Colorectal Malignant Polyps: Characterization and Endoscopic Resection Technique

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Colorectal cancer, currently the third most common malignancy worldwide, can be significantly reduced through early detection and endoscopic resection of polyps. This review discusses the main classifications of colonic lesions and the most effective evidence-based technologies for their detection, characterization, and management. A practical roadmap for risk stratification and a management algorithm are proposed, based on the latest recommendations from the European and American Societies of Gastrointestinal Endoscopy. By combining clinical experience with a critical analysis of key studies from the past decade, this article provides practical tools to enhance optical diagnosis and guide therapeutic decisions, minimizing the need for surgical interventions. This review serves as an essential resource for clinicians, offering practical guidance for effective and individualized management of colorectal lesions, thereby enhancing cancer prevention and optimizing healthcare resource utilization.

Keywords: colorectal polyps; colorectal cancer; histology predictor; colonoscopy; optical diagnosis; Narrow Band Imaging

Introduction

Colorectal cancer (CRC) is one of the leading causes of cancer-related morbidity and mortality worldwide. According to 2018 data, approximately 2 million new cases and 1 million deaths were attributed to this disease. Although overall mortality has been decreasing, with an annual decline of about 2% between 2011 and 2020, an increase in mortality among individuals under the age of 50 has been observed, with annual rises ranging between 0.5% and 3% [1].

Furthermore, it is projected that by 2040, the incidence of CRC will reach 3.2 million new cases and 1.6 million deaths globally. The risk of colorectal cancer, currently the third most common cancer worldwide, can be reduced via colonoscopy, due to early detection and resection of precancerous lesions [2].

It is estimated that around 70% of colorectal polyps are smaller than 5 mm (diminutive polyps) and pose a negligible risk of malignant transformation or invasive carcinoma [3]. Also, 90% of colorectal polyps are smaller than 10 mm and can be removed by endoscopic resection [4].

Conversely, approximately 10% of colorectal polyps are larger than 20 mm, have an adenomatous histotype (as defined by the Vienna classification), tend to infiltrate lower mucosal layers, and, in the case of neoplastic cells, transform into invasive carcinoma [5,6].

In such cases, endoscopic resection is not always a viable option due to the high risk of metastasis caused by the tumor spreading into the vascular and lymphatic networks [7]. Therefore, patients affected by such polyps must be referred to a surgeon to undergo intestinal resection surgery and locoregional lymphadenectomy.

In brief, most colorectal polyps are benign formations and can thus be endoscopically resected. In order to optimize patient management and reduce healthcare costs, it is crucial to characterize the histotypes of colorectal polyps during real-time endoscopic examinations. This process, known as "histology prediction" or "optical diagnosis", enables accurate identification of polyp types and guides appropriate treatment decisions [8]. The European Society for Gastrointestinal Endoscopy (ESGE) recommends adopting the "resect and discard" strategy, wherein diminutive rectosigmoid polyps, with a negative predictive value (NPV) of 90% or more for adenomatous histology, can be safely discarded without histological examination [9,10]. This ap-

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proach not only eliminates the need for histopathological analysis, leading to potential cost savings, but also ensures efficient screening efficacy [11]. The "Resect and Discard" strategy can offer significant benefits in terms of reducing the need for multiple biopsies, thereby improving treatment efficiency and minimizing complication risks. However, it also involves substantial risks, primarily related to the over-reliance on *in vivo* visual classification of lesions. A critical issue is inter-operator variability, as lesion assessment can differ depending on the experience and training of endoscopists. This increases the risk of misdiagnoses, potentially leading to unnecessary lesion removals or failure to identify malignant lesions. Furthermore, over-relying on *in vivo* classification exposes patients to the risk of diagnostic errors, as not all benign lesions can be accurately identified during endoscopy. Another limiting factor is technological variability between centers: in some clinical settings, particularly those that are not highly equipped, the lack of advanced tools or insufficient staff training can compromise the accuracy of classification, reducing the strategy's reliability. In these contexts, the lack of resources may prevent the correct implementation of the "Resect and Discard" strategy, increasing the risk of inappropriate treatments. However, when applied correctly, in well-resourced centers with properly trained personnel, this strategy offers significant advantages, such as more rapid management of benign lesions, avoiding unnecessary invasive procedures, and improving overall healthcare efficiency.

However, it is important to exercise caution when implementing these strategies, particularly in excluding the histopathologic study for diminutive polyps. The recommendation to exclude histology should be supported by robust evidence and consider the extremely low risk of metastasis associated with these polyps (0–0.06%) [6]. Thus, proper adherence to the guidelines and accurate histology prediction during endoscopy can significantly contribute to effective management of colorectal polyps, reducing the burden of unnecessary surgical interventions and optimizing cost savings in healthcare systems [4,12]. Some hereditary conditions, such as Familial Adenomatous Polyposis (FAP) and Lynch Syndrome (LS), carry a significantly higher risk of developing malignant polyps and colorectal carcinoma. These conditions require specific approaches in the surveillance and management of polyps. Management includes annual endoscopic surveillance programs aimed at monitoring the polyp burden and detecting suspicious lesions early. Endoscopic resection of polyps serves as a therapeutic strategy to reduce malignant transformation risk and delay the need for surgical intervention [13].

