NBI and CE, however, the colonoscope withdrawal averaged 7 minutes longer for CE versus NBI. Further evaluation of newer generations of NBI are anticipated.

Random Versus Targeted Biopsy During CE

Increasingly, performance of random colon biopsies has been recognized as low yield. It has been suggested that an endoscopist's time, attention, and resources may be more efficiently focused on careful inspection of the mucosa with targeted biopsy, rather than performance of 30 to 40 random biopsies. In a 2004 study, 100 patients with long-standing UC underwent "back to back" colonoscopies for dysplasia surveillance.[65] During the first examination, visible abnormalities were biopsied and 4 quadrant biopsies were obtained every 10 cm. During the second examination, pancolonic indigo carmine was used and additional visible abnormalities were biopsied. Dye spray with targeted biopsies took the same time as standard withdrawal with multiple nontargeted biopsies (median withdrawal times 11 minutes and 10 minutes for first and second procedures, respectively, $P = 0.13$). The targeted protocol required 157 biopsies, of which 9 were dysplastic. The nontargeted protocol required 2904 biopsies, of which 0 were dysplastic. The SCENIC International Consensus panelists were unable to come to agreement regarding random biopsies when using HDWLE colonoscopy or CE .[17] Targeted biopsy rather than random biopsy is recommended during CE in guidelines put forth by the ASGE, ECCO, NICE, Cancer Council of Australia, BSG, and the APAGE (Table 1).

In a randomized controlled noninferiority trial conducted at 52 sites in Japan, 246 patients with greater than 7 years of UC were assigned to dysplasia surveillance with random biopsies every 10 cm in addition to targeted biopsies or targeted biopsies only from locations of suspected neoplasia.[60] Pancolonic CE was not used but CE was used for any lesions suspected of being neoplastic. Larger numbers of biopsy samples per colonoscopy were collected in the random biopsy group (34.8 vs 3.1, $P < 0.001$) and the total examination time was longer (41.7 minutes vs 26.6 minutes, $P < 0.001$). The detection rate of patients with neoplasia was 11.4% of patients in the target group and 9.3% of patients in the random group ($P = 0.617$). The target group was noninferior to the random group. A numerically higher percentage of patients had a diagnosis of neoplasia in the targeted biopsy only group (10.5% vs 3.7%, $P = 0.052$). The authors speculated that bleeding due to random biopsy could disrupt precise endoscopic examination, making targeted biopsy more difficult, or the large number of biopsies and increased examination time in the random biopsy group could distract from meticulous examination leading endoscopists to overlook suspicious lesions, but the reason for this difference is unclear.

In a prospective study, 1000 consecutive patients undergoing surveillance colonoscopy with CE underwent targeted biopsy or endoscopic resection of suspicious lesions, followed by 4 quadrant random biopsies every 10 cm.[66] Neoplasia was detected at 140 sites in 94 patients, 112 (80%) from targeted biopsy or resected lesions and 28 (20%) by random biopsy. The random biopsy neoplasia yield was 0.2% per biopsy, 1.2% per colonoscopy, and 12.8% per patient with neoplasia. On multivariate analysis, dysplasia detected on random biopsy was associated with personal history of neoplasia, tubular appearance of the colon, and presence of PSC .[66] This data suggest that a risk-stratified surveillance strategy may be considered, with use of a random and targeted biopsy strategy in high risk groups, and targeted biopsy alone in lower risk groups. Implementation of such a strategy could be a time- and costsaving approach.

CE Versus SDWLE

In a meta-analysis that included 8 studies, 815 patients were surveyed with SDWLE and CE.[17] Dysplasia detection increased with CE, relative risk (RR) = 1.8 (1.2 – 2.6), absolute risk increase 6% (3% – 9%). In meta-analysis of the 2 randomized, parallel group studies, dysplasia detection increased with CE, RR = 2.3 (1.1 – 4.6).[67, 68] In meta-analysis of the 4 tandem studies, in which patients underwent WLE and CE, dysplasia detection increased with CE, RR = 1.9 (1.4 – 2.7).

HDCE E Verses HDWLE

The majority of the data used to support the SCENIC consensus statement were generated from studies that used SD equipment. Undoubtedly, HD colonoscopy was introduced when some of these studies were taking place, but the manuscripts did not analyze the data based on HD versus SDWLE. In a nonIBD population, a randomized controlled trial found that HDWLE identified more adenomas per patient in those

Downloaded from https://academic.oup.com/ibdjournal/article/24/7/1440/4969996 by Columbia University Libraries user on 10 March 2026

undergoing screening and surveillance colonoscopy compared to SDWLE.[69] In a well-matched cohort, a retrospective analysis compared dysplasia detection rate of SDWLE versus HDWLE in patients with long-standing IBD (160 in the SD group and 209 in the HD group). Eleven dysplastic lesions (6 on targeted biopsy) were detected in 8 patients in the SD group and 32 dysplastic lesions (27 on targeted biopsy) were detected in 24 patients in the HD group. The adjusted prevalence ratio for HD versus SD for finding any grade of dysplasia was 2.21 (95% CI 1.09-4.45); $P = 0.03$.[34]

