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Endoscopic Management of Polyps, Polypectomy, and Combined Endoscopic and Laparoscopic Surgery

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Key Concepts

- Colonoscopic polypectomy is the treatment of choice for diagnosing and removing most colon polyps.
- Operator variability influences the quality of colonoscopy for both detection and resection.
- Multiple questions remain about best practice techniques for colonoscopic polypectomy.
- EMR of colorectal lesions is safe and effective but results in piecemeal resection that may prevent accurate histological diagnosis. Colonoscopy surveillance is required to assess for and manage local recurrence of neoplasia.
- ESD is able to resect superficial lesions en bloc regardless of tumor size, location, and fibrosis. These advantages come at a cost of an increased risk of perforation, bleeding, and a longer procedure time as compared with EMR.
- Combined endo-laparoscopic surgery is an adjunct to endoscopic polypectomy that may help to avoid colectomy.

Introduction

It is estimated that 93,090 new cases of colon cancer will be diagnosed in the year 2015 with almost 50,000 estimated deaths due to colon cancer [1]. Although colon cancer is still the third most common cause of cancer related mortality in the USA, there has been a steady decline in the colorectal cancer incidence since the mid-1980s which is partially attributed to the introduction of colorectal cancer screening [2]. There has even been a more rapid decline in recent years (4% or greater per year from 2008 to 2011) which may be multifactorial but likely reflects the increased use of screening colonoscopy. Among adults aged 50–75 years, colonoscopy use increased from 19.1% in 2000 to 54.5% in 2013 [3]. Recently published data of the long-term follow-up from patients enrolled in the National Polyp Study provides evidence that colonoscopic removal of adenomatous polyps reduces colon cancer incidence and related mortality [4].

Colonoscopic polypectomy is the treatment of choice for diagnosing and removing most colon polyps. In the past decade, polypectomy technique, instrumentation, and evolution of endoscopy skills have improved polyp detection rates and the ability to remove polyps. Even so, large polyps or polyps in an anatomically difficult location can be challenging to remove endoscopically. Traditionally the most common recommendation for these patients has been to undergo a colon resection. Although the laparoscopic approach has reduced the morbidity of an abdominal operation, it still poses potential morbidities related to bowel resection. A combined approach using both laparoscopy and colonoscopy has more recently been described as an alternative to bowel resection in select patients with polyps that cannot be removed endoscopically. This chapter addresses endoscopic polypectomy—basic and advanced techniques and combined endoscopic endo-laparoscopic techniques.

Identification of Polyps

Although there is little dispute about the impact of colonoscopy, there remains marked variability in the quality of colonoscopy. Indicators of quality colonoscopy include cecal intubation, withdrawal time, and polyp detection rate [5]. The need for cecal intubation is based on the persistent finding that a substantial fraction of colorectal neoplasms are located in the proximal colon including the cecum. Low cecal intubation rates have been associated with higher rates of interval proximal colon cancers [6]. Colonoscopy studies in screening patients in the USA have reported cecal intubation rates of 97% or higher [7, 8]. As the detection of neoplastic lesions is the primary goal of most colonoscopic examinations, careful inspection of the mucosa is essential. In 2002,

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the US Multi-Society Task Force on Colorectal Cancer recommended a withdrawal time (defined as the time from cecal intubation to the time the colonoscope is withdrawn out of the anus) of at least 6 min as an indicator of quality colonoscopy [9]. In 2006, Barclay et al. found a correlation between longer withdrawal time and an increased rate in the detection of adenomas [10]. There have been variations in the adenoma detection rates (ADR) and for this reason, targets for ADR have been recommended. The American Society for Gastrointestinal Endoscopy (ASGE) and the American College of Gastroenterology (ACG) recommends a minimum target for overall ADR of at least 25% based on the observation that higher ADRs were associated with a reduced risk of both proximal and distal cancer [11, 12].