Optimal management of colorectal polyps, as outlined in ESGE guidelines, faces significant real-world challenges shaped by geographic, economic, and organizational barriers that profoundly impact patient access and outcomes.

Access disparities persist at both global and local levels. In low-income countries and rural areas, the lack of advanced endoscopic equipment (e.g., Narrow Band Imaging (NBI)-capable scopes) and trained personnel limits the adoption of real-time optical diagnosis or advanced resection techniques like Endoscopic Submucosal Dissection (ESD). Even in high-resource settings, socioeconomically disadvantaged patients and minority groups often experience delayed diagnoses and lower screening participation. Healthcare system constraints further exacerbate these issues. Shortages of skilled endoscopists, long procedure wait times, and inadequate infrastructure (e.g., hybrid operating rooms) hinder the implementation of complex techniques like ESD. Reimbursement policies frequently exclude advanced procedures, inadvertently promoting less effective but more affordable alternatives.

This paper elaborates on relevant studies of colorectal polyps, their histological characterization (histology predictor) and the stratification of risks. Furthermore, multicentric clinical trials, commissioned by the ESGE and published in the "Endoscopy" journal between 2019–2022, were thoroughly revised, summarized and compared to other studies.

In brief, this article reviews the various classifications of colonic lesions as well as the use of the most appropriate evidence-based technologies to detect, characterize and manage such lesions. It also provides a road map for risk stratification and an algorithm for a valid evaluation of colorectal lesions and their appropriate management strategies. When an endoscopist encounters a colorectal polyp, their primary purpose is to identify, characterize, and manage the lesion appropriately. The process involves a series of steps aimed at reducing the risk of malignancy and determining the most suitable treatment for the patient. Our Algorithm for the management of colorectal polyps is summarized below, reporting the multiple steps that guide decision-making (Table 1).

Identification of the Polyp

The first step in the management of a colorectal polyp is its identification during endoscopy. The endoscopist must carefully examine the colon to locate the polyp and assess its size and morphology. Polyps can vary in size and shape, which directly impacts the risk of malignancy. Larger polyps, for instance, are more likely to harbor advanced dysplasia or invasive carcinoma, so they should be monitored more closely. The polyp's morphology also plays a crucial role in determining the potential risk of deep invasion and guides the decision on how to approach removal.

Characterization of the Polyp

Once the polyp is identified, the following step is to characterize it to better understand its malignancy risk. This involves further investigation using specialized classifications. The Kudo pit pattern classification helps differentiate between benign and malignant lesions by analyzing the glandular pattern on the polyp's surface. A polyp with

Table 1. A practical roadmap for management of colorectal polyps.

Stage	Key actions	Tools/Classifications	Clinical significance
1. Identification	Locate polyp, assess size and morphology	HD colonoscopy	Determines initial risk stratification
2. Characterization	Analyze: • Size • Paris morphology • Kudo pit pattern • NBI vascularity	Paris classification Kudo classification NBI	Predicts histology and invasion depth
3. Decision	Choose between: • Endoscopic resection (low risk) • Surgery (high risk)	ESGE Risk Criteria	Guides the therapeutic approach
4. Resection	Select technique based on polyp features: • CSP (<10 mm) • HSP (pedunculated) • EMR (>20 mm) • ESD (invasive)	Cold/Hot Snares Submucosal injection	Balances efficacy and safety
5. Follow-up	Surveillance or additional treatment based on histology	Surveillance intervals (3–5 years)	Prevents recurrence/missed lesions

HD, high-definition; NBI, Narrow Band Imaging; CSP, cold snare polypectomy; HSP, hot snare polypectomy; EMR, Endoscopic Mucosal Resection; ESD, Endoscopic Submucosal Dissection; ESGE, European Society of Gastrointestinal Endoscopy.

a malignant pattern would likely require more aggressive treatment. Additionally, the vascularization of the po, evaluated using Narrow Band Imaging (NBI), helps determine whether the polyp is benign or malignant. A more irregular or abnormal vasculature often suggests a higher likelihood of malignancy, prompting further management.

Polyp Removal

If the polyp is deemed to have a manageable risk and the endoscopist is trained and competent, the next step is to proceed with endoscopic resection. Polypectomy is the preferred method for removing most polyps, especially those with low or moderate risk of malignancy. However, the decision to remove a polyp endoscopically is greatly influenced by the polyp's characteristics, including its size, shape, and the depth of invasion. The invasion depth classification helps assess whether the polyp has invaded the colon wall and whether endoscopic resection will be sufficient, or if a more invasive surgical procedure is necessary.

Histological Evaluation

After removal, the polyp should undergo histological evaluation to confirm whether it contains any dysplasia or invasive carcinoma. This is a critical step, as histology confirms the nature of the lesion, ensuring that any malignancy is properly identified. The histological results can also guide further management, such as whether the patient requires additional surveillance or more aggressive treatment. The initial classification of the polyp, including its size, morphology, and vascularization, can provide important clues that make the histological evaluation more precise, allowing for earlier detection of malignancy.

