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REVIEW ARTICLE

Endoscopic Characterization and Management of Colorectal Polyps

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ABSTRACT

Colorectal polyps are among the most frequently detected lesions during colonoscopy and represent a heterogeneous group with diverse histopathological characteristics and malignant potential. Their accurate detection and management are fundamental to effective colorectal cancer prevention. Recent advances in endoscopic imaging, including high-definition white-light and narrow-band imaging (NBI), have improved optical diagnosis, enabling endoscopists to predict histopathology, identify advanced neoplasia, and estimate submucosal invasion risk to facilitate therapeutic decision-making. This narrative review bridges validated optical classification systems with risk-based therapeutic selection, providing an integrated perspective on endoscopic diagnosis and management. We conducted a narrative literature review using MEDLINE/PubMed, Embase, and the Cochrane Library to synthesize evidence on colorectal polyp detection, optical classification, AI-assisted diagnosis, and endoscopic resection strategies. This review examines key frameworks, including NICE, WASP, and JNET, alongside morphological criteria that guide selection of cold or hot snare polypectomy, endoscopic mucosal resection (EMR), and endoscopic submucosal dissection (ESD). Optical diagnosis complements, rather than replaces, formal histopathology and requires validated training and high diagnostic confidence.

Keywords. Colorectal cancer prevention; Colorectal polyps; Colonoscopy; Endoscopic imaging; Endoscopic resection; Narrow-band imaging (NBI); Optical diagnosis.

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INTRODUCTION

Serous tumors constitute a major category of epithelial ovarian neoplasia and encompass lesions with markedly different morphological, molecular, and clinical characteristics.[1] Serous borderline tumors, low-grade serous carcinoma (LGSC), and high-grade serous carcinoma (HGSC) may all involve extraovarian sites, particularly the peritoneum and omentum, but they represent biologically distinct disease processes. Accurate characterization of peritoneal lesions is therefore important for both pathological classification and assessment of disease behavior. Colorectal polyps and mucosal lesions comprise a heterogeneous group of abnormalities that vary in morphology, histological type, and malignant potential. They may be polypoid, non-polypoid, or depressed. By size, colorectal polyps are classified as diminutive (≤5 mm), small (6–9 mm), or large (≥10 mm).[1] Morphologically, polypoid lesions may be pedunculated, with a fibrovascular stalk, or sessile, with a broad mucosal attachment. Histologically, colorectal lesions include non-neoplastic lesions and neoplastic precursor lesions. According to the World Health Organization (WHO) classification, conventional adenomas are categorized as tubular, tubulovillous, or villous adenomas. Serrated lesions include hyperplastic polyps, sessile serrated lesions (SSLs), and traditional serrated adenomas (TSAs).[2] The term "sessile serrated lesion" is preferred over "sessile serrated adenoma/polyp" because these lesions may lack a polypoid appearance and do not necessarily exhibit conventional adenomatous dysplasia. Beyond the conventional adenoma–carcinoma sequence, the serrated neoplasia pathway represents a major mechanism of colorectal carcinogenesis and is estimated to account for approximately 15–30% of colorectal cancers.[1]

Advances in endoscopic imaging and optical diagnosis have improved endoscopists' ability to characterize colorectal polyps in real time. Integrating lesion size, morphology, and surface and vascular patterns enables prediction of histology, assessment of submucosal invasion risk and depth, and selection of an appropriate therapeutic strategy.[3] Understanding the histological subtypes and endoscopic characteristics of colorectal polyps is fundamental to accurate diagnosis, appropriate management, and effective colorectal cancer prevention.