Criteria for Polypectomy

Polyps occur in all parts of the colon. It is the current practice, that when polyps are detected that they should be removed as any adenomatous tissue visualized should be assumed to carry some malignant potential [13, 14]. It is widely accepted that more than 95% of colorectal cancers arise from adenomatous polyps [15, 16]. This adenoma-carcinoma sequence is well described and is often an indolent process that takes many years. Polyps are characterized by their size and morphology (pedunculated or sessile), which are two important features that may predict underlying malignancy and should guide how polyps are managed. As defined by the US National Polyp Study, an advanced adenoma is one that is ≥ 1 cm in size or contains high grade dysplasia or appreciable villous tissue. When screening colonoscopy is performed in average-risk, asymptomatic individuals over the age of 50, the prevalence of advanced adenomas ranges from 6 to 9% [7]. It is accepted that removal of large adenomas is advisable to prevent progression to colorectal cancer. The malignant potential of adenomas < 0.5 cm is not as well studied. In order to determine the clinical significance of polyps <0.5 cm, a retrospective study from Vienna, 7590 adenomatous polyps from 4216 patients between 1978 and 1996 were analyzed. Size was the strongest predictor of advanced pathologic features. Advanced pathologic features were defined as high grade dysplasia or invasive cancer. The percentages of adenomas with advanced pathologic features were 3.4%, 13.5% and 38.5% for adenomas <0.5 cm, 0.5–1.0 cm and >1 cm respectively. Villous change, left sided location and age ≥60 were also associated with advanced pathologic features. No invasive cancer was found in any polyp ≤ 0.5 cm, but since 3.4% of these contained high-grade dysplasia, the authors recommended removal whenever possible [17]. Another study found that a small (≤0.5 cm) right sided polyp in a young patient (≤60 years of age) has only a 3.8% risk for containing advanced pathologic features whereas polyps in patients over age 60, in the presence of anemia, polyp size > 1 cm, or left sided location as single or combined parameters had a maximum predictive value of 75.4% for advanced adenomas [18].

There are several reasons why a polyp should not be removed during colonoscopy. If there are characteristics suspicious for malignancy and if its endoscopic appearance suggests penetration deeper than the submucosa, a polypectomy should not be performed. The characteristics of a polyp that may be indicative of malignancy are firmness or hardness, mucosal irregularity, vascular pattern on narrow band imaging, ulceration or central umbilication, large size, and if the polyp does not lift with submucosal injection [19, 20]. In these cases, one would consider biopsy of the polyp instead of removal. Large polyp size may be another reason to defer polypectomy. Large polyps in the cecum have a higher risk of perforation during resection, and therefore, one may consider doing a combined endo-laparoscopic approach. Finally, a polypectomy should not be performed if the risks outweigh the benefits. Examples of this would be any polyp in an asymptomatic patient whose life expectancy is less than 2 years (patients with terminal cancer), polyps discovered during unfavorable circumstances (patients undergoing workup for bleeding), patients with comorbidities or on medications that would make polypectomy too risky (anticoagulation) [19].

Polypectomy Techniques

Polypectomy is fundamental to the practice of colonoscopy. The principles of polypectomy are to remove all visibleadenomatous tissue. There are many different techniques that are used in creating a wide variability in practice. Reasons for variability likely reflect the lack of standardized polypectomy protocols, difference in training and experience, missizing of polyps, and concern regarding adverse events and time constraints [21].

Polypectomy is best performed with the polyp in the 5–7 o'clock position. Cold forceps biopsy is the simplest method of polypectomy. This is frequently used for diminutive lesions (polyps < 5 mm). In a survey of 187 gastroenterologists, forceps removal was the resection technique of choice for lesions 1–3 mm in size [22]. The technique for polypectomy using cold biopsy forceps is simple. The biopsy forceps is passed through the biopsy channel of the colonoscope and the jaws are positioned over the polyp. The polyp tissue is grasped and removed. The forceps is removed for tissue retrieval [23]. This technique requires minimal manipulation, uses no electrocautery, and has an insignificant risk of perforation [24]. Frequently however, more than one bite is needed to remove all polypoid tissue. In addition, after the initial bite, minor bleeding can obscure the field, increasing the risk of leaving residual polyp behind. Biopsy and histologic evaluation of polypectomy sites after what was considered a complete cold forceps polypectomy can show residual polypoid tissue in 29–38% of specimens [25–27]. In addition, if two bites are taken in one pass, the tissue obtained with the

first bite can become dislodged and get lost. Therefore, a single-bite polypectomy may be more efficient and decrease the risk of incomplete polypectomy. In comparing jumbo forceps (jaw volume 12.44 mm) to standard forceps (jaw volume 7.22 mm) in a randomized controlled trial, a trend toward a higher complete histologic eradiation was noted with the jumbo forceps but this did not reach statistical significance [28].

Another method of removing small polyps is with the application of electrocautery to the forceps during tissue removal. The application of thermal energy fulgurates the base of the polyp while the specimen is protected in the jaws of the forceps [29]. There are several drawbacks to this technique, which have caused it to fall out of favor. There may be architectural distortion from thermal energy resulting in impaired histologic evaluation of the specimen [30]. This technique has also been associated with an increased risk of delayed bleeding and perforation in the right colon [31, 32]. It has also been suggested that the use of hot biopsy forceps is unreliable in completely removing all adenomatous tissue with 17% of polypectomy sites revealing persistent viable polyp remnants [33]. National societies recommend avoidance of hot biopsy forceps for polyps >5 mm and those in the right colon [34, 35].