Recent efforts in IBD have focused on evaluation of CE with HDWLE and other evolving technologies. In a retrospective analysis of the IBD surveillance colonoscopy practices at the University of Calgary, 454 colonoscopies were analyzed, incorporating multiple approaches ranging from SDWLE with random biopsies to iScanHD with targeted biopsies. Evaluation of differences between HDWLE and HDCE was limited because there were only 28 cases that used HDCE, as compared with 182 HDWLE with random or targeted biopsies. The dysplasia detection rate was 17.2% (95% CI, 9.6%–28.9%) with HDWLE with targeted biopsies, compared to 29.2% (95% CI, 14.9%–49.2%) in the procedures performed with HDCE with targeted biopsies ($P = 0.06$).[70] Another retrospective non-randomized study examined the dysplasia detection rate of IBD surveillance colonoscopy performed over a 13-year period at 3 referral centers.[71] Over the study period, the use of HDCE was adopted using either 0.1% methylene blue or 0.3% indigo carmine. The yield of HDCE was compared with WLE for dysplasia detection, but the authors did not specify the percentage of WLE procedures performed with HD equipment. Dysplasia was detected in 48 of 440 cases (11%) in the HDCE group and 189 of 1802 cases (10%) in the WLE group ($P = 0.80$), questioning the advantage of CE over WLE when using high definition equipment.

Three randomized studies comparing HDCE to HDWLE have been presented only in abstract form with mixed results. Iacucci et al performed a randomized trial comparing the neoplastic lesion detection rate in 225 consecutive patients with inactive long-standing UC or Crohn's colitis (>8 years from diagnosis, or PSC with IBD from diagnosis) that were randomized 1:1:1 to HDWLE alone, HDCE, or HD virtual chromoendoscopy (VCE).[72] Neoplasia detection rates were similar among the 3 arms of the study (HDWLE: 28%, HDCE 22.6%, HDVCE 17.3%, p=NS). In a study by Park et al, 210 patients with long-standing UC (> 8 years of extensive colitis or > 10 years of left-sided UC) were randomized to undergo HDWLE with random biopsies or HDCE with targeted biopsies.[73] There was a trend toward improvement in detection of all dysplasia including colitis-associated dysplasia and sporadic adenoma with HDCE, as compared with HDWLE (21/102, 20.6% vs 13/108, 12.0%, respectively, $P = 0.093$) but not colitis-associated dysplasia specifically. How colitis-associated dysplasia was distinguished from a sporadic adenoma was not described. Additionally, HDCE with targeted biopsies did not prolong the procedure time (17.8 ± 7.3 min vs 18.9 ± 7.1 min, $P = 0.288$). There were significantly fewer biopsies obtained in the HDCE with targeted biopsy group (9.2 ± 4.5 vs 33.6 ± 10.9, $P < 0.001$). Mohammed and colleagues compared the visible dysplasia detection rate in patients with extensive UC of greater than 10-years duration using HDWLE and targeted biopsy (N = 53) or HDCE with 2% indigo carmine and targeted biopsy (N = 50).[74] Six dysplastic lesions were found in 5 patients (9.4%) using HDWLE, and 14 dysplastic lesions were detected in 11 patients (22%) using HDCE. Use of HDCE improved detection of endoscopically visible dysplastic lesions per patient evaluated ($P = 0.04$). On average, procedure time increased by 8 minutes with use of HDCE as compared with HDWLE.

Picco and colleagues performed a tandem study of HDWLE and HDCE with indigo carmine for surveillance colonoscopy in 75 patients with long-standing UC. Visible dysplasia was found in 9.3% of patients with use of HDWLE and 21.3% of patients with use of HDCE ($P = 0.007$). Dysplasia was not identified in any of the random biopsies obtained.[58] In a prospective multicenter study from Spain that included both tertiary referral centers and community hospitals, 350 patients with inactive UC proximal to the rectum, CD , or indeterminate colitis involving at least one-third of the colon of greater than 8-years duration or PSC and IBD of any duration were referred for dysplasia screening.[62] WLE was compared with CE. Colonoscopies were performed using SD equipment in 145 cases (41.4%) and HD equipment in 205 cases (58.6%). Each colonic segment was evaluated with WLE followed by CE (0.4% indigo carmine). The incremental yield for dysplasia detection with CE was similar when endoscopies performed with SD and HD equipment were compared (51.5% vs 52.3%, $P = 0.30$). The rate of dysplasia detection was comparable between endoscopists with previous CE experience (n = 6) and endoscopists without prior CE experience (n = 9), (12.7% vs 16.2% , respectively, $P = 0.46$). The incremental yield for dysplasia detection with CE was also similar for CE-expert and CE-nonexpert endoscopists (66.6% vs 53.7%, $P = 0.48$). A summary of the prospective studies comparing the dysplasia detection rate in patients with IBD with HDWLE and HDCE is presented (Table 3).