REVIEW

This article is an expert narrative review of the endoscopic diagnosis and management of colorectal polyps. We searched MEDLINE/PubMed, Embase, and the Cochrane Library between May 2025 and July 2026 and limited results to English-language publications. We placed particular emphasis on literature published in

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the preceding 5–10 years, while considering earlier publications when clinically relevant or foundational. The search strategy covered colorectal polyp histology, classification, optical diagnosis, artificial intelligence (AI)-assisted detection and characterization, endoscopic resection, and post-resection surveillance. Boolean operators (AND and OR) were used to combine related search terms. We identified additional publications through reference-list screening.
We selected publications based on their relevance to the review objectives and clinical significance. We prioritized clinical practice guidelines, systematic reviews and meta-analyses, diagnostic-accuracy studies, randomized controlled trials, major observational studies, and relevant narrative reviews. Both authors participated in publication selection and resolved disagreements by consensus. Approximately 50 publications were reviewed. This was not a systematic or scoping review. We did not perform a formal risk-of-bias assessment, structured evidence-certainty grading, or quantitative synthesis. The authors synthesized findings narratively, considering study design, clinical relevance, and applicability to current practice. We considered potential overlap between guidelines, systematic reviews, and primary studies when interpreting the evidence, and acknowledged areas of uncertainty.

Types of colorectal polyps

Accurate endoscopic characterization of colorectal polyps requires an understanding of their underlying histological subtypes. Colorectal polyps are broadly classified into non-neoplastic and neoplastic lesions, each with distinct endoscopic features, biological behavior, and malignant potential.

Hyperplastic polyps

Hyperplastic polyps are the most common non-neoplastic epithelial lesions of the colorectum. They are typically small (≤5 mm), sessile lesions located predominantly in the rectosigmoid colon. Histologically, they are characterized by epithelial hyperplasia without cytological dysplasia and are generally considered to have negligible malignant potential.[4] Endoscopically, hyperplastic polyps typically appear as small, pale, smooth, sessile lesions and are most commonly identified in the distal colon. Although conventional hyperplastic polyps have little or no malignant potential, accurate differentiation from sessile serrated lesions is essential because of their distinct biological behavior and increased risk of colorectal carcinogenesis.[5]

Sessile serrated lesion

Sessile serrated lesions (SSLs) may resemble hyperplastic polyps endoscopically but have distinct histological architectural distortion of the basal crypts. The World Health Organization (WHO) recommends the term sessile serrated lesion (SSL) over alternative terms such as sessile serrated adenoma and sessile serrated adenoma/lesion. Although SSLs may resemble hyperplastic polyps on conventional white-light endoscopy, they exhibit characteristic histological abnormalities, including distorted and dilated crypts with abnormal basal architecture. SSLs account for up to 8% of colorectal polyps detected during screening colonoscopy and are predominantly located in the proximal colon.[6] Once considered innocuous, SSLs are now recognized as important precursors of colorectal cancer through the serrated neoplasia pathway, which accounts for approximately 15–30% of sporadic colorectal cancers.[7] Endoscopic features suggestive of SSL include pale color, a mucus cap, indistinct borders, a cloud-like or nodular surface, dilated or dark crypt openings, and irregular shape.[8]

Adenomatous polyps

Adenomatous polyps are the most common neoplastic lesions of the colorectum and the principal precursors in the conventional adenoma–carcinoma sequence. Histologically, they are classified as tubular, tubulovillous, or villous adenomas according to the proportion of villous architecture.[9]

Tubular adenomas are the most common subtype, accounting for approximately 65–80% of adenomatous polyps. They may be sessile or pedunculated and generally show less cytological atypia. Villous adenomas have long, finger-like projections and account for about 5–10% of adenomatous polyps. They are more frequently sessile and associated with higher risks of high-grade dysplasia and malignant transformation. Tubulovillous adenomas combine tubular and villous architectural features and account for about 10–25% of adenomatous polyps.[3]

Conventional adenomas develop through the chromosomal instability pathway, involving sequential alterations in APC, KRAS, and TP53. Loss of APC function activates the Wnt signaling pathway and initiates adenoma formation, whereas subsequent KRAS and TP53 mutations promote progression toward colorectal carcinoma.[10] Endoscopically, adenomatous polyps may be pedunculated or sessile and typically have a granular or lobulated surface. Larger lesions may show features of advanced neoplasia, including surface irregularity, ulceration, or depression. Careful endoscopic assessment is essential for predicting histology, estimating submucosal invasion risk, and selecting appropriate therapy.[11]

