Revista de Gastroenterología de México 86 (2021) 276–286

REVISTA DE GASTROENTEROLOGÍA DE MÉXICO
www.elsevier.es/rgmx

REVIEW ARTICLE

Serrated polyps of the colon and rectum: a concise review☆

R. Monreal-Robles[a,b,*], J.O. Jáquez-Quintana[a], D.E. Benavides-Salgado[a], J.A. González-González[a]

[a] *Servicio de Gastroenterología, Hospital Universitario Dr. José E. González, Universidad Autónoma de Nuevo León, Monterrey, Nuevo León, Mexico*
[b] *Escuela de Medicina y Ciencias de la Salud, Instituto Tecnológico y de Estudios Superiores de Monterrey, Monterrey, Nuevo León, Mexico*

Received 4 November 2020; accepted 26 February 2021
Available online 9 June 2021

KEYWORDS
Hyperplastic polyps;
Adenoma;
Colonoscopy;
Polypectomy;
Colorectal cancer

Abstract ''Serrated polyps'' is the term used for epithelial lesions of the colon and rectum that have a ''sawtooth'' pattern on the polyp's surface and crypt epithelium. The so-called serrated pathway describes the progression of sessile serrated adenomas and traditional serrated adenomas to colorectal cancer. Said pathway is well recognized as an alternative mechanism of carcinogenesis and accounts for 15-30% of the cases of colorectal cancer. It also explains a large number of the cases of interval colorectal cancer. Thus, due to their usually aggressive and uncertain behavior, serrated polyps are of the utmost importance in colorectal cancer screening. Our aim was to review the history, current nomenclature, pathophysiology, morphology, treatment, and surveillance of serrated polyps.

PALABRAS CLAVE
Pólipos hiperplásicos;
Adenoma;
Colonoscopia;
Polipectomía;
Cáncer colorrectal

Pólipos serrados del colon y el recto: una revisión concisa

Resumen «Pólipos serrados» es el término utilizado para describir lesiones epiteliales del colon y recto que demuestran un patrón de «dientes de sierra» de la superficie y epitelio de las criptas. La llamada vía serrada describe la progresión de adenomas serrados sésiles y adenomas serrados tradicionales a cáncer colorrectal. Esta vía está bien reconocida como un mecanismo de carcinogénesis alternativo, el cual representa el 15-30% de los casos de cáncer colorrectal, explicando además una proporción significativa de los casos de cáncer colorrectal de intervalo.

☆ Please cite this article as: Monreal-Robles R, Jáquez-Quintana JO, Benavides-Salgado DE, González-González JA. Pólipos serrados del colon y el recto: una revisión concisa. Revista de Gastroenterologíade México. 2021;86:276–286.

* Corresponding author.
E-mail address: roberto.monreal@tec.mx (R. Monreal-Robles).

Por tal motivo, debido a su comportamiento incierto y usualmente agresivo, los pólipos serrados son un tema de suma relevancia en el cribado de cáncer colorrectal. Nuestro objetivo fue revisar la historia, nomenclatura actual, fisiopatología, características morfológicas, tratamiento y vigilancia de los pólipos serrados.

Introduction

The term ''serrated polyps'' is used to describe epithelial lesions of the colon and rectum demonstrating a histologic ''sawtooth'' pattern of the polyp's surface and crypt epithelium.[1] Previously, all lesions showing those characteristics were considered hyperplastic polyps (HPs).[2] In recent decades, colorectal polyps, in general, were divided into 2 types: HPs and adenomas. Adenomas were considered the only precursor of colorectal cancer (CRC), and HPs were considered lesions with no malignant potential.[2] However, reports from 3 decades ago described the association of HPs with the potential for malignant transformation. In 1990, Longacre and Fenoglio-Preiser specified a type of mixed colorectal polyp that shared adenoma and HP features, exhibiting architectural but not cytologic features of a HP, and called them ''traditional serrated adenomas'', emphasizing the neoplastic potential of those lesions.[3] In 1996, Torlakovic et al. first described what we now know as sessile serrated adenomas. Those lesions are characterized by displaying an abnormal architecture with no cytologic dysplasia.[4]

Currently, the different morphologic and molecular profiles of those serrated lesions and their potential for malignant transformation are well known. The so-called serrated pathway describes the progression of serrated adenomas and traditional serrated adenomas to CRC. Said pathway is well recognized as an alternative mechanism of colorectal carcinogenesis that accounts for 15% to 30% of cases of colorectal cancer.[5] In addition, the lack of identification of those serrated lesions could explain a significant proportion of interval CRCs.[6,7]

The current nomenclature of serrated polyps, according to the latest World Health Organization (WHO) classification, is divided into HPs, sessile serrated adenoma/polyps (SSA/Ps), and traditional serrated adenomas (TSAs).[8] The accurate differentiation of each of those lesions is crucial because of their different potential for malignant transformation.[9] Unlike HPs, which are the most common serrated lesions (80-90%) found in the colon and rectum, SSA/Ps and TSAs are thought to have malignant transformation potential. SSA/Ps comprise 8% to 20% of the serrated lesions of the colon and rectum and therefore are considered the most relevant of the serrated lesions, given the rarity of TSAs.[10,11]

Serrated lesion subtypes

Hyperplastic polyps

True HPs are the most common serrated lesion subtype. They account for 70% to 95% of all serrated polyps[12] and 25% to 30% of all colonic polyps,[13] and are characterized by their lack of malignant potential. HPs predominate in the distal colon and they are usually smaller than 5 mm. Endoscopically, they are flat or slightly elevated lesions that are transparent or pale[10,11] (Fig. 1A). Histologically, HPs are characterized by straight crypts, with 'serration' typically restricted to the upper half[14] (Fig. 1B).

HPs are also subclassified as microvesicular HPs, goblet cell-rich HPs, and mucin-poor HPs, based on the type of mucin pattern.[15] The microvesicular subtype is the most common, making up 60% of all HPs.[12] Histologically, they are characterized by columnar cells with multiple small cytoplasmic vacuoles (microvesicular).[16]

Sessile serrated adenoma/polyp

SSA/Ps are the most relevant of the serrated lesions, not only because of their malignant potential, but also for their difficult detection. They are most commonly located in the right colon and account for approximately 5% to 25% of all serrated polyps[12,13] and 1.7% to 9% of all colonic polyps.[17,18] The presence of an SSA/P is associated with female sex and an increased number of polyps in the colonoscopy examination.[17,19]

Expertise and image enhancing endoscopy techniques are necessary for the detection and proper resection of SSA/Ps.[20] Endoscopically, they are usually > 10 mm, flat and slightly elevated, with inconspicuous margins. Their color is similar to that of the surrounding mucosa, with a cloud-like surface, the underlying mucosal vascular pattern is interrupted, and they are frequently covered by a yellow mucous layer[10,14,21] (Figs. 2A and B). Histologically, SSA/Ps present with distorted crypt architecture, with marked serration located at the base of the crypts. Basal crypts are dilated and laterally extended into a mucus-filled L or inverted T shape, with the presence of mature cells above the *muscularis mucosae*[9,14] (Fig. 2C).