A recent systematic review of randomized trials comparing CE with other endoscopic techniques for dysplasia surveillance in IBD identified 10 trials that met the search criteria.[75] There were only 2 trials comparing HDCE with HDWLE and 1 trial that compared HDCE to HDWLE and to iScan.[72–74] All 3 of these trials have only been presented in abstract form. The analysis found that CE identified a greater number of patients with dysplasia, but in subgroup analyses this effect was confined to CE compared with SDWLE. HDCE and HDWLE had similar effectiveness in detecting dysplasia in patients with IBD (risk ratio 1.42; 95% CI 0.80-2.52). These results are tempered by small sample sizes and suboptimal study quality. Some subanalyses were limited to a single study. Additionally, studies such

Downloaded from https://academic.oup.com/ibdjournal/article/24/7/1440/4969996 by Columbia University Libraries user on 10 March 2026

TABLE 3: Summary of Prospective Trials Comparing the Per Patient Dysplasia Detection Rate Between HDWLE and HDCE in Patients with IBD

	Trial Design	With Random Biopsy or Targeted Biopsy	HDWLE Dysplasia Detection Rate	HDCE Dysplasia Detection Rate	*P* Value	Withdrawal Time (minutes)
Iacucci et al[72] (Abstract)	Randomized	HDWLE targeted biopsy or HDCE targeted biopsy	21/75 (28%)	17/75 (22.6%)	$P = 0.45_a$ (NS)	Not provided
Park et al[73] (Abstract)	Randomized	HDWLE random biopsy or HDCE targeted biopsy	13/108 (12.0%)	21/102 (20.6%)	$P = 0.093$ (NS)	HDWLE 18.9 ± 7.1 HDCE 17.8 ± 7.3 $P = 0.288$
Mohammed et al[74] (Abstract)	Randomized	HDWLE targeted biopsy or HDCE targeted biopsy	5/53 (9.4%)	11/50 (22%)	$P = 0.04$	HDWLE 13.6 ± 3.3 HDCE 21.2 ± 5.8 $P < 0.001$
Picco et al[58]	Tandem	HDWLE targeted biopsy or HDCE targeted biopsy	7/75 (9.3%)	16/75 (21.3%)	$P = 0.007$	Only provided total time for the tandem exams
Carballal et al[62]	Tandem	HDWLE targeted biopsy or HDCE targeted biopsy	Per patient analysis not provided. 20 IBD associated dysplastic lesions in 205 patients	Per patient analysis not provided. 42 IBD associated dysplastic lesions in 205 patients	52.3% incremental yield with HDCE vs HDWLE (OR 2.1; 95% CI: 1.34-3.29)$_b$	Only provided total time for the tandem exams

$_a$ *P* value computed by the authors of this review as it was not reported in the main paper

$_b$ 95% CI was not provided in the manuscript, data provided from a personal communication with Sabela Carballal.

as Carballal et al that showed similar advantage for CE with both SD and HD colonoscopy were not included due to the tandem study design with use of WLE followed by CE.[62] Outcomes such as CRC-related mortality and time to interval dysplasia or cancer could not be assessed. In addition, a cost-effectiveness comparison between CE with other techniques including HDWLE could not be performed because cost data were not reported. To definitively address the superiority or inferiority and cost effectiveness of CE for colonic dysplasia detection in IBD, additional high-quality, prospective randomized trials with adequate follow-up are needed.

Clinical Implications of Dysplasia Found During CE in IBD

In the absence of adequate data to address these questions, widespread acceptance and implementation of CE technique for dysplasia surveillance has been somewhat limited.[76, 77] Many of the concerns raised regarding universal implementation of CE for dysplasia surveillance are similarly applicable to dysplasia surveillance using HDWLE. Questions specific to CE include: (1) Is the natural history of dysplasia detected using CE the same as that for dysplasia detected using HDWLE? (2) Is CE cost effective if implemented for all dysplasia surveillance procedures? (3) Does use of CE reduce the incidence of CRC in IBD patients? and (4) Will CE result in more unnecessary mucosal resections, increased invasive surveillance procedures, and possibly increased rates of colectomy due to minute patches of dysplasia that may remain indolent over time? This last question should also be applied to HDWLE examinations that identify dysplasia only on a random biopsy. To date, there is no evidence to support the hypothesis that small lesions with low-grade dysplasia (LGD) identified by CE have less malignant potential as compared with lesions with LGD identified using other endoscopic techniques. However, there is minimal data on the natural history of LGD identified using HDCE.