Surgical Intervention

In some cases, the polyp may be too large, too deeply invasive, or located in a way that endoscopic resection is not feasible. In such cases, surgical intervention may be required. The decision to opt for surgery is informed by the depth of invasion and other characteristics of the polyp, such as its morphology and vascular pattern. These classifications help guide the endoscopist in determining when endoscopic removal is not sufficient and when surgical intervention is necessary for complete excision and to minimize the risk of metastasis.

Role of the Classifications and Overall Importance

The integrated use of these classifications, morphology, pit pattern, vascularization, and invasion depth offers a comprehensive view of colorectal polyps. By combining all these elements, the endoscopist is better equipped to assess the risk of malignancy and determine the most appropriate course of action. This holistic approach not only enhances diagnostic accuracy but also minimizes unnecessary invasive procedures. Furthermore, by identifying malignant polyps early and managing them appropriately, the risk of cancer progression is reduced, and healthcare costs are kept lower by avoiding unnecessary surgeries and procedures. Ultimately, the use of these classifications improves both the quality of patient care and the overall efficiency of the healthcare system.

Polyps Characterization

Polyp Size Classification

Colorectal polyps are divided into five categories based on size: (1) diminutive polyps, (2) small polyps, (3) medium-sized polyps and (4) large polyps [14] and (5) laterally spreading tumor (LST) (Fig. 1).

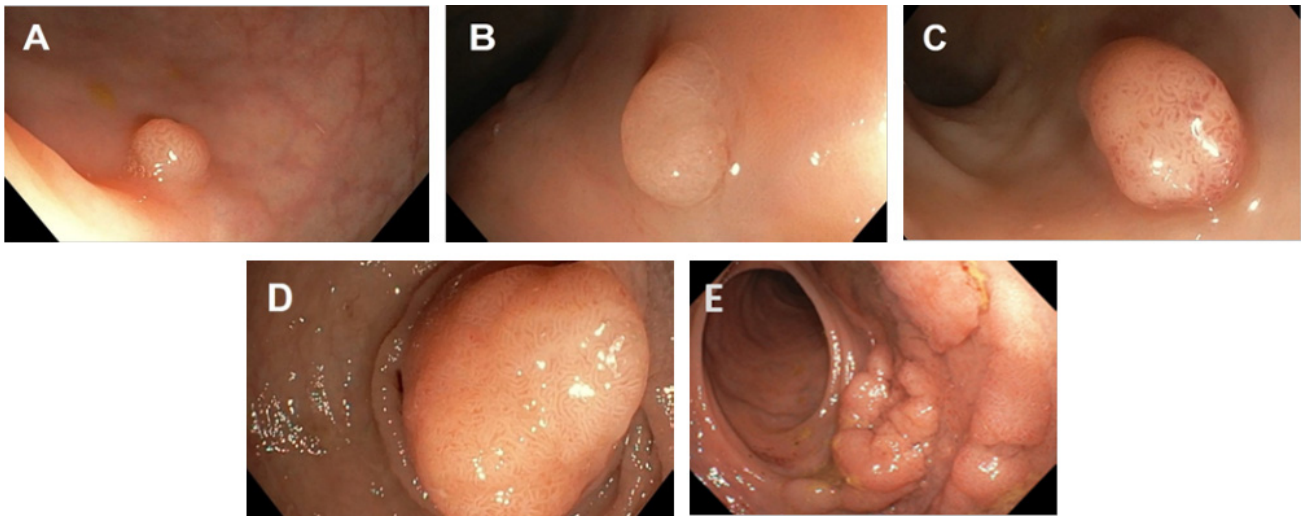


Fig. 1. Polyps classification according to size. (A) Diminutive polyps (<5 mm). (B) Small polyps (6–9 mm). (C) Medium-sized polyps (10–19 mm). (D) Large polyps (>20 mm). (E) Laterally spreading tumor (LST), a flat lesion, non solely, dependent on diameter size (>10 mm). Archive photo: Prof. Giovanni Tomasello. The endoscopic resection procedures were approved through informed consent duly signed by the patients who gave authorization for the use of the endoscopic images.

Importance of Polyp Size Classification in the Risk of Carcinogenesis

The classification of colorectal polyps based on size is a fundamental tool for assessing the risk of malignant transformation. There is a direct correlation between polyp size and cancer risk: diminutive polyps (<5 mm) carry an extremely low risk, whereas larger polyps (≥10 mm) have a significantly higher probability of harboring advanced dysplasia or invasive carcinoma. This straightforward criterion effectively guides clinical decisions regarding the urgency of removal, the choice of resection technique, and the scheduling of endoscopic surveillance, thereby enhancing colorectal cancer prevention strategies. Small and diminutive colorectal polyps are the most prevalent findings during colonoscopies [10,15]. Advanced pathology risk estimates within diminutive polyps are low, with a range of 0% to 0.6%. Large colorectal polyps larger than 10 mm in diameter, referred to as laterally spreading tumors (LSTs), can be categorized as granular, non-granular, or mixed. Granular LSTs tend to have shallower penetration and can be treated endoscopically, while non-granular LSTs with a smoother surface have a higher likelihood of penetrating the deeper layers and consequently a higher risk of carcinogenesis [16].