Snare polypectomy is the preferred method for polypectomy among clinical gastroenterologists [22]. Once the instrument is passed through the working channel of the scope, the snare is extended from a plastic sheath and then passed around the base of the polyp. Once it is in proper position, the snare is closed transecting the base of the polyp. Advancing the catheter tip or sheath to the base of the polyp will avoid the snare from slipping back over the head of the polyp [23]. Snare polypectomy can be done with a cold technique or combined with electrocautery. It has been suggested that cold snaring is the preferred technique for all small (<10 mm) and most diminutive polyps but this has not been well studied [36, 37]. The technique of cold snaring allows for a resection of a 1–2 mm margin of normal tissue around the polyp. Bleeding is typically minor and not significant [38]. Several randomized controlled trials have shown that the risk of bleeding is similar between cold and hot snare polypectomy in lesions up to 8 mm and use of the cold snare may actually shorten procedure times [38–40]. The application of electrocautery with snare polypectomy is more common for larger polyps (>7–8 mm) and pedunculated polyps [21, 22, 41]. As previously stated, the polyp should optimally be in the 5–7 o'clock position and if it is a pedunculated polyp, one may consider repositioning the patient so the base of the polyp is not in a dependent position to make post-polypectomy bleeding easier to control. When using electrocautery, the polyp should be tented toward the center of the lumen to stretch the submucosa away from the muscularis propria and serosa. The duration of energy delivery should be minimized to prevent injury to the wall of the colon. For pedunculated polyps, the snare should be closed at a third or halfway from the base of the polyp to ensure a sufficient stump to regrasp if there is immediate bleeding. Energy should be applied early and the snare should be closed slowly [23]. There are many different snare devices available and there are no trials to establish the advantage of one device over another. In a study looking at 147,174 subcentimeter polyps from the English Bowel Cancer Screening Program, pedunculated polyps were most commonly removed using hot snare (84.7%) although this technique was used somewhat less frequently in the right side of the colon than in the left side for all polyps sizes (69.6% vs. 88.3%, $p<0.001$). For non-pedunculated polyps, hot snare was also the most commonly used technique overall (29.2%) [21].

Endoscopic Mucosal Resection

Large polyps, those involving more than one third of the circumference of the colon or two haustral folds, or those with a flat or depressed morphology are more challenging to remove with the standard polypectomy technique. [42] Endoscopic mucosal resection (EMR) can assist in removal of these lesions that may otherwise require surgical intervention. EMR allows removal of superficial tumors of the gastrointestinal tract. This technique was originally described and popularized in Japan for the treatment of gastric and esophageal tumors. It was further described for removal of colorectal polyps that were not amenable to traditional endoscopic polypectomy techniques. Because the plane of resection of EMR is typically the middle to deep submucosal layer, compared with standard polypectomy, which normally provides resection at the mucosal layer, EMR offers the potential advantage of providing en bloc resection specimens for histopathologic analysis. Unfortunately however, EMR tends to result in piecemeal excision of polyps which can cause difficulty with histologic diagnosis, staging and evaluation of margins. In addition, in contrast to the stomach, the colon wall is much thinner which can lead to higher rates of complications, i.e., perforation. Indications for EMR include adenomas or small well differentiated carcinomas that are confined to the mucosa or with superficial invasion of the submucosa, polyps less than 1/3 the circumference of the lumen and flat or depressed polyps [42].

EMR is a modification of conventional snare polypectomy. A solution is injected into the submucosa beneath the lesion. This serves to elevate the mucosal layer that contains the lesion on a submucosal fluid cushion providing a safety zone for snare resection. Many different solutions have been used for injection including normal saline, hypertonic saline, 50% dextrose, glycerol solutions, hyaluronic acid, and diluted epinephrine solution. The ideal agent prolongs the "pillow effect" which decreases the risk of bleeding and perforation [42]. Once the lesion is raised, snare polypectomy is performed. For large lesions, piecemeal polypectomy is invariably required. The cap-assisted technique (EMRC) is