The natural history of LGD in IBD, including progression to high-grade dyplasia (HGD) or CRC, is poorly understood. A recent meta-analysis of cohort studies by Fumery et al examined the outcomes of LGD in patients with UC.[78] In 12 surgical cohort studies that included 450 patients who underwent colectomy for UC with LGD, 34 patients were found to have synchronous CRC (pooled prevalence, 17%; 95% CI, 8–33). However, when the analysis was limited to the 2 studies that included more than 36 patients, CRC was identified in the colectomy specimen in only 5 of 220 (2%) and 4 of 126 (3%).[79, 80] In 14 surveillance cohort studies, which included

Downloaded from https://academic.oup.com/ibdjournal/article/24/7/1440/4969996 by Columbia University Libraries user on 10 March 2026

4238 patient-years of follow-up and 671 patients with UC with LGD, the pooled incidence rate (IR) of advanced neoplasia in patients with nonvisible LGD was 6.1 per 100 patient-years of follow-up (95% CI, 0.9–11.4). With endoscopically visible dysplasia, the pooled IR of advanced neoplasia was 1.0 per 100 patient-years of follow-up (95% CI, 0–2.1). It is unfortunate that the studies in this meta-analysis did not consistently report the use of CE. The study by Choi et al reported a potential beneficial effect with use of CE, demonstrating a lower risk of progression to advanced neoplasia in patients with LGD (hazard ratio, 0.5; 95% CI, 0.3–1.0).[81] It should be noted that CE was gradually applied over the 1993 to 2012 timeframe of the Choi et al study, with CE implementation beginning in 2003. Full HD equipment (including colonoscopes, cables, and monitors) did not become available until 2011, thus the efficacy of HDCE cannot be reliably determined.

A recently published study from 3 referral centers in the Netherlands examined the outcomes of LGD identified by SDWLE, HDWLE, or HDCE.[82] Of the 1065 patients that underwent dysplasia surveillance for long-standing IBD, LGD was identified in 196 patients. The 159 patients that underwent follow-up examinations were stratified by the method used to identify the index LGD: SDWLE (n = 80); HDWLE (n = 21); HDCE (n = 32); and detection with random biopsy (n = 26). During the median 4.7 years of follow-up, 5 patients developed HGD and 5 patients developed CRC, with an incidence rate of 1.34 cases of advanced neoplasia per 100 patient-years. The incidence of advanced neoplasia did not differ among patients with LGD index lesions detected by either HDCE or HDWLE. Although the follow up was short and the number of events in each subgroup was small, the natural history of LGD identified by CE does not appear to differ from LGD identified by other methods. For those enrolled in the surveillance program, the predictive value of an examination without evidence of dysplasia by HDCE or HDWLE for subsequent risk of LGD or advanced neoplasia is presently under evaluation (Bas Oldenburg, personal communication).

CONCLUSIONS

Colonoscopy remains the present gold standard for dysplasia surveillance in patients with IBD. The quality of endoscopic surveillance can be improved with optimal bowel preparation, use of HD endoscopy systems, and use of CE. The most frequency cited reason for noncompliance with colonoscopy surveillance recommendations in a patient questionnaire study was difficulty with bowel preparation.[83] Improvements in bowel preparation are required to improve surveillance adherence and quality and to permit use of CE.

The guidelines of most international subspecialty societies advocate implementation of CE during surveillance examination to increase dysplasia detection. Additional data are needed to determine whether the increased dysplasia detection gained with CE will result in reduced incident CRC, decreased morbidity and mortality from CRC, and improved cost-effective patient care. However, it is worth noting that implementation of surveillance colonoscopy programs in patients with IBD is supported and universally advocated, without direct evidence of reduction in CRC incidence and mortality. The possibility of net patient harm must also be considered with numerous biopsies, more frequent invasive surveillance procedures, and increased endoscopic mucosal resections for potentially indolent dysplasia, with potential complications. Currently, evidence to support the hypothesis that small lesions with LGD identified by CE have less malignant potential as compared with lesions with LGD identified using other endoscopic techniques is lacking. In the authors opinion, dysplasia found with CE or on random biopsy should be treated the same. Here CE has an advantage in that the dysplasia is visible and it is known if it was removed, which is not the case for dysplasia identified on a random biopsy. Identification of minute areas of dysplasia on CE that are removed with biopsy forceps could result in more frequent follow-up procedures, however, a truly negative for dysplasia CE procedure could result in less frequent follow-up procedures and fewer interval cancers. For example, if it could be demonstrated that a normal index HDCE examination is more predictive of lack of dysplasia on subsequent surveillance examinations, as compared with a normal index HDWLE examination, this would permit added confidence in implementation of a risk-stratified surveillance program, such as that endorsed by the ECCO, NICE, BSG, and Cancer Council of Australia. Cost effectiveness of the technique would improve with more universal implementation of risk-stratified interval patient follow-up and performance of targeted biopsies or a risk-stratified biopsy strategy.

Training in CE technique appears to be achievable among practitioners without previous formal training, in both academic and community settings, based on the limited available literature. Several written and video-based resources exist to support this training; see Table 2. WLE with 4 quadrant random biopsies or CE with targeted biopsies takes more time than routine screening colonoscopy. However, CE with targeted biopsies takes less time than a random biopsy strategy and fewer biopsies results in a cost savings. Financial compensation for time and additional costs associated with the procedure still need to be addressed.