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Polyp detection and morphologic characterization

Accurate endoscopic assessment of colorectal polyps begins with lesion detection and systematic morphological characterization. Lesion size, location, morphology, and surface characteristics provide the initial information required for subsequent optical diagnosis and assessment of malignant potential.[3,12]

Polyp detection quality depends on adequate bowel preparation, systematic mucosal inspection, and careful examination during colonoscope withdrawal. Document bowel preparation quality using a validated scale, such as the Boston Bowel Preparation Scale (BBPS), one of the most extensively validated instruments. Withdrawal time is also an important quality indicator: ESGE recommendations identify a mean withdrawal time of at least 6 minutes as the minimum standard and 10 minutes as the target for negative screening or diagnostic colonoscopies without biopsy or therapeutic intervention. However, withdrawal technique and the completeness of mucosal inspection also determine detection performance.[13]

Paris classification

The Paris classification is the most widely used international system for describing the endoscopic morphology of superficial colorectal lesions. It provides standardized nomenclature for predicting malignant potential, estimating submucosal invasion risk, and selecting the appropriate endoscopic resection technique.[11]

Type 0 lesions are classified as polypoid (type 0-I) or non-polypoid (type 0-II), whereas excavated lesions (type 0-III) are rare in the colorectum. Polypoid lesions are further classified as pedunculated (type 0-Ip) or sessile (type 0-Is), while non-polypoid lesions are subdivided into slightly elevated (type 0-IIa), flat (type 0-IIb), and slightly depressed (type 0-IIc). Depressed (type 0-IIc) lesions account for approximately 1–6% of non-polypoid lesions but are associated with a high risk of deep submucosal invasion, with reported rates of 27–35.9%; estimates vary according to lesion size, study population, and clinical setting.[14]

Optical diagnosis

Optical diagnosis using image-enhanced endoscopy provides additional information on the vascular and surface characteristics of colorectal lesions, complementing conventional morphological assessment. Several classification systems have been developed to standardize optical characterization and improve real-time prediction of histology and invasive cancer risk, including the NICE, WASP, and JNET classifications.[15-18]

WASP classification

Endoscopic detection and differentiation of sessile serrated lesions (SSLs) from other benign colorectal polyps remain challenging because of their subtle appearance. Indistinct borders may result in incomplete resection, increasing the risk of interval and synchronous colorectal cancer. Accurate recognition of SSL features is therefore essential to improve detection, guide treatment, and reduce colorectal cancer risk.[15]

The Workgroup serrated polyps and Polyposis (WASP) classification was developed as a stepwise approach incorporating the NBI International Colorectal Endoscopic (NICE) classification and specific SSL features. It was designed to differentiate adenomas, hyperplastic polyps, and SSLs. Four characteristic features suggestive of SSLs are assessed: (i) cloud-like surface, (ii) indistinct borders, (iii) irregular shape, and (iv) dark spots inside crypts (**Tab.1**).[16]

TABLE 1. Typical endoscopic features of hyperplastic polyps and sessile serrated lesions[16]

	HP	SSL
Location	Distal Colon	Proximal Colon
Size	Usually <5mm	Often >10mm
Morphology	Flat or slightly elevated, oval or round	Flat- elevated or sessile irregular
Border	Well-defined	Indistinct
Surface	Smooth	Cloud-Like

In clinical practice, clinicians apply the WASP classification stepwise after the initial NICE assessment. At least two of the four characteristic features support an optical diagnosis of SSL. However, diagnostic confidence and accuracy depend on appropriate training and lesion assessment, and the absence of these features does not exclude an SSL. Additional endoscopic characteristics, including proximal location, size greater than 5 mm, and flat morphology, should also be considered.[15,16] Recent evidence has highlighted limitations of the WASP classification. A 2024 cross-sectional study reported 38.8% sensitivity, 97.8% specificity, and 94.0% overall accuracy for SSL diagnosis. Notably, 61.2% of histopathologically confirmed SSLs did not fulfill WASP criteria, and 41.3% showed none of its four characteristic features. The authors therefore emphasized considering additional endoscopic features alongside WASP to maximize diagnostic sensitivity.