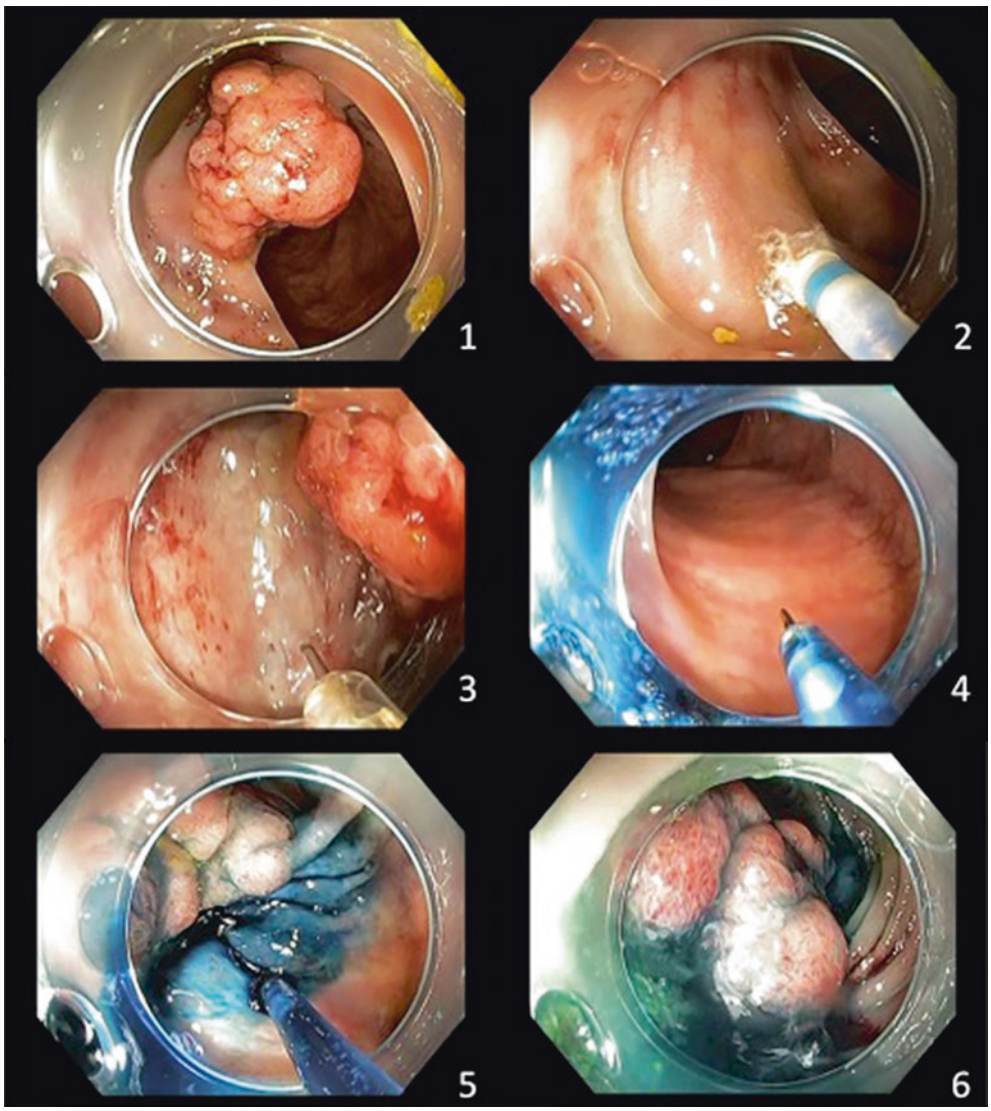

Figure 5-1. Illustration of piecemeal endoscopic mucosal resection. 1–6: mucosal lift by submucosal injection of indigo carmine.

another method used which involves a cap with a lip on the distal end. A snare is positioned around the lip of the cap and then the target mucosa is suctioned into the cap. Once the tissue is aspirated, the snare is then closed around the tissue (Figures 5-1 and 5-2). The benefits of this technique are reported better visualization and the possibility of resecting lesions in variable positions. The pressure of the cap on the wall of the colon allows flattening of the folds maximizing the view of interhaustral lesions. This technique is frequently performed in the stomach in Japan. EMRC is not as popular for colorectal polyps for fear of entrapping the muscularis propria into the snare, therefore increasing the risk of perforation [43].