The majority of dysplasia in patients with IBD is visible. CE improves detection of dysplasia over HDWLE in some, but not all studies. Additional data comparing HDCE to HDWLE are necessary. The goal of endoscopic surveillance is detection of dysplasia; therefore, use of the most sensitive technique for dysplasia detection that is readily available is optimal. Prospective data are needed regarding the impact of CE on incidence, morbidity, and mortality from CRC in patients with IBD. With widespread use of CE, dysplasia risk

Downloaded from https://academic.oup.com/ibdjournal/article/24/7/1440/4969996 by Columbia University Libraries user on 10 March 2026

stratification is needed among IBD patients, and traditional guidelines for colonoscopy surveillance intervals must be reexamined. If patients can be offered a higher quality surveillance examination that permits less frequent endoscopy in some patient groups, this may also serve to improve overall patient adherence to surveillance recommendations and reduce costs of care.

REFERENCES

1. Bernstein CN, Blanchard JF, Kliewer E, et al. Cancer risk in patients with inflammatory bowel disease: a population-based study. *Cancer*. 2001;91:854–62.
2. Söderlund S, Brandt L, Lapidus A, et al. Decreasing time-trends of colorectal cancer in a large cohort of patients with inflammatory bowel disease. *Gastroenterology*. 2009;136:1561–7.
3. Jess T, Rungoe C, Peyrin-Biroulet L. Risk of colorectal cancer in patients with ulcerative colitis: a meta-analysis of population-based cohort studies. *Clin Gastroenterol Hepatol*. 2012;10:639–45.
4. Friedman S, Rubin PH, Bodian C, et al. Screening and surveillance colonoscopy in chronic Crohn's colitis: results of a surveillance program spanning 25 years. *Clin Gastroenterol Hepatol*. 2008;6:993–8; quiz 953.
5. Lutgens MW, van Oijen MG, van der Heijden GJ, et al. Declining risk of colorectal cancer in inflammatory bowel disease: an updated meta-analysis of population-based cohort studies. *Inflamm Bowel Dis*. 2013;19:789–99.
6. Rutter MD, Saunders BP, Wilkinson KH, et al. Cancer surveillance in longstanding ulcerative colitis: endoscopic appearances help predict cancer risk. *Gut*. 2004;53:1813–6.
7. Rutter MD, Saunders BP, Wilkinson KH, et al. Thirty-year analysis of a colonoscopic surveillance program for neoplasia in ulcerative colitis. *Gastroenterology*. 2006;130:1030–8.
8. Soetikno RM, Lin OS, Heidenreich PA, et al. Increased risk of colorectal neoplasia in patients with primary sclerosing cholangitis and ulcerative colitis: a meta-analysis. *Gastrointest Endosc*. 2002;56:48–54.
9. Vera A, Gunson BK, Ussatoff V, et al. Colorectal cancer in patients with inflammatory bowel disease after liver transplantation for primary sclerosing cholangitis. *Transplantation*. 2003;75:1983–8.
10. Askling J, Dickman PW, Karlén P, et al. Family history as a risk factor for colorectal cancer in inflammatory bowel disease. *Gastroenterology*. 2001;120:1356–62.
11. Velayos FS, Loftus EV Jr, Jess T, et al. Predictive and protective factors associated with colorectal cancer in ulcerative colitis: a case-control study. *Gastroenterology*. 2006;130:1941–9.
12. Collins PD, Mpofu C, Watson AJ, et al. Strategies for detecting colon cancer and/or dysplasia in patients with inflammatory bowel disease. *Cochrane Database Syst Rev* 2006:CD000279.
13. Karlén P, Kornfeld D, Broström O, et al. Is colonoscopic surveillance reducing colorectal cancer mortality in ulcerative colitis? A population based case control study. *Gut*. 1998;42:711–4.
14. Eaden J, Abrams K, Ekbom A, et al. Colorectal cancer prevention in ulcerative colitis: a case-control study. *Aliment Pharmacol Ther*. 2000;14:145–53.
15. Lutgens MW, Oldenburg B, Siersema PD, et al. Colonoscopic surveillance improves survival after colorectal cancer diagnosis in inflammatory bowel disease. *Br J Cancer*. 2009;101:1671–5.
16. Ananthakrishnan AN, Cagan A, Cai T, et al. Colonoscopy is associated with a reduced risk for colon cancer and mortality in patients with inflammatory bowel diseases. *Clin Gastroenterol Hepatol* 2015;13:322–9.
17. Laine L, Kaltenbach T, Barkun A, et al.; SCENIC Guideline Development Panel. SCENIC international consensus statement on surveillance and management of dysplasia in inflammatory bowel disease. *Gastroenterology*. 2015;148:639–51.
18. Laine L, Kaltenbach T, Barkun A, et al.; SCENIC Guideline Development Panel. SCENIC international consensus statement on surveillance and management of dysplasia in inflammatory bowel disease. *Gastrointest Endosc*. 2015;81:489–501.e26.
19. Itzkowitz SH, Present DH, Crohn's, et al. Consensus conference: colorectal cancer screening and surveillance in inflammatory bowel disease. *Inflamm Bowel Dis* 2005;11:314-21.
20. Rufo PA, Denson LA, Sylvester FA, et al. Health supervision in the management of children and adolescents with IBD: NASPGHAN recommendations. *J Pediatr Gastroenterol Nutr*. 2012;55:93–108.
21. Annese V, Daperno M, Rutter MD, et al.; European Crohn's and Colitis Organisation. European evidence based consensus for endoscopy in inflammatory bowel disease. *J Crohns Colitis*. 2013;7:982–1018.