NICE classification

The NBI International Colorectal Endoscopic (NICE) classification is a simple, standardized system for optically characterizing colorectal lesions using narrow-band imaging (NBI). It is based on three principal endoscopic features—lesion color, vascular pattern, and surface pattern—and was designed to differentiate hyperplastic from adenomatous polyps. The NICE

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classification can be applied with NBI, with or without magnification, and does not require dye-based chromoendoscopy. Type 1 lesions have a color similar to or lighter than the surrounding mucosa, absent or lacy vessels, and a regular surface pattern. In contrast, Type 2 lesions are typically browner, with brown vessels surrounding white surface structures and a more adenomatous surface pattern. The classification was subsequently expanded to include Type 3 lesions, characterized by markedly distorted or absent vessels and an amorphous or absent surface pattern, suggestive of deep submucosal invasive carcinoma. The NICE classification has limitations in distinguishing the full spectrum of histological subtypes within Type 2 lesions and should not be considered a definitive predictor of invasion depth in every case. Reliable optical diagnosis depends on appropriate training and operator experience, and diagnostic confidence should be considered when interpreting NICE findings.[17,18]

Japan Narrow Band Imaging Expert Team (JNET) classification

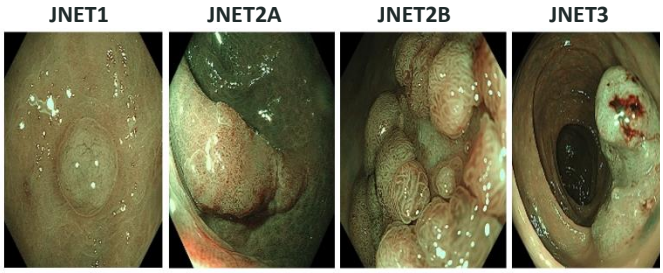
The Japan Narrow-Band Imaging Expert Team (JNET) classification was developed to provide detailed optical characterization of colorectal neoplasia using magnifying narrow-band imaging (NBI). Unlike the three-category NICE classification, JNET subdivides neoplastic lesions into Types 2A and 2B, enabling more detailed stratification according to vascular and surface patterns. The JNET classification categorizes colorectal lesions into four types (**Tab.2**). Type 1 corresponds to hyperplastic polyps and sessile serrated lesions, Type 2A to low-grade intramucosal neoplasia, Type 2B to high-grade intramucosal neoplasia or superficial submucosal invasive cancer, and Type 3 to deep submucosal invasive cancer.[19] JNET Type 2B remains the most challenging category because magnifying NBI alone may not reliably predict invasion depth; additional pit-pattern analysis may improve diagnostic accuracy.[20,21]

When JNET Type 2B lesions are encountered, additional assessment using the Kudo pit-pattern classification may help refine the diagnosis and guide treatment selection. An irregular pit pattern characterizes Kudo Type VI and may be associated with high-grade neoplasia or submucosal invasion. In contrast, Type VN has a non-structured or amorphous surface pattern with markedly reduced or absent pits and strongly suggests deep submucosal invasion. This distinction is clinically important because optical prediction of histology and assessment of invasion depth are related but distinct diagnostic objectives.[20-22] A subsequent meta-analysis demonstrated high diagnostic performance of JNET for optical characterization of colorectal lesions, comparable to pit pattern classification for predicting histology and guiding treatment decisions (**Fig.1**). JNET has therefore become an important tool for colorectal lesion classification and treatment planning.[22]