EMR is limited by the difficulty in determining which lesions are likely to be confined to the mucosa. In a prospective, multicenter cohort, risk factors for submucosal invasion and failure of successful EMR were identified. In their experience, risk factors for submucosal invasion were Paris classification 0-IIa+c morphology, non-granular surface morphology, or Kudo pit pattern type V (Tables 5-1 and 5-2). The presence of multiple risks factors magnified the risk of submucosal invasion [44]. In this study, EMR was attempted on 464 patients and successful in 89% of patients. Risk factors for failure included a prior attempt at EMR (OR=3.8; 95% CI: 1.77–7.94), difficult position (OR=2.17; 95%CI: 1.14–4.12) and ileocecal valve involvement (OR=3.38; 95%CI: 1.20–9.52).

EMR is effective and practical with good outcomes (Table 5-3). When performed by experts, anywhere from 3 to 7% of patients are referred for surgical resection because of inability to remove the polyp endoscopically [45, 46]. Approximately 44% of lesions are removed en bloc and the remaining are removed piecemeal [45]. Complication rates

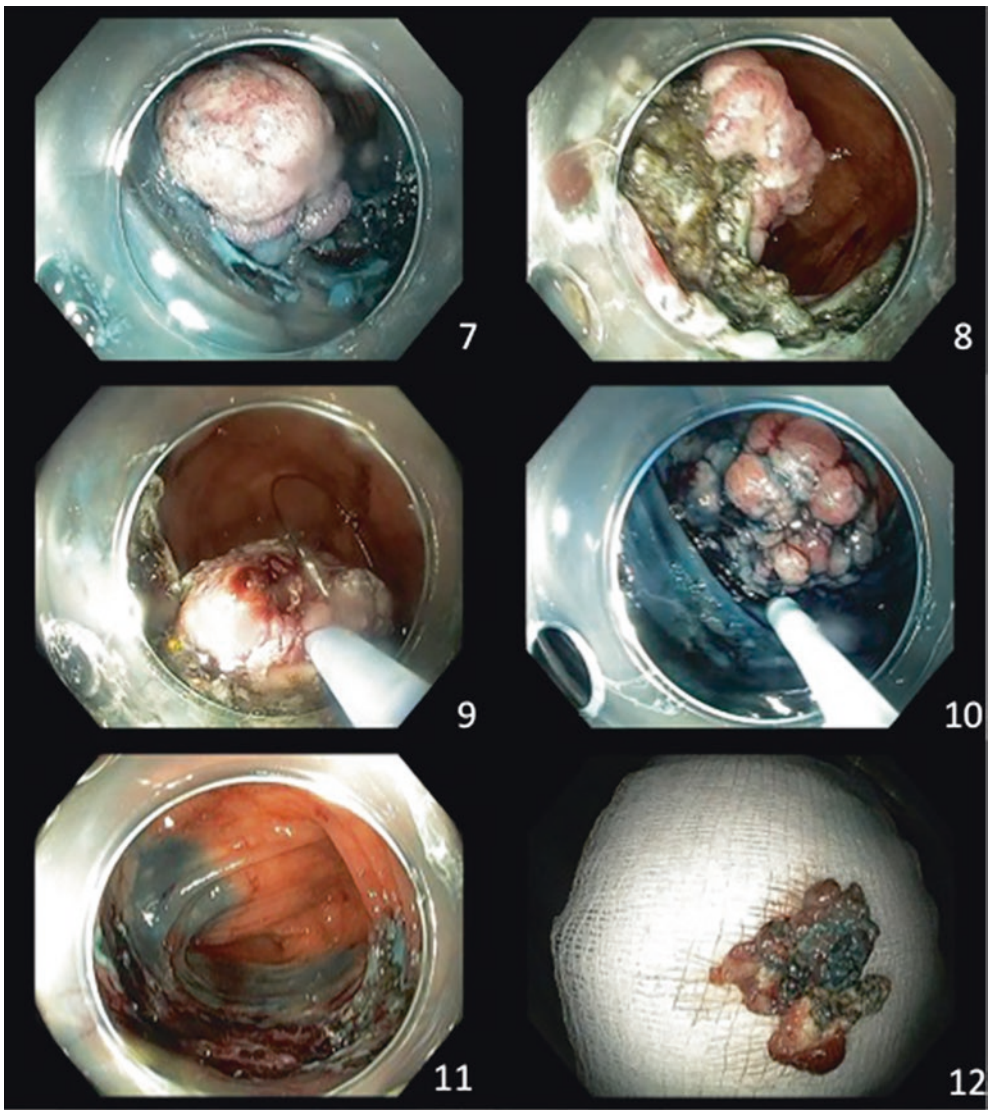

FIGURE 5-2. Illustration of piecemeal endoscopic mucosal resection. 7–10: Piecemeal hot snare polypectomy. 11: intact muscularis. 12: Removed specimen.