22. Cairns SR, Scholefield JH, Steele RJ, et al.; British Society of Gastroenterology; Association of Coloproctology for Great Britain and Ireland. Guidelines for colorectal cancer screening and surveillance in moderate and high risk groups (update from 2002). *Gut*. 2010;59:666–89.
23. Ooi CJ, Makharia GK, Hilmi I, et al.; Asia Pacific Association of Gastroenterology (APAGE) Working Group on Inflammatory Bowel Disease. Asia Pacific Consensus Statements on Crohn's disease. Part 1: definition, diagnosis, and epidemiology: (Asia Pacific Crohn's disease consensus–part 1). *J Gastroenterol Hepatol*. 2016;31:45–55.
24. Ooi CJ, Fock KM, Makharia GK, et al.; Asia Pacific Association of Gastroenterology Working Group on Inflammatory Bowel Disease. The Asia-Pacific consensus on ulcerative colitis. *J Gastroenterol Hepatol*. 2010;25:453–68.
25. *Colonoscopic Surveillance for Prevention of Colorectal Cancer in People with Ulcerative Colitis, Crohn's Disease or Adenomas*. London: National Institute for Health and Clinical Excellence, 2011. NICE Clinical Guidelines, No. 118. https://www.ncbi.nlm.nih.gov/pubmedhealth/PMH0033569/pdf/PubMedHealth_PMH0033569.pdf
26. Cancer Council Australia Surveillance Colonoscopy Guidelines Working Party. *Clinical Practice Guidelines for Surveillance Colonoscopy*. Sydney: Cancer Council Australia. [Version URL: https://wiki.cancer.org.au/australiawiki/index.php?oldid=173458, cited March 16, 2018]. https://wiki.cancer.org.au/australia/Guidelines:Colorectal_cancer/Colonoscopy_surveillance
27. Gaidos JK, Bickston SJ. How to optimize colon cancer surveillance in inflammatory bowel disease patients. *Inflamm Bowel Dis*. 2016;22:1219–30.
28. American Society for Gastrointestinal Endoscopy Standards of Practice C, Shergill AK, Lightdale JR, et al. The role of endoscopy in inflammatory bowel disease. *Gastrointest Endosc* 2015;81:1101-21.
29. Van Assche G, Dignass A, Bokemeyer B, et al.; European Crohn's and Colitis Organisation. Second European evidence-based consensus on the diagnosis and management of ulcerative colitis part 3: special situations. *J Crohns Colitis*. 2013;7:1–33.
30. Farraye FA, Odze RD, Eaden J, et al. AGA technical review on the diagnosis and management of colorectal neoplasia in inflammatory bowel disease. *Gastroenterology*. 2010;138:746–74.
31. Rutter MD, Riddell RH. Colorectal dysplasia in inflammatory bowel disease: a clinicopathologic perspective. *Clin Gastroenterol Hepatol*. 2014;12:359–67.
32. East JE. Colonoscopic cancer surveillance in inflammatory bowel disease: what's new beyond random biopsy? *Clin Endosc*. 2012;45:274–7.
33. Subramanian V, Ragunath K. Advanced endoscopic imaging: a review of commercially available technologies. *Clin Gastroenterol Hepatol*. 2014;12:368–76.
34. Subramanian V, Ramappa V, Telakis E, et al. Comparison of high definition with standard white light endoscopy for detection of dysplastic lesions during surveillance colonoscopy in patients with colonic inflammatory bowel disease. *Inflamm Bowel Dis*. 2013;19:350–5.
35. Rubin DT, Rothe JA, Hetzel JT, et al. Are dysplasia and colorectal cancer endoscopically visible in patients with ulcerative colitis? *Gastrointest Endosc*. 2007;65:998–1004.
36. Rutter MD, Saunders BP, Wilkinson KH, et al. Most dysplasia in ulcerative colitis is visible at colonoscopy. *Gastrointest Endosc*. 2004;60:334–9.
37. Barclay RL, Vicari JJ, Doughty AS, et al. Colonoscopic withdrawal times and adenoma detection during screening colonoscopy. *N Engl J Med*. 2006;355:2533–41.
38. Nett A, Velayos F, McQuaid K. Quality bowel preparation for surveillance colonoscopy in patients with inflammatory bowel disease is a must. *Gastrointest Endosc Clin N Am*. 2014;24:379–92.
39. Toruner M, Harewood GC, Loftus EV Jr, et al. Endoscopic factors in the diagnosis of colorectal dysplasia in chronic inflammatory bowel disease. *Inflamm Bowel Dis*. 2005;11:428–34.
40. Soetikno R, Kaltenbach T, McQuaid KR, et al. Paradigm shift in the surveillance and management of dysplasia in inflammatory bowel disease (west). *Dig Endosc*. 2016;28:266–73.
41. Rutter M, Bernstein C, Matsumoto T, et al. Endoscopic appearance of dysplasia in ulcerative colitis and the role of staining. *Endoscopy*. 2004;36:1109–14.
42. Boiteux S, Gajewski E, Laval J, et al. Substrate specificity of the Escherichia coli Fpg protein (formamidopyrimidine-DNA glycosylase): excision of purine lesions in DNA produced by ionizing radiation or photosensitization. *Biochemistry*. 1992;31:106–10.
43. Olliver JR, Wild CP, Sahay P, et al. Chromoendoscopy with methylene blue and associated DNA damage in Barrett's oesophagus. *Lancet*. 2003;362:373–4.
44. Davies J, Burke D, Olliver JR, et al. Methylene blue but not indigo carmine causes DNA damage to colonocytes in vitro and in vivo at concentrations used in clinical chromoendoscopy. *Gut*. 2007;56:155–6.
45. Kiesslich R, Neurath MF. Chromoendoscopy in inflammatory bowel disease. *Gastroenterol Clin North Am*. 2012;41:291–302.
46. Leong RW, Butcher RO, Picco MF. Implementation of image-enhanced endoscopy into solo and group practices for dysplasia detection in Crohn's disease and ulcerative colitis. *Gastrointest Endosc Clin N Am*. 2014;24:419–25.
47. Subramanian V, Bisschops R. Image-enhanced endoscopy is critical in the surveillance of patients with colonic IBD. *Gastrointest Endosc Clin N Am*. 2014;24:393–403.
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.