TABLE 2. JNET diagnostic criteria and predicted histology

	Type 1	Type 2A	Type 2B	Type 3
Vessel Pattern	Invisible	Regular Caliber; Regular Distribution (meshed/Spiral pattern)	Variable Caliber; Irregular Distribution	Loose vessel areas; Interruption of thick vessel
Surface Pattern	Regular dark or white spots; Similar to surrounding normal mucosa	Regular (tubular/ branched/papillary	Irregular or Obscure	Amorphous areas
Most Likely Histology	Hyperplastic polyp/Sessile serrated lesion	Low Grade intramucosal neoplasia	High-grade intramucosal neoplasia or superficial submucosal invasive cancer	Deep Submucosal invasive cancer

FIGURE 1. Representative endoscopic images of colorectal lesions according to the Japan NBI Expert Team (JNET) classification (Types 1, 2A, 2B, and 3).



Limitations and external validity of optical diagnosis

Although image-enhanced endoscopy can provide useful information for the optical characterization of colorectal lesions, its application requires appropriate training and expertise. ESGE recommends performing real-time optical diagnosis under strictly controlled conditions using validated diagnostic scales, with adequate photodocumentation, by experienced and adequately trained endoscopists, and with ongoing audit. In addition, high-definition white-light endoscopy combined with chromoendoscopy is recommended to predict the presence and depth of submucosal invasion before treatment. Therefore, optical diagnosis should be used to predict histology and estimate invasion risk rather than as a universal substitute for histopathological assessment.[23]

Lateral spreading tumor (LST)

Lateral spreading tumor (LST) refers to flat colorectal lesions larger than 10 mm that grow laterally along the

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colonic wall. LSTs are classified into granular (LST-G) and nongranular (LST-NG) types. LST-G can be further classified as homogeneous type (Paris classification 0-IIa), characterized by a granular and homogeneous surface, or mixed-nodular type (Paris classification 0-IIa + Is), characterized by one or more sessile nodules. LST-NG can be classified as flat-elevated type (Paris classification 0-IIa) or pseudodepressed type (Paris classification 0-IIa + IIc).[24]

Clinically, LST-NG lesions tend to have a higher risk of advanced neoplasia and submucosal invasion, particularly the pseudodepressed subtype, with a pooled rate of submucosal invasion of 31.6% (95% CI, 19.8%–43.4%). In contrast, submucosal invasion is uncommon in LST-G homogeneous lesions, with a pooled rate of 0.5% (95% CI, 0.1%–1.0%), irrespective of lesion size (**Tab.3**).[25]

TABLE 3. Subtypes of LST and risk of submucosal invasion

LST category	LST subtype	Risk of submucosal invasion, %
Granular (LST-G)	Homogeneous (LST-G-H)	0.5%
Granular (LST-G)	Nodular mixed (LST-G-NM)	10.5%
Non-granular (LST-NG)	Flat elevated (LST-NG-FE)	4.9%
Non-granular (LST-NG)	Pseudodepressed (LST-NG-PD)	31.6%

Assessment of invasive cancer risk

Assessment of submucosal invasion depth is essential for determining the malignant potential of colorectal lesions and selecting appropriate treatment. The assessment differs by lesion morphology, with specific classification systems for pedunculated and sessile lesions. Haggitt classification describes invasion depth in pedunculated polyps, whereas the Kikuchi classification assesses submucosal invasion in sessile lesions.

Haggitt classification of pedunculated polyps

Haggitt et al. developed a classification system for invasion depth in pedunculated polyps.26 It categorizes polyps into five levels (0–4). Level 0 corresponds to neoplastic cells confined to the mucosa without breaching the muscularis mucosae and therefore does not meet the clinical definition of colorectal cancer. Level 1 indicates invasion of the submucosa of the polyp head. Levels 2 and 3 indicate invasion of the neck (the junction between the head and stalk) and any region of the stalk, respectively. Level 4 denotes invasion into the submucosa of the colorectal wall below the polyp stalk, without invasion of the muscularis propria.[11]