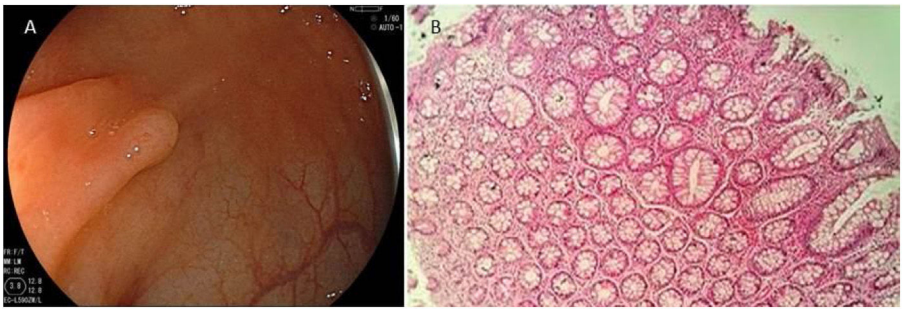

Figure 1 A) Endoscopic appearance of a hyperplastic polyp. It is characterized by a flat or slightly elevated lesion that is transparent or pale. B) Histologic appearance of hyperplastic polyp, showing elongated crypts, a higher number of cells than in normal mucosa, conserved structure and maturation, a normal number of goblet and absorptive cells, with regular nucleus and basal distribution. A chronic inflammatory type of lymphocytic predominance can be seen in the lamina propria.

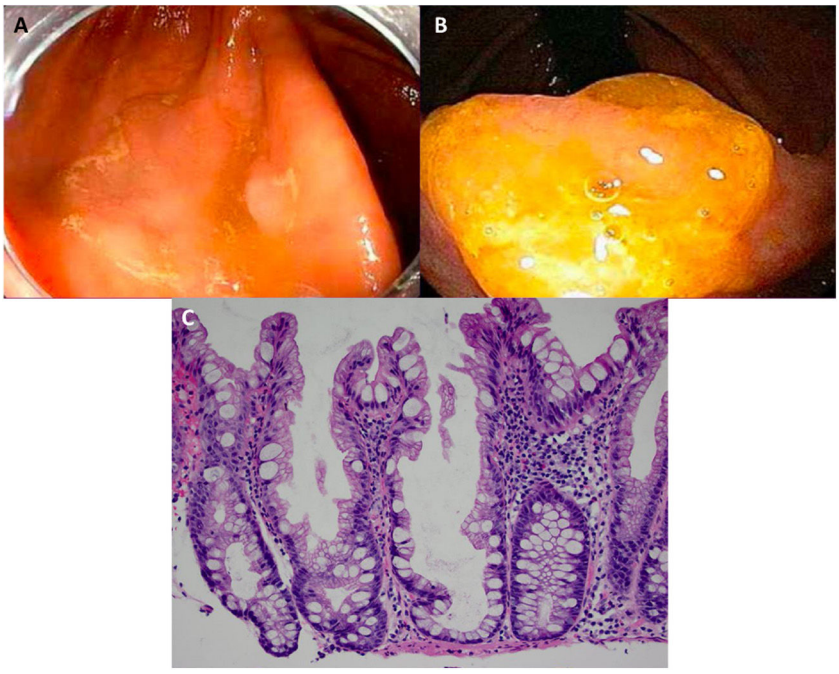

Figure 2 Sessile serrated adenoma/polyp. A) A mostly flat sessile serrated polyp in the right colon. Note the color similar to that of the adjacent normal colon, the paucity of blood vessels on the surface of the lesion, and the accumulation of yellow ''debris'' at the edges. B) A sessile serrated polyp in the right colon. Note the prominent ''yellow mucus cap.'' C) Histologic appearance of a sessile serrated adenoma/polyp. It has distorted crypt architecture, with marked serration at the base of the crypts; basal crypts are dilated.
(endoscopic images taken with authorization: Rex D. Serrated Polyps in the Colon. Gastroenterol Hepatol 2014; 10 (10). Histologic image was taken with authorization: Kuo E. Sessile serrated adenoma [accessed July 2, 2020]. Available at: http://www.pathologyoutlines.com/topic/colontumorsessileserrated.html.

Traditional serrated adenoma

Even though TSAs also have a risk for malignant transformation, they are the least frequent type of serrated lesions. They account for approximately 1% of all colorectal polyps[13] and are more commonly located in the distal colon. Endoscopically, with narrow band imaging (NBI), they appear as superficial or protruding and sometimes pedunculated lesions and are usually > 5 mm in size, with dilated vessels.[13,22] Histologically, TSAs are characterized by a protuberant, villous growth pattern.[13] The presence of ectopic crypts perpendicular to the axis of the villous structures, cytologic atypia, and prominent eosinophilic cytoplasm are their characteristic features[23] (Fig. 3).

Table 1 and Table 2 provide a summary of the main clinical endoscopic and histopathologic characteristics of serrated polyps, respectively.

The pathways of serrated carcinogenesis

The serrated pathway is recognized as the second most important pathway leading to CRC, after the adenoma-carcinoma pathway. In regard to serrated polyps and CRC,

Table 1 Main clinical and endoscopic characteristics of serrated polyps.

	Hyperplastic polyps	SSA/P	TSA
Frequency	Very common	Common	Rare
Sex predominance	None	Female	None
Predominant location	Left colon and rectum	Right colon	Left colon and rectum
Size	< 5 mm	> 10 mm	> 5 mm
Endoscopic appearance	Flat or slightly elevated lesions that are transparent or pale	Sessile, inconspicuous, yellow margins, covered by a mucous layer	Sessile
Malignant potential	No	Yes	Yes

SSA/P: sessile serrated adenoma/polyp; TSA: traditional serrated adenoma.

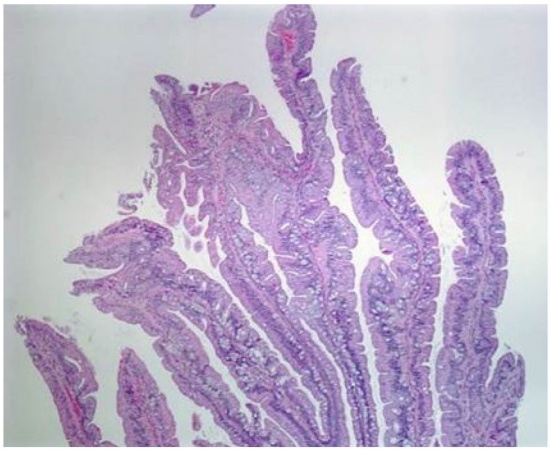

Figure 3 Histologic section of a traditional serrated adenoma, showing a protuberant villiform growth pattern with slit-like serrations.
Taken from: Kuo E, Gonzalez R. Traditional serrated adenoma [accessed July 2, 2020]. Available at: http://www.pathologyoutlines.com/topic/colontumortraditionalserratedadenoma.html.

the biology is heterogeneous, culminating in 2 main postulated serrated pathways to CRC: the BRAF mutation pathway and the KRAS mutation pathway.