This new endoscopic classification allows a universal description of colonic lesions, thus standardizing the language used by various endoscopic centers, but most importantly, correlating the endoscopic appearance with the degree of neoplastic infiltration (the degree of invasion of the submucosa according to the Paris classification) [16].

Paris Classification

Morphological Classification

The Paris classification system helps in categorizing the morphology of colorectal polyps, thus distinguishing between polypoid and non-polypoid lesions [15]. The morphology of endoscopic lesions can suggest depth penetration throughout the submucosal layer [17]. This categorization also includes superficial neoplastic colorectal lesions, which are frequently detected with the spread of colonic-rectal cancer screenings.

The "superficial" neoplastic lesion is defined as type-0 and can be subdivided as either (1) polypoid-type lesions (type 0–I) and (2) non-polypoid lesions (type 0–II) [17]. The superficial polypoid lesions (type 0–I) can be further subdivided into: (1) Pedunculated polypoid lesions (0–Ip); and (2) Sessile polypoid lesions (type 0–Is). The superficial non-polypoid lesions can be further subdivided into: (1) Elevated non-polypoid lesions (0–IIa); (2) Flat non-polypoid lesions (0–IIb); and (3) Depressed polypoid lesions (0–IIc).

The difference between a sessile polypoid lesion (0–Is) and an elevated non-polypoid lesion (0–IIa) is given by the elevation from the mucosal plane: above 2.5 mm in the former case, under 2.5 mm in the latter (Fig. 1). Non-polypoid lesions can also be of the mixed type, when both—an elevated region and a depressed region—are present. These can thus be categorized as 0–IIc + IIa if the depressed component is more prevalent, and 0IIa + IIc if the elevated component is the more prevalent [17].

The Paris endoscopic polyps classification takes into consideration the parameters of polyp size and relationship with the surrounding mucosal surface, from which the lesion's depth can be deduced. From this, we can evaluate the polyp's likelihood to develop in depth or develop laterally

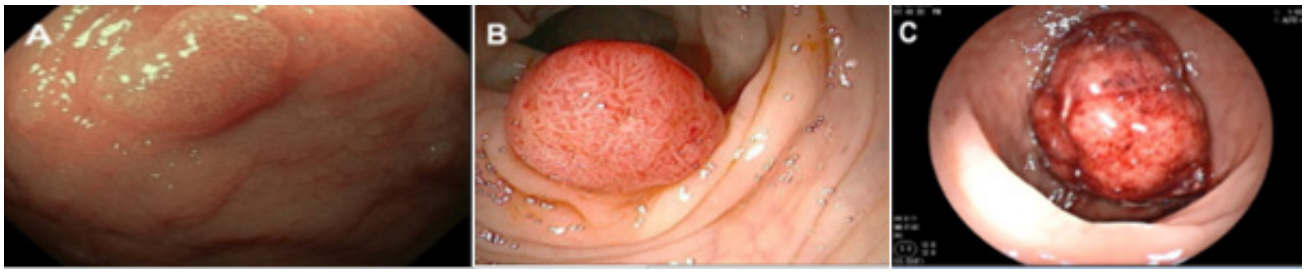


Fig. 2. Pit Patterns - Kudo's classification. (A) Type 1: Hyperplastic polyps. (B) Type 2: Adenomatous polyp. (C) Type 3: Invasive polyp: deep submucosal invasive cancer. Archive photo: Prof. Giovanni Tomasello. The endoscopic resection procedures were approved through informed consent duly signed by the patients who gave authorization for the use of the endoscopic images.

across the mucosal plane. The elevated non-polypoid lesions (0–IIa), the most common type, have a low chance of infiltrating the submucosa; even so, they usually do not reach depths beyond 1000 micrometers and are thus suitable for definitive endoscopic treatment. Depressed lesions (0–IIc), on the other hand, more often present infiltration deeper than 1000 micrometers, and thus endoscopic mucosectomy does not represent definitive treatment, due to the risk of locoregional lymph node metastases [18]. This new endoscopic classification allows a universal description of colonic lesions, thus standardizing the language used by various endoscopic centers, but most importantly, correlating the endoscopic appearance with the degree of neoplastic infiltration (the degree of invasion of the submucosa according to the Paris classification) [18].

Pit Pattern Kudo Classification

The Kudo classification system has been developed by endoscopists in Japan to assess the appearance of polyp surfaces [19]. It focuses on evaluating the musculoskeletal glandular pattern visible on the surface, known as the "pit pattern", to anticipate the likelihood of malignant transformation [20]. This classification is made possible by the advanced features of last-generation endoscopes, such as magnification and electronic colorization chromoscopy, which provide *in-vivo* staining coloration without the risk of artifacts [21].

The Kudo classification includes:

1. Type I: Pit Pattern corresponds to normal mucosa.
2. Type II: Pit Pattern refers to inflamed or hyperplastic mucosa.
3. Type III: Pit Pattern is characteristic of protruding adenomas.
4. Type IIIS: Pit Pattern has a glandular appearance, typical of depressed-type tumors.
5. Type IV: Pit Pattern corresponds to neoplastic lesions in the majority of cases.
6. Type V: Pit Pattern includes submucosal cancers and late-stage cancers.