TABLE 5-1. Paris classification

Pedunculated	Ip
Subpedunculated	Isp
Sessile, higher than height of closed forceps (2.5 mm)	Is
Slightly elevated, below height of closed forceps (2.5 mm)	IIa
Completely flat lesion, does not protrude above mucosal surface	IIb
Slightly depressed, lower than mucosa but depth < 1.2 mm	IIc
Excavated/ulcerated, deep ulcer below mucosa below 1.2 mm	III

TABLE 5-2. Kudo pit pattern

Pit pattern type	Characteristics
I	Round pits
II	Stellar or papillary pits
III S	Small tubular or round pits (smaller than type I pits)
III L	Large tubular or round pits (larger than type I pits)
IV	Branch-like or gyrus-like pits
V	Irregular or non-structured pits (absence of pit pattern)

are low. Intraprocedural bleeding occurs in about 8% of patients, post-procedural bleeding in 0–1%, and perforation 1–2% [45, 46]. Local recurrence after EMR is variable and reported in up to 27% of cases [47]. In a multicenter, prospective study of 1000 consecutive patients treated with EMR where the lesion was thought to have been completely treated, early recurrent/residual adenoma (4 months following EMR) was present in 16% and late recurrent/residual adenoma (16 months following EMR) was uncommon (4%). On multivariate analysis, risk factors for recurrence were

Table 5-3. Endoscopic mucosal resection

Author	Year	Polyps	Polyp size (cm)	Macroscopic classification	Operating time (min)	En bloc resection (%)	LOS (day)	Leakage/ fistula (%)	Postoperative bleeding (%)	Cancer (%)	Depth	Recurrence (%)
Gomez	2014	131	3.3	NA	NA	27	NA	3	2.3	7.6	Unknown	17
Maguire	2014	269	2.8	NA	NA	0	NA	1.3	3	16	Tis: 6.3%; T1: 9.3%	24
Knabe	2013	252	>2.0	Paris	NA	12	NA	1.6	1.6	3.2	Unknown	22
Buchner	2012	315	2.3	Paris	NA	54	<1	0.4	7.2	4.4	Unknown	27
Conio	2004	139	2.0	NA	NA	0	NA	0	0	12.2	Tis: 6; T1: 3; T2: 1	21.9
Stergiou	2002	68	>3.0	Sessile/pedunculated	NA	38	NA	0	4	10	Unknown	29

LOS length of stay, *Tis* carcinoma in situ, *NA* not available

lesion size >4 cm, use of argon plasma coagulation to ablate adenomatous tissue and intraprocedural bleeding. The recurrent adenoma was usually unifocal and diminutive, and was managed endoscopically in 93% of cases [45]. Further reported risk factors for recurrence include granular appearance of the lesion and distal rectal lesions. Incomplete resection and resections with deep positive margins should be considered for surgery [48].

Endoscopic Submucosal Dissection

The technique of endoscopic submucosal dissection (ESD) developed for en bloc resection for large and ulcerative lesions in the stomach has been widely accepted in Japan for the treatment of early gastric cancer [49]. Compared with EMR, ESD has the advantage of definitively permitting an en bloc and therefore histologically complete resection. With this technique, one is able to resect superficial lesions regardless of tumor size, location, and fibrosis [50–52]. These advantages come at the cost of an increased risk of perforation, bleeding, and a longer procedure time as compared with EMR. [53]

As the major difference between surgical resection and endoscopic resection is the absence of lymph node dissection, endoscopic resection should only be considered in lesions that have an insignificant risk of lymph node metastasis. The risk of lymphatic disease is largely based on a tumor's depth of invasion, and hence, a large part of the evaluation is determining this. Therefore, the use of ESD for colorectal lesions has been limited to patients who have undergone accurate preoperative diagnosis. This technique is indicated when an en bloc resection cannot be done with EMR. It is also indicated for polyps with intramucosal to shallow submucosal invasion as well as lesions with submucosal fibrosis that cannot be lifted with submucosal injection during conventional EMR. It may also be indicated in sporadic localized tumors in conditions of chronic inflammation such as ulcerative colitis or local residual or recurrent early carcinomas after endoscopic resection [54]. Experience with ESD outside of Japan is still limited. In a consensus statement by a panel of experts, the goals of ESD remain: treating mucosal cancer, achieving an R0 resection, meeting quality standards, ensuring the procedure is performed by endoscopists trained in this technique and under institutional review board approval [55].