Kikuchi classification of sessile polyps

Kikuchi et al. introduced a classification system for sessile polyps based on the depth of submucosal invasion (SMI).[27] Lesions are classified as SM1, invasion into the upper third; SM2, invasion into the middle third; and SM3, invasion into the lower third of the submucosa. However, routine application requires an adequate amount of submucosa in the resection specimen to determine the deepest extent of invasion. Therefore, we also measure the absolute depth of SMI from the muscularis mucosae. A depth of 1000 µm is traditionally used to distinguish superficial submucosal invasion (<1000 µm) from deep submucosal invasion (≥1000 µm). Although deep submucosal invasion has historically been associated with lymph node metastasis (LNM) rates of approximately 10%–18%, more recent evidence challenges its role as an independent predictor.[11]

A meta-analysis by Zwager et al. found that deep submucosal invasion was not a statistically significant independent predictor of LNM after adjustment for other histopathological risk factors. When deep invasion was the only adverse histological feature, the pooled absolute risk of LNM was approximately 2.6%.[28]

Nevertheless, invasion depth remains part of guideline-based risk assessment following endoscopic resection. The decision to proceed with additional oncological surgery should therefore be based on the overall histopathological risk profile, including invasion depth, lymphovascular invasion, tumor differentiation, tumor budding, and resection margin status, rather than relying on the 1000-µm threshold alone.[28.29]

In addition to formal classification systems, several endoscopic features are associated with deep submucosal invasion, including ulceration, excavation, deep demarcated depression, Paris 0-IIc or 0-IIa + IIc morphology, mucosal friability, and fold convergence.[22]

Magnifying chromoendoscopy or virtual chromoendoscopy can further assess surface and vascular abnormalities in suspicious areas. An irregular pit pattern characterizes Kudo pit pattern type VI. It may indicate advanced neoplasia or submucosal invasion, whereas a non-structured or amorphous surface pattern characterizes type VN and strongly suggests deep submucosal invasion.[29]

Endoscopic treatment of colorectal polyps

Endoscopic resection is the treatment of choice for most colorectal polyps and superficial neoplasms. The choice of resection technique depends on lesion size, morphology, location, histological prediction, and estimated submucosal invasion risk.[21]

The principal techniques include cold snare polypectomy (CSP), hot snare polypectomy (HSP), endoscopic mucosal resection (EMR), and endoscopic

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submucosal dissection (ESD), with indications based on lesion characteristics.[29]

Cold snare polypectomy

Cold snare polypectomy (CSP) removes colorectal polyps by mechanical transection without electrocautery. According to the ESGE guideline, CSP is recommended as first-line treatment for diminutive (≤5 mm) and small (6–9 mm) colorectal polyps, with a 1–2 mm margin of normal tissue to ensure complete resection. ESGE also recommends (piecemeal) CSP or cold EMR for sessile serrated lesions of any size without suspected dysplasia.[29]

Hot snare polypectomy

HSP uses electrocautery to remove colorectal polyps and is recommended by ESGE for nonpedunculated adenomatous polyps measuring 10–19 mm.[29]

Management of pedunculated polyps

Most pedunculated polyps are readily resectable. Large polyps with a head ≥20 mm or stalk ≥10 mm have an increased risk of immediate post-polypectomy bleeding. ESGE suggests prophylactic stalk treatment with dilute adrenaline injection and/or mechanical hemostasis before resection to reduce bleeding risk.[26]

Endoscopic mucosal resection

EMR enables removal of large superficial colorectal lesions following submucosal injection. According to the ESGE guideline, conventional (diathermy-based) EMR is recommended for large (≥20 mm) nonpedunculated adenomatous polyps. Underwater EMR may be considered as an alternative in selected cases. After piecemeal EMR of large nonpedunculated colorectal polyps using a hot snare, ESGE recommends thermal ablation of the resection margins with snare-tip soft coagulation to reduce adenoma recurrence. Prophylactic endoscopic clip closure of the mucosal defect is also recommended after EMR of large nonpedunculated colorectal polyps in the right colon to reduce delayed bleeding.[29]