Following assessment of the lesion using the Paris classification [17] and Kudo pit pattern classification (Fig. 2), an endoscopist can decide, during the endoscopy in real-time, whether to resect the polyp, with which technique, or whether to perform a biopsy and mark the lesion, and then refer the patient for surgical intervention.

Vascular Pattern - Narrow Band Imaging (NBI) Classification

In chromoendoscopy, a popular technique is Narrow Band Imaging (NBI), which uses optical filters to see the morphology of the mucosa in high detail, without resorting to the use of chemical stains (push-button technology).

This technique is based on an optical phenomenon where the depth of penetration of light depends on its wavelength: the greater the wavelength, the greater the penetration depth. In the visible spectrum, blue light only penetrates shallowly, whereas red light penetrates the deeper layers. The advantage of NBI is that additional tools or substances are not needed; a simple press of a button on the endoscope itself is sufficient. All NBI endoscopes are high-resolution.

Virtual chromoendoscopy, along with high-definition white-light endoscopy, can provide a detailed assessment of the mucosal and submucosal layers of colorectal polyps [17]. By utilizing these advanced endoscopic technologies, neoplastic polyps can be differentiated from non-neoplastic ones. NBI technology (Olympus Inc., Tokyo, Japan) has been approved and declared to be compliant with regulations. It is one of the most well-studied and advanced among the electronic techniques for the acquisition of endoscopic images, for the purpose of detecting dysplasia or superficial carcinoma [22].

The NBI uses built-in red-green-blue (RGB) optical filters, which eliminate the red portion of light and reduce the green portion, while preserving the blue portion to illuminate tissues. The high intensity of the blue light improves the visualization of mucosal patterns, which reveals the superficial structures, due to its low tissue penetration depth. Hemoglobin absorption of blue light also allows a detailed inspection of the superficial micro-vascularization of the mucosa [22].

Several studies have demonstrated the importance of high-resolution endoscopy, in combination with NBI technology, in endoscopic monitoring for patients in follow-up for

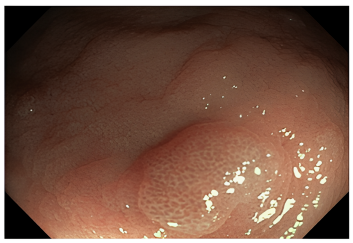
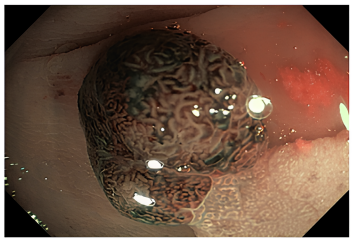
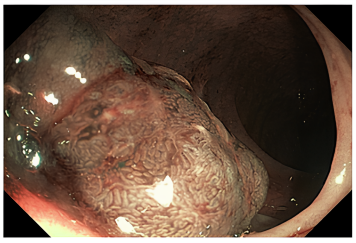
TYPE 1 The color is the same or lighter than background; none, or isolated lacy vessels coursing across the lesion; the surface pattern is dark or white spots of uniform size, or homogeneous absence of pattern; the most likely pathology is a Hyperplastic polyp.	
TYPE 2 The color is browner relative to background (verify color arises from vessels); brown vessels surrounding white structures; the surface pattern is oval, tubular or branched white structure surrounded by brown vessels; the most likely pathology is an Adenoma.	
TYPE 3 The color is brown to dark brown relative to background; sometimes patchy whiter areas; has area(s) of disrupted or missing vessels; the surface pattern is amorphous or absent surface pattern; the most likely pathology is Deep Submucosal invasive cancer. Here you can put a mark in this amorphous base of the polyp.	

Fig. 3. NBI International Colorectal Endoscopic. Endoscopic Image: Giovanni Tomasello. The endoscopic resection procedures were approved through informed consent duly signed by the patients who gave authorization for the use of the endoscopic images. NBI, Narrow Band Imaging.

intestinal polyposis and with Barrett's esophagus [23]. In addition, 13 studies conducted in Japan using different classification systems have shown that NICE has a sensitivity of 77% (95% CI: 68%–84%) and a specificity of 98% (95% CI: 95%–99%), showing that it has high specificity and sensitivity [24].

Narrow Band Imaging (NBI), when combined with high-definition endoscopy, has proven to significantly enhance the detection and characterization of colorectal polyps.

A meta-analysis published in Gastroenterology demonstrated that NBI improves the adenoma detection rate (ADR) compared to white-light endoscopy (WLE), especially under optimal bowel preparation conditions. Specifically, the ADR was 45.2% with NBI versus 42.3% with WLE, suggesting that NBI use can elevate colonoscopy quality by increasing the detection of precancerous lesions [25].

Additionally, another study published in BMC Gastroenterology evaluated the effectiveness of the Narrow Band Imaging International Colorectal Endoscopic (NICE) classification in predicting colorectal polyp histology without the need for optical magnification. The results showed that the NICE classification, based on NBI, has high diagnostic accuracy and reproducibility among both experts and non-experts.