The BRAF mutation pathway is characterized by high levels of the CpG island methylator phenotype (CIMP), which leads to the silencing of the hMLH1 mismatch repair gene, resulting in high microsatellite instability (MSI-H) and the consequent evolution into dysplasia, high-grade dysplasia, and ultimately, CRC (BRAF mutation/CIMP-high/MSI-H/).[24] Colorectal carcinomas following the *BRAF mutation/CIMP-high/MSI-H pathway* make up the majority of sporadic non-syndromic CRCs with MSI-H, accounting for approximately 12-15% of all CRCs.[7]

In contrast, the KRAS mutation pathway is characterized by a low level of CpG island methylation, with no inactivation of the hMHL1 mismatch repair gene, and with microsatellite stability (*KRAS mutation/CIMP-low/MSS*). Thus, the main stimulus toward carcinogenesis in those cases is the mutation of suppressor genes, as is the case with SLIT-2 and p53.[7,25] Colorectal carcinoma that follows the *KRAS mutation/CIMP-low/MSS* pathway makes up approximately 5% of all CRC.[26]

Table 2 Main histopathologic characteristics of serrated polyps.[95,96]

	Hyperplastic polyps (microvesicular)	SSA/P	TSA
Crypt architecture	Straight crypts	Distorted crypt architecture	Protuberant and villiform growth pattern
Serrations	Restricted to the upper half of the crypts	Located at the base of the crypt	Slit-like, clefted serrations
Basal crypt	Narrow	Dilated and laterally extended (L or inverted T)	Ectopic crypt foci
Crypt branching	No	Yes	No
Proliferative zone	Located at the basal third	Not at its usual location at the base of the crypts	Abnormally positioned crypts, with bases not seated at the *muscularis mucosae*
Cell maturation	Maturation from crypt base to surface	Base of the crypt	Loss of orientation towards the *muscularis mucosae*
Main characteristic feature	Straight crypts with upper serration	Inverted growth and dilated basal crypt	Slit-like serrations, ectopic crypts, cells with eosinophilic cytoplasm

SSA/P: sessile serrated adenoma/polyp; TSA: traditional serrated adenoma.

By correlating the histologic characteristics of serrated polyps with their molecular genetic features, SSAs and TSAs appear to be two genetically distinct entities. Predominantly, SSAs with dysplasia have the BRAF mutation, whereas TSAs have the KRAS mutation.[27]

Histologic correlation with endoscopic imaging

Unlike adenomas, whose incidence is around 30-40% in the overall population, serrated lesions are found in only 5-8%. Nevertheless, they may be underestimated because of the difficulty in identifying them in routine screening colonoscopy.[28,29]

In general, SSA/Ps can be differentiated from HPs by the presence of a mucous cap and dilated pits (type II open pit pattern).[22,30] However, several other specific endoscopic features, such as indistinct borders, a cloud-like surface, irregular shape, and dark spots inside the crypts, on high-resolution white-light endoscopy and NBI, have aided in identifying SSA/P histology with a high degree of accuracy.[21]

The distinction between non-malignant SSA/Ps and SSA/Ps with dysplasia is of major relevance. The NBI technique has been shown to be of great value in both identifying the high-risk features of malignancy in serrated lesions and increasing the detection of proximal colon serrated lesions.[31] The detection of irregular vessels through magnifying NBI has 100% sensitivity, 99% specificity, an 86% positive predictive value, and a 100% negative predictive value for identifying cancer coexisting with SSA/P.[30] Other characteristics, such as lesion size (OR 1.9 for dysplasia for every 10 mm increase in lesion size), increasing age (OR 1.69 per decade), Kudo III, IV, or V (adenomatous) pit pattern, and the 0-Is component of the Paris classification have been shown to correlate well with dysplasia.[32]

Interval cancers

Interval cancers are defined as CRC diagnosed within 5 years of a complete / clearing colonoscopy. They account for approximately 2-6% of all CRC.[33,34]

Several factors have been identified as a cause of interval cancers. Missed lesions due to suboptimal colon preparation, incomplete examination of the colon, incomplete resection of polyps, and missed or unrecognized lesions (e.g. SSA/P) predominantly located in the right colon are the main factors associated with interval CRC.[33]

There is evidence that sporadic CRC may arise from SSA/P lesions. Firstly, interval CRC occurs 3 times more frequently in the right colon, compared with sporadic cancer.[33] In addition, interval colon cancer is 4 times more commonly associated with mismatch repair gene dysfunction than sporadic cancer.[35,36] Those data suggest a possible BRAF mutation serrated origin.[7] Besides the factors previously mentioned, CIMP-H and MSI-H cancers present accelerated growth or evolution, becoming malignant in fewer than 10 years from the last colonoscopy examination.[13]

Progression to malignancy

The rate of serrated lesions that progress to carcinoma is not clear and may differ, depending on the occurrence of MSI-H. Among the serrated lesions with malignant potential, the rate of dysplasia is higher in TSA (9.3%) compared with SSA/P (2%).[37] The reported appearance of high-grade dysplasia and carcinoma in serrated adenomas is between 2-3.2%,[37,38] which is lower than the 9.3% rate in conventional adenomas.[37]

A 5% risk of serrated cancer following the endoscopic resection of an index serrated adenoma has been reported.[39] The fact that the rate of progression to non-serrated carcinoma is greater when conventional adenomas are not resected (14.3%) suggests that the rate of neoplastic transformation for non-resected serrated adenomas is greater than 5%.[39]

Regarding the time of progression to malignancy, a case report showed a rapid progression of SSA/P to early invasive carcinoma within 8 months.[40] However, a study analyzing 106 serrated polyps, most of which were from the right colon, that preceded 91 MSI-adenocarcinomas showed slower progression, with a mean time interval between polypectomy and the development of subsequent adenocarcinoma of 7.3 years (range 1.2-19.3 years).[41] Even though there is no clear evidence of the proportion and rate of progression, the malignant potential of serrated lesions has been well documented, making up a significant proportion of overall CRC cases. Therefore, serrated lesions should be considered an important target for CRC prevention, to impact the incidence of right CRC.

Metachronous and synchronous cancer

In patients with serrated lesions (HP, SSA/P, or TSA), the occurrence of metachronous serrated CRC occurred in 5% of cases, after a mean of 14.25 years, following index examination.[39] Whether serrated lesions increase the risk of metachronous neoplasia, in comparison with conventional adenomas, is a subject of debate. Some reports showed a risk of metachronous neoplasia in 2-5% of patients with serrated lesions,[39,42] which was not significantly different from the CRC rate in patients with conventional adenoma (2.2%).[39] Other studies reported a significantly higher risk of metachronous neoplasia in patients with SSA/P (12.5%) than in patients with HP (1.8%) and adenomas (1.8%).[43]

The association between serrated lesions and synchronous neoplasia is more certain.[18,44] The rate of additional serrated lesions (SSA/Ps, SSA/Ps with dysplasia, and TSAs) in patients with a resected index SSA/P was 18%, compared with 5% in a control population.[45] Proximal and large ($\geq$ 10 mm) HPs, as well as proximal and large ($\geq$ 10 mm) SSA/Ps, have been associated with synchronous advanced neoplasia.[18] The rate of synchronous advanced neoplasia is about 17.8% in proximal HP and SSA/P, compared with 8% in non-proximal polyps, and the rate of synchronous advanced neoplasia is about 27% in large polyps (HP and SSA/P) > 10 mm, compared with smaller polyps (8.6%).[18]

Risk factors for serrated lesions

Multiple factors, such as ethnicity, family history, and modifiable lifestyle and diet, have been associated with a higher

risk for serrated polyps. In connection with race/ethnicity, the risk of serrated polyps (in the left colon) is lower in African Americans (RR: 0.65, 95% CI: 0.50-0.85) and Hispanics (RR: 0.33, 95% CI: 0.20-0.55), compared with Whites.[46] A family history of CRC or polyps is associated with serrated lesions in the right colon.[46,47]

The main modifiable lifestyle factors associated with serrated lesions are obesity and cigarette smoking.[46,48] A body mass index $\geq$ 30 was associated with a 27% increase in the risk of serrated lesion in the left colon, compared with normal weight. Current cigarette smoking increased the risk of left serrated lesions (RR: 2.18, 95% CI: 1.80-2.65) and of left-sided advanced serrated lesions (RR: 3.42, 95% CI: 1.91-6.11), compared with no smoking.[46] Heavy alcohol drinking ($\geq$ 14 drinks/week) was also significantly associated with an increased risk of advanced neoplasia (OR: 2.65, 95% CI: 1.37-5.15).[48] Among the dietary factors, increased fat intake increased the risk of serrated lesion in both the right colon (RR: 1.27, 95% CI: 1.03-1.56) and the left colon (RR: 1.45, 95% CI: 1.01-2.10). Red meat intake significantly increased the risk of left advanced serrated polyps (RR: 1.93, 95% CI: 0.97-3.84).[46]