The technique of ESD is similar to EMR in that it involves a single channel scope and submucosal injection. The border of the lesion may first be marked out by injecting indigo carmine or using indigo carmine dye spray. A variety of solutions have been used for submucosal injection but the most common are normal saline, glycerol or hyaluronic acid. Normal saline is safe and widely available but the lift that it creates is of short duration, which may come at a disadvantage. For safety in the thin walls of the colon, longer lasting solutions such as glycerol or hyaluronic acid are needed [56]. The optimal injection solution should achieve and maintain the necessary submucosal lifting height and duration, not influence the histological evaluation, not have tissue toxicity and be easily prepared and administrated [57]. Once the lesion is lifted, specialized endoscopic knives help to dissect out the lesion (Figure 5-3). There are a variety of knives available but the two traditional types of needle knives and insulted tip knives. Both types of knives are used in combination with electrocautery to dissect and separate the mucosal and submucosal layers. Bleeding is common during ESD, and therefore, management of bleeding is important for the procedure to be successful. Hemostasis is maintained using either monopolar or bipolar coagulation forceps, which can increase the risk of perforation or hemoclips, which can obstruct the plane of dissection [56].

Similar to new techniques elsewhere, ESD has a high learning curve. Compared with gastric lesions, ESD in the colon and rectum is more difficult due to anatomic features (thin wall, peristalsis, folds) and the position of the endoscopic is less stable especially outside of the rectum. Probst and colleagues divided their experience with ESD into three periods and demonstrated a clear learning curve over time with resection rates increasing and procedure times decreasing as expected. They suggest a learning curve of 25–50 cases [58]. Others have suggested 40 procedures are necessary to acquire skill in avoiding perforation and 80 cases to be proficient in resecting large colorectal lesions [59]. Successful en bloc resection may be as low as 60% in initial cases but increases up to 88–97% with experience [58–60]. Similarly, R0 resection rate improves with experience and is reported as high as 96% [58]. Procedural complications are higher than with EMR and consist of bleeding in 1.5–7.9% and perforation in up to 10.7% of cases (Table 5-4) [58, 60, 61]. Frequently, complications are successfully treated with endoscopic clipping. Follow up and surveillance after ESD should be case dependent. The aim of surveillance is to detect residual disease or recurrent disease early. The follow up plan should be based on whether resection was en bloc or piecemeal, the pathology of the lesion, risk factors for multiple lesions and underlying disease [54].

Combined Endo-Laparoscopic Surgery (CELS)

As previously discussed, large polyps or polyps within or behind a haustral fold can be very challenging to remove endoscopically. Although EMR and ESD are performed for