Endoscopic submucosal dissection

Endoscopic submucosal dissection (ESD) is a minimally invasive technique that enables en bloc removal of large colorectal polyps and selected superficial neoplastic lesions. According to the ESGE guideline, ESD may be considered as an alternative to EMR for large (≥20 mm) nonpedunculated colorectal polyps in selected cases and high-volume centers.[29]
Furthermore, ESGE recommends en bloc resection, including en bloc EMR, ESD, endoscopic intermuscular dissection, endoscopic full-thickness resection, or surgery, for lesions with suspected superficial invasive carcinoma that cannot be removed en bloc by standard polypectomy or conventional EMR.[29]

Management of lesions suspicious for invasive carcinoma

Choose a resection strategy based on the estimated risk of submucosal invasion and the need for accurate histopathological staging. Lesions without features of invasive carcinoma may be suitable for piecemeal EMR, whereas suspected superficial invasive carcinoma should undergo en bloc resection for accurate histopathological assessment. When such lesions cannot be removed en bloc by standard polypectomy or conventional EMR, ESGE recommends considering en bloc EMR, endoscopic submucosal dissection (ESD), endoscopic intermuscular dissection, endoscopic full-thickness resection (EFTR), or surgery according to lesion characteristics and local expertise.[29]

Morphological features associated with an increased risk of covert submucosal invasion include nongranular laterally spreading tumors with a pseudodepressed component (LST-NG-PD) and granular laterally spreading tumors with a dominant nodule (LST-G-NM). These features should prompt careful optical assessment and consideration of en bloc resection to facilitate accurate histopathological staging. The final choice of technique should take into account the estimated invasion depth, lesion characteristics, and local expertise.[24,29]

Histopathological assessment of malignant colorectal polyps

Accurate histopathological assessment after endoscopic resection of a malignant colorectal polyp is essential for determining the risk of residual or recurrent cancer and the need for additional treatment. The pathology report should include histologic type, differentiation grade, depth and extent of invasion, resection margin status, and lymphovascular invasion. Also document specimen integrity, polyp size and morphology, and tumor budding.30 According to the US Multi-Society Task Force recommendations, high-risk features in nonpedunculated malignant polyps include poor tumor differentiation, lymphovascular invasion, submucosal invasion depth greater than 1 mm, tumor involvement of the cautery margin, and tumor budding. For pedunculated malignant polyps, high-risk features include poor tumor differentiation, lymphovascular invasion, and tumor located within 1 mm of the resection margin. Interpret these criteria according to polyp morphology. In particular, tumor involvement of the cautery margin, clearance of 1 mm or less, and indeterminate margin status should be distinguished, as they do not necessarily convey the same information

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regarding local residual disease or the adequacy of pathological assessment.[30]

Resection technique also affects pathological assessment. En bloc resection allows more reliable evaluation of invasion depth and resection margins, whereas piecemeal resection of a malignant polyp may compromise pathological staging, particularly assessment of invasion depth and margin status. When the specimen cannot be assessed reliably, consider additional oncologic surgery given the risk of residual disease and lymph-node metastasis. The decision should also account for the histopathological risk profile, specimen integrity, the patient's surgical risk and comorbidities, and the feasibility of reliable further assessment. Multidisciplinary discussion involving the gastroenterologist, pathologist, oncologist, surgeon, and patient is recommended.[30]

Post-polypectomy surveillance

Post-polypectomy surveillance is an essential component of colorectal polyp management and should be tailored to polyp number, size, histology, and completeness of resection. According to the US Multi-Society Task Force (USMSTF), patients with 1–2 tubular adenomas <10 mm completely removed at a high-quality examination should undergo repeat colonoscopy in 7–10 years, whereas adenomas ≥10 mm, those with villous or tubulovillous histology, or high-grade dysplasia warrant surveillance at 3 years. For serrated lesions, the recommended interval depends on lesion subtype, size, number, and dysplasia. For example, 1–2 sessile serrated lesions (SSLs) <10 mm warrant surveillance in 5–10 years under USMSTF recommendations.[31]