Together, these findings underline the critical role of NBI combined with high-definition endoscopy in improving early detection, histological characterization, and overall management of colorectal lesions, ultimately contributing to colorectal cancer prevention [26].

Furthermore, NBI technology represents the most rigorously studied method for "virtual chromoendoscopy" and researchers recommend its use in order to improve the accuracy and efficacy of dysplasia detection [27] (Fig. 3).

NICE Classification

In brief, NBI is the first validated method of electronic chromoscopy [22]. Nowadays, there are several other methods providing good images, based on similar principles, not all widely validated, but several of them with good and validated applicability, as we see in Fujinon and Pentax corresponding equipment.

Polyp Walls Assessment & Invasiveness Risk

Assessing the depth of penetration of colorectal polyps into the colorectal wall is crucial for determining the efficacy of endoscopic mucosectomy and evaluating the risk of metastases [18]. The maximum safe depth for endoscopic mucosectomy is considered to be 1000 micrometers of tumor infiltration into the submucosa, corresponding to the Sm1 classification. When infiltration is limited to Sm1, the incidence of lymph node metastases is negligible (up to a maximum of 2%), but deeper infiltrations have an incidence exceeding 15% [28].

Knowing that the mucosa is made up of three layers—the epithelium, the lamina propria and the muscularis mucosae, the "m" infiltration depth distinction is adapted [29]:

1. m1 = the lesion penetrates up to the epithelium.
2. m2 = the lesion penetrates up to the lamina propria.
3. m3 = the lesion penetrates up to the muscularis mucosae.

Underneath the mucosa, we find the submucosa, which is also divisible into thirds to give three layers:

1. Sm1 = first third of the submucosal layer.
2. Sm2 = second third of the submucosal layer.
3. Sm3 = last third of the submucosal layer.

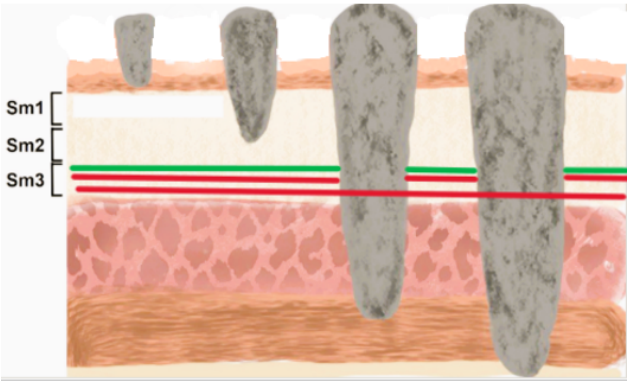


Fig. 4. The mucosal and submucosal layers and levels of tumor invasion. Blood vessels and lymphatic vessels are indicated by green and red lines. Picture was created by RC and DB using Canva (1.112.0, Canva Pty Ltd., Sydney, Australia).

Combined, the three layers of the mucosa and the first third of the submucosa reach a total depth of 1000 micrometers measured from the basal membrane and not from the epithelial Stratum [29]. Fig. 4 illustrates the different levels of tumor invasion.

The European Society of Gastrointestinal Endoscopy (ESGE) recommends using high-definition white-light endoscopy along with virtual chromoendoscopy to identify the presence and extent of submucosal invasion in nonpedunculated colorectal polyps before initiating any therapy [9].

With the aid of chromoendoscopy and high-definition (HD) endoscopic technology, colorectal polyps can be characterized as neoplastic or not. According to ESGE, high-definition endoscopy can be employed in average-risk patients to improve the endoscopist's adenoma diagnosis rate. For small colorectal polyps (less than 5 mm), virtual chromoendoscopy can provide real-time optical diagnosis, potentially replacing the need for histological analysis. Skilled endoscopists can perform real-time visual diagnosis, accurately recording mucosal patterns and capturing pictures for reporting purposes [30].

Technique for Removing Polyps

There are several techniques for removing colon polyps, and the choice of technique depends on the histological type of the polyp and its ability to invade the colon wall. If the center is not capable of providing safe and effective treatment, the patient should be transferred to a higher-level center, even after consulting with their multidisciplinary cancer team.

The ESGE guidelines provide recommendations for different endoscopic treatment strategies:

1. Diagnose and Leave Strategy: This strategy involves making a diagnosis of the polyp and leaving it in place without removal. It is based on optical diagnosis using real-time characterization of the polyp. This strategy can be applied to diminutive polyps (<5 mm) in the rectosigmoid region or polyps with hyperplastic or regular vascular-glandular patterns. However, these polyps need to be evaluated in subsequent endoscopic checks, and if there are signs of malignant transformation, they should be removed [28]. During screening colonoscopy Colorectal cancer (CRC) or advanced histology like villous histology or high-grade dysplasia are not found in the vast majority of these lesions [15].
2. Resect and Discard Strategy: This strategy involves resecting the polyp and discarding it without further histological examination. It is suitable for low-risk polyps that can be characterized in real-time using optical diagnosis. This strategy applies to diminutive polyps (<5 mm) with a low index of carcinogenicity or polyps with hyperplastic patterns [31].
3. Polypectomy Snare (Hot snare or Cold snare technique): Polypectomy is performed using an electrosurgical snare inserted into the operating channel of the endoscope. The electric current generated by an electrocoagulation unit helps coagulate the blood vessels of the polyp and facilitate its resection. Hot-snare polypectomy is commonly used, but cold-snare polypectomy is preferred in many cases, especially to avoid the risks associated with deep fulguration. This method is recommended for pedunculated polyps, polyps smaller than 20 mm, and polyps with an undegenerated vascular-glandular pattern [32,33]. After polypectomy, patients should be referred to specific endoscopic surveillance programs to monitor for possible relapses and to detect any new polyps that may develop in the colon. The comparison of cold snare polypectomy (CSP) and hot snare polypectomy (HSP) in terms of complete polyp resection (non-pedunculated polyp of 4–9 mm) showed no significant difference between them. Either HSP with electrocautery or CSP without electrocautery can be used for polyps smaller than 10 mm in diameter. Electrocautery is the main cause of these perforations, but CSP can prevent them [34,35]. Post-procedural abdominal complaints were more frequently associated with HSP than CSP [36]. The use of CSP is faster and has a lower risk of perforation [37].

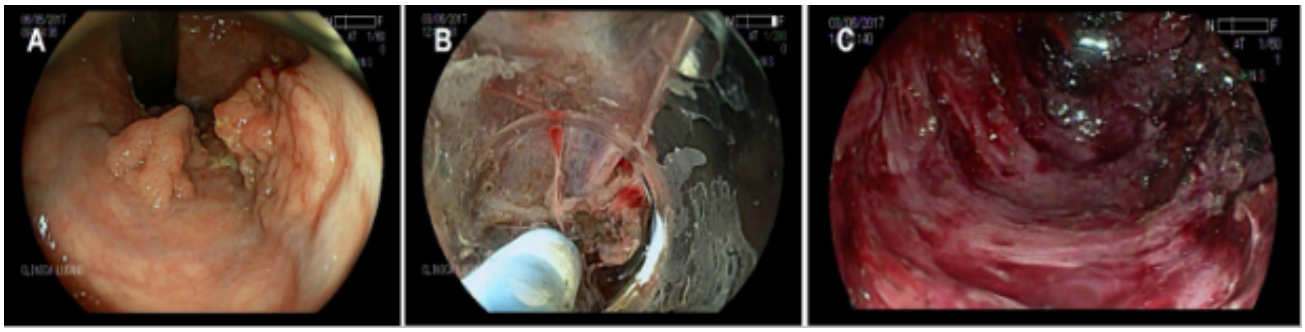


Fig. 5. Endoscopic Submucosal Dissection (ESD) for colon polyps resection. This figure shows the sequential steps to resect a (A) LST of the distal rectum with fibrosis after radiotherapy using ESD performed by Prof. Maria Cristina Sartor. (B) A knife dissection of the submucosa was conducted until (C) all the submucosal layer is removed, marking the end of the ESD procedure. Image archive: Prof.ssa M.C. Sartor; Giovanni Tomasello. The endoscopic resection procedures were approved through informed consent duly signed by the patients who gave authorization for the use of the endoscopic images.

Cold snares procedures are frequently used for polypectomies of small polyps <10 mm in dimension, but there is also evidence reporting the application of cold snares for larger polyps. CSP has been used as the principal method for the removal of non-pedunculated colorectal polyps <10 mm because of its safety, effectiveness, and lower costs; Furthermore, complete histologic resection rates with CSP vary widely (44%–96%) [38]. For the removal of sessile polyps of 10–19 mm in size, current guidelines recommend HSP, with or without submucosal injection [38,39]. For pedunculated polyps, HSP is also the recommended first-line modality [39,40].

4. Endoscopic Mucosal Resection (EMR): EMR is considered the primary therapy for the removal of polyps larger than 20 mm. This method involves using an electrosurgical snare placed at the base of the polyp to resect it, along with a minimal portion of the surrounding intact mucosal membrane. Before the procedure, a saline or gelatinous solution is injected to lift the mucosal plane from the submucosa (lifting sign), which helps prevent thermal damage to the deeper layers of the intestinal wall and reduces the risk of perforation. A positive lifting sign indicates the absence of submucosal infiltration by the neoplastic lesion. EMR is a safe eradication technique when performed by experienced professionals. Tertiary reference endoscopy centers have reported technical success rates of over 90% [41].

5. Endoscopic Submucosal Dissection (ESD): ESD involves the resection of the neoplastic lesion along with the mucosal and submucosal layers. It allows for wider and deeper resection, reaching the edge of the muscle layer of the colonic wall. ESD is particularly effective for removing large lesions that extend beyond the mucosal layer, enabling radical resection (R0). Studies have shown that ESD successfully removes colon polyps in over 96% of treated patients [42] (Fig. 5).