Downloaded from https://academic.oup.com/ibdjournal/article/24/7/1440/4969996 by Columbia University Libraries user on 10 March 2026

49. Kudo S, Rubio CA, Teixeira CR, et al. Pit pattern in colorectal neoplasia: endoscopic magnifying view. *Endoscopy*. 2001;33:367–73.
50. Tanaka S, Kaltenbach T, Chayama K, et al. High-magnification colonoscopy (with videos). *Gastrointest Endosc*. 2006;64:604–13.
51. Bisschops R, Bessissow T, Dekker E, et al. Pit pattern analysis with high-definition chromoendoscopy and narrow-band imaging for optical diagnosis of dysplasia in patients with ulcerative colitis. *Gastrointest Endosc* 2017.
52. Iacucci M, Hassan C, Fort Gasia M, et al. Serrated adenoma prevalence in inflammatory bowel disease surveillance colonoscopy, and characteristics revealed by chromoendoscopy and virtual chromoendoscopy. *Can J Gastroenterol Hepatol*. 2014;28:589–94.
53. Kaltenbach T, Sandborn WJ. Endoscopy in inflammatory bowel disease: advances in dysplasia detection and management. *Gastrointest Endosc* 2017;86:962–71.
54. East JE, Toyonaga T, Suzuki N. Endoscopic management of nonpolypoid colorectal lesions in colonic IBD. *Gastrointest Endosc Clin N Am*. 2014;24:435–45.
55. Soetikno R, Kaltenbach T. Dynamic submucosal injection technique. *Gastrointest Endosc Clin N Am*. 2010;20:497–502.
56. Polymeros D, Kotsalidis G, Triantafyllou K, et al. Comparative performance of novel solutions for submucosal injection in porcine stomachs: an ex vivo study. *Dig Liver Dis*. 2010;42:226–9.
57. Sanduleanu S, Kaltenbach T, Barkun A, et al. A roadmap to the implementation of chromoendoscopy in inflammatory bowel disease colonoscopy surveillance practice. *Gastrointest Endosc*. 2016;83:213–22.
58. Picco MF, Pasha S, Leighton JA, et al. Procedure time and the determination of polypoid abnormalities with experience: implementation of a chromoendoscopy program for surveillance colonoscopy for ulcerative colitis. *Inflamm Bowel Dis*. 2013;19:1913–20.
59. Soetikno R, Subramanian V, Kaltenbach T, et al. The detection of nonpolypoid (flat and depressed) colorectal neoplasms in patients with inflammatory bowel disease. *Gastroenterology*. 2013;144:1349–52.
60. Watanabe T, Ajioka Y, Mitsuyama K, et al. Comparison of targeted vs random biopsies for surveillance of ulcerative colitis-associated colorectal cancer. *Gastroenterology*. 2016;151:1122–30.
61. Shaukat A, Oancea C, Bond JH, et al. Variation in detection of adenomas and polyps by colonoscopy and change over time with a performance improvement program. *Clin Gastroenterol Hepatol*. 2009;7:1335–40.
62. Carballal S, Maisterra S, Lopez-Serrano A, et al. Real-life chromoendoscopy for neoplasia detection and characterisation in long-standing IBD. *Gut*. 2016.
63. Har-Noy O, Katz L, Avni T, et al. Chromoendoscopy, narrow-band imaging or white light endoscopy for neoplasia detection in inflammatory bowel diseases. *Dig Dis Sci*. 2017;62:2982–90.
64. Bisschops R, Bessissow T, Joseph JA, et al. Chromoendoscopy versus narrow band imaging in UC: a prospective randomised controlled trial. *Gut* 2017.
65. Rutter MD, Saunders BP, Schofield G, et al. Pancolonic indigo carmine dye spraying for the detection of dysplasia in ulcerative colitis. *Gut*. 2004;53:256–60.
66. Moussata D, Allez M, Cazals-Hatem D, et al. Are random biopsies still useful for the detection of neoplasia in patients with IBD undergoing surveillance colonoscopy with chromoendoscopy? *Gut* 2017.
67. Kiesslich R, Fritsch J, Holtmann M, et al. Methylene blue-aided chromoendoscopy for the detection of intraepithelial neoplasia and colon cancer in ulcerative colitis. *Gastroenterology*. 2003;124:880–8.