With respect to treatment prescription, the use of aspirin (81 mg) reduced the risk of non-advanced serrated lesions in the right colon. A higher dose of aspirin (325 mg) provided a protective effect for advanced lesions in the right colon.[46] Cereal fiber intake > 4.2 g per day (RR: 0.65, 95% CI: 0.43-0.98) and vitamin D intake > 645 U per day (RR: 0.61, 95% CI: 0.39-0.97) were also associated with a reduced risk for advanced neoplasia.[48]

Serrated polyposis syndrome

Serrated polyposis syndrome (SPS) is characterized by the development of multiple serrated polyps throughout the colon. Since the publication of the fourth edition of the WHO criteria for SPS diagnosis in 2010,[15] the understanding of SPS has improved substantially, resulting in an update of the 2010 diagnostic criteria, incorporated in the fifth edition of the WHO classification of Digestive System Tumours in 2019.[8] The following are the updated criteria for SPS diagnosis:

I More than or equal to 5 serrated lesions/polyps proximal to the rectum, all $\geq$ 5 mm in size, with at least 2 $\geq$ 10 mm.
II More than 20 serrated lesions/polyps of any size distributed throughout the large bowel, with $\geq$ 5 proximal to the rectum.

The 2019 updated diagnostic criteria for SPS made several important changes, the most notable of which was the elimination of criterion II (2010), whereas criterion I (2010) and criterion III (2010) underwent minor modifications. The 2010 criterion I only included polyps proximal to the sigmoid colon, whereas the 2019 criterion I now includes serrated polyps in the sigmoid colon. In addition, all serrated polyps in the 2019 criterion I must now be $\geq$ 5 mm, excluding diminutive serrated polyps for the diagnosis of SPS (Table 3).

Even though that classification provides standardized diagnostic criteria, enabling the comparison between studies, it is somewhat arbitrary and restrictive. Thus, patients with 5 serrated polyps, only one of which is > 10 mm in diameter, or patients with 10 to 20 serrated polyps < 10 mm, do not fit the SPS definition. However, even though that subgroup does not entirely meet the WHO definition of SPS, it still has clinical significance.

A retrospective study performed at the Cleveland Clinic and the Genomic Medicine Institute analyzed patients with serrated polyps, recognizing 3 phenotypic patterns: large sessile (> 10 mm) serrated polyps in the right colon (right-sided phenotype 48%); multiple, small hyperplastic polyps in the left colon (left-sided phenotype 16%); and a third phenotype with characteristics of the previous two types (mixed phenotype 37%).[49] The 3 phenotypes had a similar incidence of CRC (right 27%, left 28%, and mixed 21%), with the right-sided phenotype presenting more SSA/Ps and tending to develop CRC at a younger age.[49]

The prevalence of SPS is low (< 0.1%) in colonoscopy screening programs.[18,50] In a selected population with positive fecal immunochemical tests, prevalence was expectedly higher (0.34-0.66%).[51,52] Patients with SPS and their relatives are at an increased risk of CRC, with an incidence between 7% and 70%[6,53–55] and an interval cancer risk of 2% to 7%.[6,53,56] The main predictors of CRC in patients with SPS are the number of proximal SSA/Ps and the presence of high-grade dysplasia in a proximal SSA/P.[53]

Unlike other hereditary colorectal cancer syndromes, such as Lynch syndrome and familial adenomatous polyposis, SPS does not have a simple Mendelian inheritance pattern.[57] Interestingly, CRC in patients with SPS has been reported to follow both the serrated pathway and the traditional adenoma-carcinoma pathway.[56] Patients with SPS and their relatives are also at an increased risk for extracolonic neoplasia (prostate, skin, leukemia/lymphoma, breast, lung, etc.).[49]

Serrated lesion detection

Colonoscopy is the most accurate and preferred method for the detection of colonic polyps.[58] Because of the relatively slow progression of serrated polyps, their detection and endoscopic resection can halt their progression to cancer. Despite this, colonoscopic surveillance programs have had a positive impact on decreasing the incidence of CRC only in the left colon, whereas the incidence and mortality associated with CRC in the right colon has not changed.[59] The lack of impact on the incidence of right CRC is implied by the lack of identification of SSA/Ps in the right colon during screening colonoscopies.[59]

Several interventions have been carried out to improve serrated lesion detection rates.[60] Image-enhanced endoscopy techniques, such as chromoendoscopy and magnification endoscopy, have improved HP detection.[61–63] High-definition colonoscopies, however, have not demonstrated an improvement in serrated lesion detection.[64,65] Chromoendoscopy has been shown to improve the detection of HPs from 23% to 45% in the entire colon and from 9% to 16% in the right colon.[58] Indigo carmine, the most common dye spraying agent used in colon chromoendoscopy, delimits the lesions more clearly, particularly flat proximal hyperplastic polyps. On the other hand, acetic acid spray, in combination with NBI, has delineated SSA/Ps more accurately, enabling complete resection.[66] Interestingly, the acetic acid-indigo

Table 3 The 2010 and 2019 World Health Organization criteria for SPS diagnosis.[97]

2010		2019
Criterion I. ≥ 5 serrated polyps proximal to the sigmoid colon with two or more of them > 10 mm	→	*Criterion I*. ≥ 5 Serrated lesions/polyps proximal to the rectum, all ≥ 5 mm in size, with at least 2 ≥ 10 mm.
Criterion II. Any number of serrated polyps proximal to the sigmoid colon in an individual with a first-degree relative with SPS		
Criterion III. > 20 serrated polyps of any size spread throughout the colon	→	*Criterion II*. > 20 serrated lesions/polyps of any size distributed throughout the large bowel, with ≥ 5 proximal to the rectum.

SPS: serrated polyposis syndrome.

carmine mixture has been reported to enhance the margin of the lesion, through a whitish change of the lesion surface.[67] However, prospective visibility/detection studies using the aforementioned techniques are required, before a strong recommendation can be given.

Digital chromoendoscopy (NBI, FICE, or iSCAN) has been used to improve serrated lesion detection rates. Nevertheless, a meta-analysis comparing NBI vs white light endoscopy found no improvement in the adenoma detection rate.[68] The use of FICE in a multicenter prospective study displayed no advantage over white light endoscopy, in terms of the general adenoma detection rate and HP identification.[69] The use of LASEREO, Blue Laser Imaging (BLI), and Linked Color Imaging (LCI) improved the diagnostic accuracy of serrated lesions in the colon and rectum, compared with white light endoscopy, alone.[70] Even though the use of BLI and LCI remained superior to white light endoscopy, more studies are needed to determine which of them is superior.[70] The utilization of i-SCAN was not associated with an improvement in adenoma detection or the prevention of missed polyps.[71] A randomized controlled trial comparing the rate of SSA/P detection between i-SCAN 1 vs standard high-definition white-light colonoscopy showed no difference.[72] We did not find any studies specifically comparing different i-SCAN effects, with respect to serrated lesion detection.