6. Endoscopic Full-Thickness Resection (EFTR): EFTR represents the ultimate therapeutic frontier of endoscopy resection. It consists of the full-thickness resection of the intestinal wall to remove those lesions that penetrate into the deepest parietal layers [43]. This method allowed us to overcome the limits placed in the endoscopic resections of the past, which reached the back of the mucosa itself. The intestinal lesions confined within the muscularis mucosa could be resected endoscopically, while those involving the muscle itself had to be directed to surgical resection. Today, with the support of new high-tech devices, this respectability limit has been exceeded through the use of EFTR. This endoscopic method uses specific devices, which simultaneously allow the resection of the entire thick section of the wall and the complete sewing of the remaining crack, without the need to resort to surgery [44].

Discussion: Navigating the Complexities of Polyp Management in Clinical Practice

The endoscopic management of colorectal polyps presents a fascinating interplay between technological advancements and real-world clinical challenges. As we refine our approaches to detection and treatment, several critical considerations emerge that shape decision-making at the bedside.

Polyp size remains one of the most fundamental factors guiding management strategies. Those tiny sub-5 mm polyps we frequently encounter in the rectosigmoid region often tell a reassuring story through their regular pit patterns and uniform vascularity when viewed under Narrow Band Imaging. For these diminutive lesions, the “resect and discard” approach has revolutionized our practice, offering both efficiency and cost-effectiveness. However, this strategy demands confidence in our optical diagnosis skills, as even these small polyps can occasionally harbor surprises that might be missed without histological confirmation.

At the other end of the spectrum, large laterally spreading tumors present an entirely different clinical picture. Their complex surface patterns and potential for subtle depressed areas often hint at deeper invasion, requiring us to carefully select between EMR and the more technically demanding ESD. While ESD offers superior en bloc resection rates,

its steep learning curve and longer procedure time present practical barriers to widespread adoption outside specialized centers.

The classification systems we rely on—Paris, Kudo, and NICE—each bring unique strengths to our diagnostic arsenal. The Paris classification helps us predict invasion depth at a glance, while Kudo's pit pattern analysis provides remarkable specificity for identifying malignant potential. NBI's vascular assessment offers real-time decision support during routine colonoscopy. Yet these systems aren't without their challenges, as interpretation variability between observers remains an ongoing concern, particularly for less experienced endoscopists.

When it comes to resection techniques, we find ourselves balancing efficacy against safety in every case. Cold snare polypectomy has become the workhorse for small polyps, offering nearly complete resection with minimal complications. For larger lesions, EMR provides a practical solution despite its higher recurrence rates, while ESD offers more definitive treatment for suspicious lesions at the cost of greater technical complexity and potential complications.

The complications we occasionally encounter—bleeding, perforation, or post-polypectomy syndrome—remind us that even routine procedures carry risks. These potential adverse outcomes are significantly influenced by operator experience, underscoring the importance of structured training programs and volume-outcome relationships in endoscopic practice.

Looking ahead, emerging technologies like artificial intelligence and hybrid techniques promise to reshape our management paradigms. As these innovations mature, they may help bridge the gap between specialized centers and community practice, potentially democratizing access to high-quality polyp management.

Ultimately, the art of polyp management lies in tailoring our approach to each unique clinical scenario, considering not just the lesion characteristics but also our institutional capabilities and the individual patient's needs. This nuanced, patient-centered approach—supported by evidence but adapted to real-world constraints—represents the future of colorectal polyp management.

Conclusions

From a procedural perspective, the endoscopist plays a pivotal role in the identification, classification, and management of colorectal polyps. It is critical to assess macroscopic features, vascular patterns, and pit patterns using optical magnification under both white light and virtual chromoendoscopy techniques such as NBI to guide therapeutic decisions.

Adopting a standardized procedural algorithm enhances diagnostic and therapeutic accuracy, minimizes errors, and improves clinical outcomes.

According to ESGE guidelines, only well-trained endoscopists should perform real-time optical diagnosis to determine appropriate management, thereby reducing reliance on histological examination. This strategy is considered safe only for diminutive polyps (<5 mm) located in the rectosigmoid region, provided that advanced imaging technologies (such as Narrow Band Imaging) are used and the endoscopist achieves a negative predictive value (NPV) for adenoma greater than 90%.

Strict adherence to procedural protocols not only elevates the quality of endoscopy but also serves as a cornerstone for patient safety, therapeutic success, and healthcare sustainability.

Endoscopic surveillance must be integral to the care pathway, given the risk of recurrence or new lesion development, especially in biologically heterogeneous neoplasms.

Availability of Data and Materials

The data generated and analyzed during the current study are available from the corresponding author on reasonable request.

Author Contributions

GT, CB, FC and VA designed the research study. RC and DB performed the research. MS and AL provided help with pictures and the table. GT, CB, RC, DB, FC, MS, LD, JM, AJ, AL and VA analyzed the data. GT, CB, RC and DB wrote the manuscript. All authors contributed to the critical revision of the manuscript for important intellectual content. All authors read and approved the final manuscript. All authors have participated sufficiently in the work and agreed to be accountable for all aspects of the work.

Ethics Approval and Consent to Participate

Not applicable.

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Conflict of Interest

The authors declare no conflict of interest.

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