68. Kiesslich R, Goetz M, Lammersdorf K, et al. Chromoscopy-guided endomicroscopy increases the diagnostic yield of intraepithelial neoplasia in ulcerative colitis. *Gastroenterology*. 2007;132:874–82.
69. Rastogi A, Early DS, Gupta N, et al. 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.
70. Gasia MF, Ghosh S, Panaccione R, et al. Targeted biopsies identify larger proportions of patients with colonic neoplasia undergoing high-definition colonoscopy, dye chromoendoscopy, or electronic virtual chromoendoscopy. *Clin Gastroenterol Hepatol*. 2016;14:704–12.e4.
71. Mooiweer E, van der Meulen-de Jong AE, Ponsioen CY, et al. Chromoendoscopy for surveillance in inflammatory bowel disease does not increase neoplasia detection compared with conventional colonoscopy with random biopsies: results from a large retrospective study. *Am J Gastroenterol*. 2015;110:1014–21.
72. Iacucci M, Gasia MF, Akinola O, et al. 624 final results of a randomized study comparing high definition colonoscopy alone with high definition dye spraying and electronic virtual chromoendoscopy using iSCAN for detection of colonic neoplastic lesions during IBD surveillance colonoscopy. *Gastroenterology* 2016;150:S129.
73. Park SJ, Kim H-S, Yang D-H, et al. Tu2086 high definition chromoendoscopy with water-jet versus high definition white light endoscopy in the detection of dysplasia in long standing ulcerative colitis: a multicenter prospective randomized controlled study. *Gastroenterology* 2016;150:S1270.
74. Mohammed N, Kant P, Abid F, et al. 446 High definition white light endoscopy (Hdwle) versus high definition with chromoendoscopy (Hdce) in the detection of dysplasia in long standing ulcerative colitis: a randomized controlled trial. *Gastrointest Endosc*. 2015;81:AB148.
75. Iannone A, Ruospo M, Wong G, et al. Chromoendoscopy for surveillance in ulcerative colitis and Crohn's disease: a systematic review of randomized trials. *Clin Gastroenterol Hepatol*. 2017;15:1684–1697.e11.
76. Marion JF, Sands BE. The SCENIC consensus statement on surveillance and management of dysplasia in inflammatory bowel disease: praise and words of caution. *Gastroenterology*. 2015;148:462–7.
77. Higgins PD. Miles to go on the SCENIC route: should chromoendoscopy become the standard of care in IBD surveillance? *Am J Gastroenterol*. 2015;110:1035–7.
78. Fumery M, Dulai PS, Gupta S, et al. Incidence, risk factors, and outcomes of colorectal cancer in patients with ulcerative colitis with low-grade dysplasia: a systematic review and meta-analysis. *Clin Gastroenterol Hepatol*. 2017;15:665–674.
79. Murphy J, Kalkbrenner KA, Pemberton JH, et al. Dysplasia in ulcerative colitis as a predictor of unsuspected synchronous colorectal cancer. *Dis Colon Rectum*. 2014;57:993–8.
80. Kiran RP, Ahmed Ali U, Nisar PJ, et al. Risk and location of cancer in patients with preoperative colitis-associated dysplasia undergoing proctocolectomy. *Ann Surg*. 2014;259:302–9.
81. Choi CH, Ignjatovic-Wilson A, Askari A, et al. Low-grade dysplasia in ulcerative colitis: risk factors for developing high-grade dysplasia or colorectal cancer. *Am J Gastroenterol*. 2015;110:1461–71.
82. Ten Hove JR, Mooiweer E, van der Meulen de Jong AE, et al. Clinical implications of low grade dysplasia found during inflammatory bowel disease surveillance: a retrospective study comparing chromoendoscopy and white-light endoscopy. *Endoscopy*. 2017;49:161–8.
83. Friedman S, Cheifetz AS, Farraye FA, et al. Factors that affect adherence to surveillance colonoscopy in patients with inflammatory bowel disease. *Inflamm Bowel Dis*. 2013;19:534–9.

Downloaded from https://academic.oup.com/ibdjournal/article/24/7/1440/4969996 by Columbia University Libraries user on 10 March 2026