Another intervention, such as longer withdrawal time (above 6 minutes), has been shown to improve the serrated polyp detection rate, with a maximum benefit at 9 minutes.[73,74] Performing retroflexion in the right colon has been described as a safe technique that modestly improves the polyp and adenoma detection rates.[75] In contrast to reports of bowel preparation improving the adenoma detection rate, it has had no impact on improving the serrated lesion detection rate. A serrated polyp detection rate of 8.8% has been found in patients with excellent bowel preparation versus 8.9% in those with fair bowel preparation.[76] Other factors, such as formal gastroenterology training, a higher procedure volume, and interestingly, fewer years in practice (≤ 9 years since the completion of training) have had a positive influence on the detection of serrated lesions.[77]

NBI enables the identification of SSA/Ps by discerning their irregular shape and dark spots inside the crypts, which indicate crypt dilatation, a characteristic histologic feature of SSA/Ps.[78,79] On the other hand, magnifying chromoendoscopy enables SSA/Ps with dysplasia or carcinoma to be differentiated from those without dysplasia, by identifying endoscopic features, such as semipedunculated morphologies, double elevations, central depressions, and reddishness, as well as the presence of IIIL, IV, VI, or VN pit patterns.[78,79]

More recently, artificial intelligence (convolutional neural networks) using deep learning models, with video/image training sets, has improved colonoscopic polyp detection and characterization.[80,81] This emerging technology has shown a high level of accuracy for detecting SSA/Ps, with an area under the curve of 0.94, a positive predictive value of 0.93, and a negative predictive value of 0.96.[82]

Endoscopic resection of serrated lesions

The complete resection of serrated lesions is the primary aim for preventing the development of CRC. The resection techniques for managing colonic lesions are the same as those used for conventional adenomas. Cold snare polypectomy is a safe technique for the resection of diminutive sessile polyps and has a high polyp retrieval rate (98-100%).[83,84] For larger superficial, elevated, or poorly defined serrated lesions, endoscopic mucosal resection, with prior submucosal injection (injection and cut), is the preferred technique.[85,86] Variations of endoscopic mucosal resection techniques, such as inject-lift-cut, cap-assisted endoscopic mucosal resection and endoscopic mucosal resection with ligation, have had good results.[85,87]

The British Society of Gastroenterology position statement on serrated polyps in the colon and rectum recommends performing the resection of complex lesions (large lesion in the right colon) in centers that have operators with expertise in the recognition and endoscopic management of those lesions.[60] That recommendation is supported by the results of several studies demonstrating a high risk of incomplete endoscopic resection and

Table 4 Surveillance recommendation after serrated polyp resection.[7,60]

Risk	Description of lesions	Surveillance interval
Low-risk lesions	Hyperplastic polyps *	No surveillance
	SSA/P < 10 mm with no dysplasia *	< 3 polyps ------- 5 years
		≥ 3 polyps ------- 3 years
High-risk lesions	SSA/P ≥ 10 mm or dysplasia	3 years**
	TSA	
SPS	Multiple serrated polyps meeting the SPS criteria	1-2 years

SPS: serrated polyposis syndrome; SSA/P: sessile serrated adenoma/polyp; TSA: traditional serrated adenoma.
* Not meeting the SPS criteria.
** After piecemeal resection of large serrated lesions > 20 mm, endoscopic revision at 3-6 months is advisable, and again one year after resection of the index lesion, for the purpose of examining the polypectomy site, in search of recurrence, before enrolling the patients in a long surveillance program.

complications, associated with resection of large sessile polyps in the right colon.[88–90] Endoscopists attempting to treat those lesions must achieve the competence and standards established in the international guidelines on the management of large non-polypoid colorectal polyps.[90]

After piecemeal resection of large serrated lesions > 20 mm, and before enrolling the patients in a long surveillance program, endoscopic revision is initially advised after 3-6 months, and then one year after resection of the index lesion, for the purpose of examining the polypectomy site, in search of recurrence.[91]

Serrated lesion surveillance

The recommendation for follow-up interval surveillance is based on the intrinsic lesion/patient risk.[60] Patients with multiple serrated polyps that meet the criteria for SPS are high-risk cases. Once the lesions have been resected, the recommended surveillance colonoscopy interval in patients with SPS is every one or 2 years. In patients with high-risk lesions, such as large SSA/Ps > 10 mm, or with associated dysplasia or TSAs,[92] the recommended interval for surveillance colonoscopy is 3 years.[93,94] Lower-risk lesions are HPs or serrated lesions < 10 mm, with no associated dysplasia. There is no evidence supporting an indication for colonoscopic surveillance, unless the lesions meet the SPS criteria, with respect to size, location, or number.[60] Table 4 provides a summary of the recommended surveillance intervals for serrated lesions.

Ethical considerations

The authors declare that the present review meets the current norms in bioethical investigations, because it is a narrative review, authorization by the ethics committee was not necessary. The authors also declare that this review does not contain any personal information that could identify patients.

Financial disclosure

We received no funding in relation to the preparation of this manuscript.

Conflict of interest

The authors declare that there are no conflicts of interest.

References

1. Bordacahar B, Barret M, Terris B, et al. Sessile serrated adenoma: From identification to resection. Dig Liver Dis. 2015;47:95–102, http://dx.doi.org/10.1016/j.dld.2014.09.006.
2. Lane N. The precursor tissue of ordinary large bowel cancer. Cancer Res. 1976;36:2669–72.
3. Longacre TA, Fenoglio-Preiser CM. Mixed hyperplastic adenomatous polyps/serrated adenomas. A distinct form of colorectal neoplasia. Am J Surg Pathol. 1990;14:524–37, http://dx.doi.org/10.1097/00000478-199006000-00003.
4. Torlakovic E, Snover DC. Serrated adenomatous polyposis in humans. Gastroenterology. 1996;110:748–55, http://dx.doi.org/10.1053/gast.1996.v110.pm8608884.
5. Leggett B, Whitehall V. Role of the serrated pathway in colorectal cancer pathogenesis. Gastroenterology. 2010;138:2088–100, http://dx.doi.org/10.1053/j.gastro.2009.12.066.
6. Boparai KS, Mathus-Vliegen EM, Koornstra JJ, et al. Increased colorectal cancer risk during follow-up in patients with hyperplastic polyposis syndrome: a multicentre cohort study. Gut. 2010;59:1094–100, http://dx.doi.org/10.1136/gut.2009.185884.
7. Huang CS, Farraye FA, Yang S, et al. The clinical significance of serrated polyps. Am J Gastroenterol. 2011;106:229–40, http://dx.doi.org/10.1038/ajg.2010.429.
8. Rosty CBL, Nagtegaal ID. Serrated polyposis. WHO classification of tumours. Digestive System Tumours. 2019.
9. Ensari A, Bilezikci B, Carneiro F, et al. Serrated polyps of the colon: how reproducible is their classification? Virchows Arch. 2012;461:495–504, http://dx.doi.org/10.1007/s00428-012-1319-7.
10. Kahi CJ, Vemulapalli KC, Snover DC, et al. Findings in the distal colorectum are not associated with proximal advanced serrated lesions. Clin Gastroenterol Hepatol. 2015;13:345–51, http://dx.doi.org/10.1016/j.cgh.2014.07.044.
11. Vleugels JLA, IJspeert JEG, Dekker E. Serrated lesions of the colon and rectum: the role of advanced endoscopic imaging. Best Pract Res Clin Gastroenterol. 2015;29:675–86, http://dx.doi.org/10.1016/j.bpg.2015.05.009.
12. Rex DK, Ahnen DJ, Baron JA, et al. Serrated lesions of the colorectum: review and recommendations from an expert panel. Am J Gastroenterol. 2012;107:1315–29, http://dx.doi.org/10.1038/ajg.2012.161.