In contrast, the European Society of Gastrointestinal Endoscopy (ESGE) recommends return to routine screening after complete removal of 1–4 adenomas <10 mm with low-grade dysplasia, irrespective of villous components, and serrated polyps <10 mm without dysplasia, provided the baseline colonoscopy was of high quality. Patients with adenomas ≥10 mm, high-grade dysplasia, or serrated lesions ≥10 mm or with dysplasia should generally undergo surveillance colonoscopy after 3 years.[32]

After piecemeal resection of an adenoma or sessile serrated lesion ≥20 mm, ESGE recommends an early repeat colonoscopy after 3–6 months to detect residual or recurrent neoplasia, followed by further surveillance 12 months after the early repeat examination.[32]

Artificial intelligence and emerging imaging technologies

Artificial intelligence (AI) is increasingly incorporated into colonoscopy, particularly through computer-aided detection (CADe) and computer-aided diagnosis (CADx) systems. CADe systems analyze real-time endoscopic images to assist in colorectal polyp detection and have been associated with increased adenoma detection rates. However, their effects on advanced neoplasia detection and long-term colorectal cancer outcomes remain uncertain. Current recommendations differ: the 2025 European Society of Gastrointestinal Endoscopy (ESGE) Position Statement issued a weak recommendation in favor of CADe use in patients who have already decided to undergo colonoscopy for screening or surveillance, whereas the BMJ/MAGIC living guideline issued a weak recommendation against its routine use. Both guidelines emphasize uncertainty regarding patient-important benefits, the small potential absolute benefit, and the possible burdens of overdiagnosis and increased surveillance.[33,34]

CADx systems aim to characterize detected lesions and predict their histology, potentially supporting clinical management decisions. However, CADx evidence should be assessed separately from CADe evidence. A 2025 systematic review and meta-analysis found that CADx did not demonstrate significantly greater diagnostic accuracy than experienced endoscopists for colorectal polyp optical diagnosis. Further evidence is needed to establish its clinical utility across different lesion types and endoscopic settings.[35]

Areas of uncertainty and future research

Despite substantial advances in optical diagnosis and endoscopic resection, several areas remain uncertain. The diagnostic performance and external validity of optical classification systems may vary according to endoscopist expertise, lesion characteristics, and clinical setting.[23,36]

Further research is needed to standardize training and competence assessment, improve the characterization of intermediate-risk lesions, validate artificial intelligence-assisted detection and characterization, and determine the long-term clinical and cost-effectiveness of emerging endoscopic technologies.[33]

CONCLUSIONS

Colorectal polyps are heterogeneous lesions with variable malignant potential, making accurate endoscopic detection, characterization, and management essential for colorectal cancer prevention. Advances in endoscopic imaging and optical classification systems, including the Paris, NICE, WASP, and JNET classifications, have improved histological

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prediction and estimation of submucosal invasion risk. However, optical diagnosis remains dependent on lesion characteristics, image quality, and endoscopist training and experience and should not be considered a universal substitute for histopathological assessment. Modern resection techniques, including CSP, HSP, EMR, and ESD, enable minimally invasive treatment tailored to lesion characteristics and invasion risk. At the same time, post-resection histopathological assessment determines the need for additional treatment. Appropriate post-polypectomy surveillance completes the management pathway. An integrated approach combining high-quality colonoscopy, optical characterization, risk-based resection, histopathological risk stratification, and surveillance is fundamental to optimizing outcomes and reducing the burden of colorectal cancer.

CONFLICT OF INTEREST

The authors declare no conflict of interest. This work received no specific funding from any public, commercial, or not-for-profit organization.

AUTHOR CONTRIBUTIONS

Both authors contributed to the conception and design of the review, literature search and selection, analysis and interpretation of the literature, and drafting and critical revision of the manuscript. Both authors approved the final version of the manuscript.

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