13. Bettington M, Walker N, Clouston A, et al. The serrated pathway to colorectal carcinoma: current concepts and challenges. Histopathology. 2013;62:367–86, http://dx.doi.org/10.1111/his.12055.
14. Langner C. Serrated and non-serrated precursor lesions of colorectal cancer. Dig Dis. 2015;33:28–37, http://dx.doi.org/10.1159/000366032.
15. Snover DC, Ahnen D, Burt R, et al. Serrated polyps of the colon and rectum and serrated polyposis syndrome. WHO classification of tumours of the digestive system. Lyon. 2010:160–5.
16. Torlakovic E, Skovlund E, Snover DC, et al. Morphologic reappraisal of serrated colorectal polyps. Am J Surg Pathol. 2003;27:65–81, http://dx.doi.org/10.1097/00000478-200301000-00008.
17. Spring KJ, Zhao ZZ, Karamatic R, et al. High prevalence of sessile serrated adenomas with BRAF mutations: a prospective study of patients undergoing colonoscopy. Gastroenterology. 2006;131:1400–7, http://dx.doi.org/10.1053/j.gastro.2006.08.038.
18. Hazewinkel Y, de Wijkerslooth TR, Stoop EM, et al. Prevalence of serrated polyps and association with synchronous advanced neoplasia in screening colonoscopy. Endoscopy. 2014;46:219–24, http://dx.doi.org/10.1055/s-0033-1358800.
19. Teriaky A, Driman DK, Chande N. Outcomes of a 5-year follow-up of patients with sessile serrated adenomas. Scand J Gastroenterol. 2012;47:178–83, http://dx.doi.org/10.3109/00365521.2011.645499.
20. Singh R, Zorrón-Cheng Tao Pu L, Koay D, et al. Sessile serrated adenoma/polyps: Where are we at in 2016? World J Gastroenterol. 2016;22:7754–9, http://dx.doi.org/10.3748/wjg.v22.i34.7754.
21. Hazewinkel Y, López-Cerón M, East JE, et al. Endoscopic features of sessile serrated adenomas: validation by international experts using high-resolution white-light endoscopy and narrow-band imaging. Gastrointest Endosc. 2013;77:916–24, http://dx.doi.org/10.1016/j.gie.2012.12.018.
22. Nakao Y, Saito S, Ohya T, et al. Endoscopic features of colorectal serrated lesions using image-enhanced endoscopy with pathological analysis. Eur J Gastroenterol Hepatol. 2013;25:981–8, http://dx.doi.org/10.1097/MEG.0b013e3283614b2b.
23. Torlakovic EE, Gómez JD, Driman DK, et al. Sessile serrated adenoma (SSA) vs. traditional serrated adenoma (TSA). Am J Surg Pathol. 2008;32:21–9, http://dx.doi.org/10.1097/PAS.0b013e318157f002.
24. O'Brien MJ, Yang S, Mack C, et al. Comparison of microsatellite instability, CpG island methylation phenotype, BRAF and KRAS status in serrated polyps and traditional adenomas indicates separate pathways to distinct colorectal carcinoma end points. Am J Surg Pathol. 2006;30:1491–501, http://dx.doi.org/10.1097/01.pas.0000213313.36306.85.
25. Beggs AD, Jones A, Shepherd N, et al. Loss of expression and promoter methylation of SLIT2 are associated with sessile serrated adenoma formation. PLoS Genet. 2013;9:e1003488, http://dx.doi.org/10.1371/journal.pgen.1003488.
26. Jass JR. Classification of colorectal cancer based on correlation of clinical, morphological and molecular features. Histopathology. 2007;50:113–30, http://dx.doi.org/10.1111/j.1365-2559.2006.02549.x.
27. Yachida S, Mudali S, Martin SA, et al. Beta-catenin nuclear labeling is a common feature of sessile serrated adenomas and correlates with early neoplastic progression after BRAF activation. Am J Surg Pathol. 2009;33:1823–32, http://dx.doi.org/10.1097/PAS.0b013e3181b6da19.
28. Abdeljawad K, Vemulapalli KC, Kahi CJ, et al. Sessile serrated polyp prevalence determined by a colonoscopist with a high lesion detection rate and an experienced pathologist. Gastrointest Endosc. 2015;81:517–24, http://dx.doi.org/10.1016/j.gie.2014.04.064.
29. Sano W, Sano Y, Iwatate M, et al. Prospective evaluation of the proportion of sessile serrated adenoma/polyps in endoscopically diagnosed colorectal polyps with hyperplastic features. Endosc Int Open. 2015;3:E354–8, http://dx.doi.org/10.1055/s-0034-1391948.
30. Chino A, Osumi H, Kishihara T, et al. Advantages of magnifying narrow-band imaging for diagnosing colorectal cancer coexisting with sessile serrated adenoma/polyp. Dig Endosc. 2016;28:53–9, http://dx.doi.org/10.1111/den.12631.
31. Rex DK, Clodfelter R, Rahmani F, et al. Narrow-band imaging versus white light for the detection of proximal colon serrated lesions: a randomized, controlled trial. Gastrointest Endosc. 2016;83:166–71, http://dx.doi.org/10.1016/j.gie.2015.03.1915.
32. Burgess NG, Pellise M, Nanda KS, et al. Clinical and endoscopic predictors of cytological dysplasia or cancer in a prospective multicentre study of large sessile serrated adenomas/polyps. Gut. 2016;65:437–46, http://dx.doi.org/10.1136/gutjnl-2014-308603.
33. Farrar WD, Sawhney MS, Nelson DB, et al. Colorectal cancers found after a complete colonoscopy. Clin Gastroenterol Hepatol. 2006;4:1259–64, http://dx.doi.org/10.1016/j.cgh.2006.07.012.
34. Bressler B, Paszat LF, Chen Z, et al. Rates of new or missed colorectal cancers after colonoscopy and their risk factors: a population-based analysis. Gastroenterology. 2007;132:96–102, http://dx.doi.org/10.1053/j.gastro.2006.10.027.
35. Arain MA, Sawhney M, Sheikh S, et al. CIMP status of interval colon cancers: another piece to the puzzle. Am J Gastroenterol. 2010;105:1189–95, http://dx.doi.org/10.1038/ajg.2009.699.
36. Sawhney MS, Farrar WD, Gudiseva S, et al. Microsatellite instability in interval colon cancers. Gastroenterology. 2006;131:1700–5, http://dx.doi.org/10.1053/j.gastro.2006.10.022.
37. Song SY, Kim YH, Yu MK, et al. Comparison of malignant potential between serrated adenomas and traditional adenomas. J Gastroenterol Hepatol. 2007;22:1786–90, http://dx.doi.org/10.1111/j.1440-1746.2006.04356.x].
38. Lash R, Schuler C, Genta R. Demographic and pathologic evaluation of 2139 patients with sessile serrated adenomas in a one-year period. Am J Gastroenterol. 2008;103:S191.
39. Lazarus R, Junttila OE, Karttunen TJ, et al. The risk of metachronous neoplasia in patients with serrated adenoma. Am J Clin Pathol. 2005;123:349–59, http://dx.doi.org/10.1309/VBAG-V3BR-96N2-EQTR.
40. Oono Y, Fu K, Nakamura H, et al. Progression of a sessile serrated adenoma to an early invasive cancer within 8 months. Dig Dis Sci. 2009;54:906–9, http://dx.doi.org/10.1007/s10620-008-0407-7.
41. Goldstein NS, Bhanot P, Odish E, et al. Hyperplastic-like colon polyps that preceded microsatellite-unstable adenocarcinomas. Am J Clin Pathol. 2003;119:778–96, http://dx.doi.org/10.1309/DRFQ-0WFU-F1G1-3CTK.
42. Salaria SN, Streppel MM, Lee LA, et al. Sessile serrated adenomas: high-risk lesions? Hum Pathol. 2012;43:1808–14, http://dx.doi.org/10.1016/j.humpath.2012.04.001.
43. Lu FI, van Niekerk DW, Owen D, et al. Longitudinal outcome study of sessile serrated adenomas of the colorectum: an increased risk for subsequent right-sided colorectal carcinoma. Am J Surg Pathol. 2010;34:927–34, http://dx.doi.org/10.1097/PAS.0b013e3181e4f256.
44. Li D, Jin C, McCulloch C, et al. Association of large serrated polyps with synchronous advanced colorectal neoplasia. Am J Gastroenterol. 2009;104:695–702, http://dx.doi.org/10.1038/ajg.2008.166.
45. Pai RK, Hart J, Noffsinger AE. Sessile serrated adenomas strongly predispose to synchronous serrated polyps

in non-syndromic patients. Histopathology. 2010;56:581–8, http://dx.doi.org/10.1111/j.1365-2559.2010.03520.x.
46. Wallace K, Grau MV, Ahnen D, et al. The association of lifestyle and dietary factors with the risk for serrated polyps of the colorectum. Cancer Epidemiol Biomarkers Prev. 2009;18:2310–7, http://dx.doi.org/10.1158/1055-9965.EPI-09-0211.
47. Schreiner MA, Weiss DG, Lieberman DA. Proximal and large hyperplastic and nondysplastic serrated polyps detected by colonoscopy are associated with neoplasia. Gastroenterology. 2010;139:1497–502, http://dx.doi.org/10.1053/j.gastro.2010.06.074.
48. Lieberman DA, Prindiville S, Weiss DG, et al. Risk factors for advanced colonic neoplasia and hyperplastic polyps in asymptomatic individuals. JAMA. 2003;290:2959–67, http://dx.doi.org/10.1001/jama.290.22.2959.
49. Kalady MF, Jarrar A, Leach B, et al. Defining phenotypes and cancer risk in hyperplastic polyposis syndrome. Dis Colon Rectum. 2011;54:164–70, http://dx.doi.org/10.1007/DCR.0b013e3181fd4c15.
50. Kahi CJ, Li X, Eckert GJ, et al. High colonoscopic prevalence of proximal colon serrated polyps in average-risk men and women. Gastrointest Endosc. 2012;75:515–20, http://dx.doi.org/10.1016/j.gie.2011.08.021.
51. Moreira L, Pellise M, Carballal S, et al. High prevalence of serrated polyposis syndrome in FIT-based colorectal cancer screening programmes. Gut. 2013;62:476–7, http://dx.doi.org/10.1136/gutjnl-2012-303496.
52. Biswas S, Ellis AJ, Guy R, et al. High prevalence of hyperplastic polyposis syndrome (serrated polyposis) in the NHS bowel cancer screening programme. Gut. 2013;62:475, http://dx.doi.org/10.1136/gutjnl-2012-303233.
53. Carballal S, Rodríguez-Alcalde D, Moreira L, et al. Colorectal cancer risk factors in patients with serrated polyposis syndrome: a large multicentre study. Gut. 2016;65:1829–37, http://dx.doi.org/10.1136/gutjnl-2015-309647.
54. Lage P, Cravo M, Sousa R, et al. Management of Portuguese patients with hyperplastic polyposis and screening of at-risk first-degree relatives: a contribution for future guidelines based on a clinical study. Am J Gastroenterol. 2004;99:1779–84, http://dx.doi.org/10.1111/j.1572-0241.2004.30178.x.
55. Leggett BA, Devereaux B, Biden K, et al. Hyperplastic polyposis: association with colorectal cancer. Am J Surg Pathol. 2001;25:177–84, http://dx.doi.org/10.1097/00000478-200102000-00005.
56. Edelstein DL, Axilbund JE, Hylind LM, et al. Serrated polyposis: rapid and relentless development of colorectal neoplasia. Gut. 2013;62:404–8, http://dx.doi.org/10.1136/gutjnl-2011-300514.
57. Carballal S, Liz Leoz M, Moreira L, et al. Hereditary colorectal cancer syndromes. Colorectal Cancer. 2014;3:1–20, http://dx.doi.org/10.2217/crc.13.80.
58. East JE, Saunders BP, Jass JR. Sporadic and syndromic hyperplastic polyps and serrated adenomas of the colon: classification, molecular genetics, natural history, and clinical management. Gastroenterol Clin North Am. 2008;37:25–46, http://dx.doi.org/10.1016/j.gtc.2007.12.014.
59. Fu X, Qiu Y, Zhang Y. Screening, management and surveillance for the sessile serrated adenomas/polyps. Int J Clin Exp Pathol. 2014;7:1275–85.
60. East JE, Atkin WS, Bateman AC, et al. British Society of Gastroenterology position statement on serrated polyps in the colon and rectum. Gut. 2017;66:1181–96, http://dx.doi.org/10.1136/gutjnl-2017-314005.
61. Jaramillo E, Tamura S, Mitomi H. Endoscopic appearance of serrated adenomas in the colon. Endoscopy. 2005;37:254–60, http://dx.doi.org/10.1055/s-2005-861007.
62. Kiesslich R, von Bergh M, Hahn M, et al. Chromoendoscopy with indigocarmine improves the detection of adenomatous and non-adenomatous lesions in the colon. Endoscopy. 2001;33:1001–6, http://dx.doi.org/10.1055/s-2001-18932.
63. Lapalus MG, Helbert T, Napoleon B, et al. Does chromoendoscopy with structure enhancement improve the colonoscopic adenoma detection rate? Endoscopy. 2006;38:444–8, http://dx.doi.org/10.1055/s-2006-925265.
64. East JE, Stavrindis M, Thomas-Gibson S, et al. A comparative study of standard vs. high definition colonoscopy for adenoma and hyperplastic polyp detection with optimized withdrawal technique. Aliment Pharmacol Ther. 2008;28:768–76, http://dx.doi.org/10.1111/j.1365-2036.2008.03789.x.
65. Subramanian V, Mannath J, Hawkey CJ, et al. High definition colonoscopy vs. standard video endoscopy for the detection of colonic polyps: a meta-analysis. Endoscopy. 2011;43:499–505, http://dx.doi.org/10.1055/s-0030-1256207.
66. Suzuki Y, Ohata K, Matsuhashi N. Delineating sessile serrated adenomas/polyps with acetic acid spray for a more accurate piecemeal cold snare polypectomy. VideoGIE. 2020;5:519–21, http://dx.doi.org/10.1016/j.vgie.2020.05.030.
67. Yamamoto S, Shafazand M. Acetic acid-indigocarmine mixture for evaluating the margins of sessile serrated adenomas/polyps. Dig Endosc. 2017;29:817–8, http://dx.doi.org/10.1111/den.12947.
68. Ket SN, Bird-Lieberman E, East JE. Electronic imaging to enhance lesion detection at colonoscopy. Gastrointest Endosc Clin N Am. 2015;25:227–42, http://dx.doi.org/10.1016/j.giec.2014.11.011.
69. Aminalai A, Rosch T, Aschenbeck J, et al. Live image processing does not increase adenoma detection rate during colonoscopy: a randomized comparison between FICE and conventional imaging (Berlin Colonoscopy Project 5, BECOP-5). Am J Gastroenterol. 2010;105:2383–8, http://dx.doi.org/10.1038/ajg.2010.273.
70. Yoshida N, Hisabe T, Ikematsu H, et al. Comparison between linked color imaging and blue laser imaging for improving the visibility of flat colorectal polyps: a multicenter pilot study. Dig Dis Sci. 2020;65:2054–62, http://dx.doi.org/10.1007/s10620-019-05930-x.
71. Hong SN, Choe WH, Lee JH, et al. Prospective, randomized, back-to-back trial evaluating the usefulness of i-SCAN in screening colonoscopy. Gastrointest Endosc. 2012;75:1011–21, http://dx.doi.org/10.1016/j.gie.2011.11.040, e1012.
72. Kidambi TD, Terdiman JP, El-Nachef N, et al. Effect of I-scan electronic chromoendoscopy on detection of adenomas during colonoscopy. Clin Gastroenterol Hepatol. 2019;17:701–8, http://dx.doi.org/10.1016/j.cgh.2018.06.024, e701.
73. de Wijkerslooth TR, Stoop EM, Bossuyt PM, et al. Differences in proximal serrated polyp detection among endoscopists are associated with variability in withdrawal time. Gastrointest Endosc. 2013;77:617–23, http://dx.doi.org/10.1016/j.gie.2012.10.018.
74. Butterly L, Robinson CM, Anderson JC, et al. Serrated and adenomatous polyp detection increases with longer withdrawal time: results from the New Hampshire Colonoscopy Registry. Am J Gastroenterol. 2014;109:417–26, http://dx.doi.org/10.1038/ajg.2013.442.
75. Chandran S, Parker F, Vaughan R, et al. Right-sided adenoma detection with retroflexion versus forward-view colonoscopy. Gastrointest Endosc. 2015;81:608–13, http://dx.doi.org/10.1016/j.gie.2014.08.039.
76. Anderson JC, Butterly LF, Robinson CM, et al. Impact of fair bowel preparation quality on adenoma and serrated polyp detection: data from the New Hampshire colonoscopy registry by using a standardized preparation-quality rating. Gastrointest Endosc. 2014;80:463–70, http://dx.doi.org/10.1016/j.gie.2014.03.021.

77. Crockett SD, Gourevitch RA, Morris M, et al. Endoscopist factors that influence serrated polyp detection: a multicenter study. Endoscopy. 2018;50:984–92, http://dx.doi.org/10.1055/a-0597-1740.
78. Murakami T, Sakamoto N, Nagahara A. Endoscopic diagnosis of sessile serrated adenoma/polyp with and without dysplasia/carcinoma. World J Gastroenterol. 2018;24:3250–9, http://dx.doi.org/10.3748/wjg.v24.i29.3250.
79. Murakami T, Sakamoto N, Nagahara A. Clinicopathological features, diagnosis, and treatment of sessile serrated adenoma/polyp with dysplasia/carcinoma. J Gastroenterol Hepatol. 2019;34:1685–95, http://dx.doi.org/10.1111/jgh.14752.
80. Hoerter N, Gross SA, Liang PS. Artificial intelligence and polyp detection. Curr Treat Options Gastroenterol. 2020, http://dx.doi.org/10.1007/s11938-020-00274-2.
81. Vinsard DG, Mori Y, Misawa M, et al. Quality assurance of computer-aided detection and diagnosis in colonoscopy. Gastrointest Endosc. 2019;90:55–63, http://dx.doi.org/10.1016/j.gie.2019.03.019.
82. Li T, Glissen Brown JR, Tsourides K, et al. Training a computer-aided polyp detection system to detect sessile serrated adenomas using public domain colonoscopy videos. Endosc Int Open. 2020;8:E1448–54, http://dx.doi.org/10.1055/a-1229-3927.
83. Deenadayalu VP, Rex DK. Colon polyp retrieval after cold snaring. Gastrointest Endosc. 2005;62:253–6, http://dx.doi.org/10.1016/s0016-5107(05)00376-7.
84. Tappero G, Gaia E, De Giuli P, et al. Cold snare excision of small colorectal polyps. Gastrointest Endosc. 1992;38:310–3, http://dx.doi.org/10.1016/s0016-5107(92)70422-2.
85. Soetikno RM, Gotoda T, Nakanishi Y, et al. Endoscopic mucosal resection. Gastrointest Endosc. 2003;57:567–79, http://dx.doi.org/10.1067/mge.2003.130.
86. Kudo S, Tamegai Y, Yamano H, et al. Endoscopic mucosal resection of the colon: the Japanese technique. Gastrointest Endosc Clin N Am. 2001;11:519–35.
87. Pattullo V, Bourke MJ, Tran KL, et al. The suction pseudopolyp technique: a novel method for the removal of small flat nonpolypoid lesions of the colon and rectum. Endoscopy. 2009;41:1032–7, http://dx.doi.org/10.1055/s-0029-1215294.
88. Rutter MD, Nickerson C, Rees CJ, et al. Risk factors for adverse events related to polypectomy in the English Bowel Cancer Screening Programme. Endoscopy. 2014;46:90–7, http://dx.doi.org/10.1055/s-0033-1344987.
89. Pohl H, Srivastava A, Bensen SP, et al. Incomplete polyp resection during colonoscopy-results of the complete adenoma resection (CARE) study. Gastroenterology. 2013;144:74–80, http://dx.doi.org/10.1053/j.gastro.2012.09.043, e71.
90. Rutter MD, Chattree A, Barbour JA, et al. British Society of Gastroenterology/Association of Coloproctologists of Great Britain and Ireland guidelines for the management of large non-pedunculated colorectal polyps. Gut. 2015;64:1847–73, http://dx.doi.org/10.1136/gutjnl-2015-309576.
91. Knabe M, Pohl J, Gerges C, et al. Standardized long-term follow-up after endoscopic resection of large, nonpedunculated colorectal lesions: a prospective two-center study. Am J Gastroenterol. 2014;109:183–9, http://dx.doi.org/10.1038/ajg.2013.419.
92. Erichsen R, Baron JA, Hamilton-Dutoit SJ, et al. Increased risk of colorectal cancer development among patients with serrated polyps. Gastroenterology. 2016;150:895–902, http://dx.doi.org/10.1053/j.gastro.2015.11.046, e895.
93. Lieberman DA, Rex DK, Winawer SJ, et al. Guidelines for colonoscopy surveillance after screening and polypectomy: a consensus update by the US Multi-Society Task Force on Colorectal Cancer. Gastroenterology. 2012;143:844–57, http://dx.doi.org/10.1053/j.gastro.2012.06.001.
94. Hassan C, Quintero E, Dumonceau JM, et al. Post-polypectomy colonoscopy surveillance: European Society of Gastrointestinal Endoscopy (ESGE) Guideline. Endoscopy. 2013;45:842–51, http://dx.doi.org/10.1055/s-0033-1344548.
95. Geramizadeh B, Robertson S. Serrated polyps of colon and rectum: a clinicopathologic review. J Gastrointest Cancer. 2017;48:291–8, http://dx.doi.org/10.1007/s12029-017-9977-y.
96. McCarthy AJ, Serra S, Chetty R. Traditional serrated adenoma: an overview of pathology and emphasis on molecular pathogenesis. BMJ Open Gastroenterol. 2019;6:e000317, http://dx.doi.org/10.1136/bmjgast-2019-000317.
97. Dekker E, Bleijenberg A, Balaguer F. Update on the World Health Organization Criteria for Diagnosis of Serrated Polyposis Syndrome. Gastroenterology. 2020;158:1520–3.