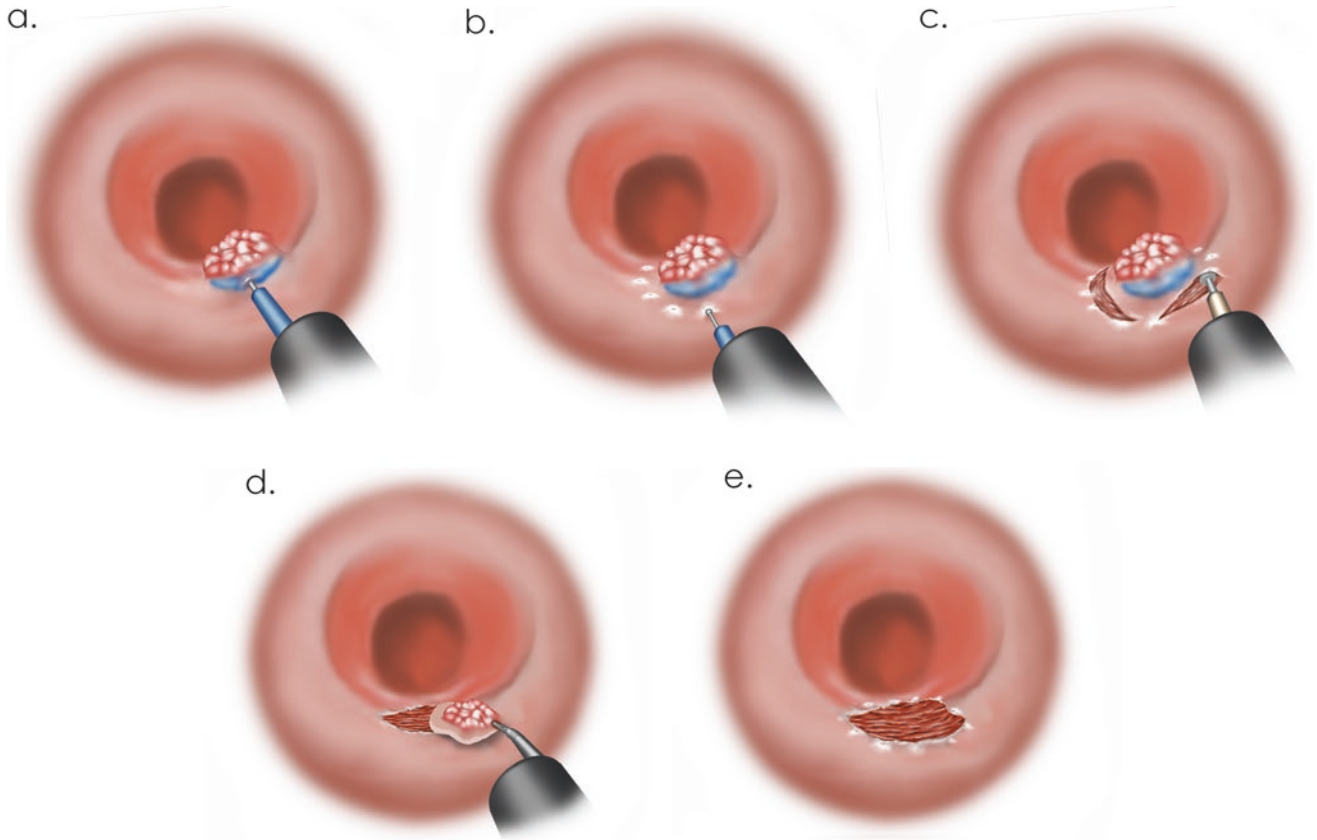

FIGURE 5-3. Steps of endoscopic submucosal dissection. (**a**) submucosal injection. (**b**) marking of the resection margin. (**c**) submucosal dissection using a needle knife. (**d**) extraction of specimen. (**e**) intact muscularis.

these polyps, these techniques are not widely available and require a high level of technical skill. Traditionally, the most common recommendation for these patients has been segmental colectomy—an oncologic resection. Although the laparoscopic approach can minimize the morbidity associated with colectomy, only a minority of the colon resections performed in the USA are being done laparoscopically [62]. Furthermore, even if a minimally invasive approach is used, it still entails a major abdominal operation with associated morbidities. Combined endo-laparoscopic surgery (CELS) has been described as an alternative to bowel resection in select patients.

Laparoscopic assisted polypectomy was first described in 1993 as a means to avoid bowel resection [63]. Larger retrospective studies have since been published indicating that the technique is safe and effective [64–69]. There are several ways in which laparoscopic assistance during colonoscopic polypectomy can be helpful: (1) the underlying colon can be invaginated to assist in snaring of a flat polyp, (2) laparoscopic mobilization of flexures and angulated colon can provide better access and exposure, and (3) full-thickness injury to the colon can be detected and repaired laparoscopically. Simultaneous performance of laparoscopy and colonoscopy can often present technical challenges. Insufflation using room air during colonoscopy can significantly obscure the laparoscopic view and compromise exposure. A technique of laparoscopically clamping the terminal ileum to minimize bowel distention has been described, but colonic distension is still a major impediment with this method [63, 64]. The use of carbon dioxide (CO_2) for insufflation during

TABLE 5-4. Endoscopic submucosal dissection

Author	Year	Polyps	Polyp size (cm)	Macroscopic classification	Operating time (min)	En bloc resection	LOS (day)	Perforation (%)	Postoperative bleeding (%)	R0 resection rate (%)	Cancer (%)	Depth	Recurrence (%)
Saito	2014	900	3.7	Paris	60	91	NA	2.7	1.7	87	74	Unknown	NA
Toyonaga	2014	468	3	NA	60	99	NA	1.5	1.5	NA	66	Tis: 49%; T1: 17%; T2: 0.4%	NA
Lee	2013	874	2.7	sessile/pedunculated	54	97	3.5	5.3	0.5	91.2	43	Tis: 28%; T1: 15%; T2: 0.2%	0.4
Yoshida	2013	530	3.1	protruding/superficial	93	91	NA	4.1	2.3	NA	54	Tis: 41%; T1: 12%	NA
Nakamura	2014	300	3.0	LST/ non-LST	90	91.7	5	1.7	5	91	99	M-SM-s: 92%; SM-d: 7%	NA

LOS length of stay, *NA* not available, *Tis* carcinoma in situ, *M-SM-s* mucosal or shallow submucosal invasion <1000 mcm from the muscularis mucosae, *SM-d* >1000 mcm of submucosal invasion

TABLE 5-5. Combined endo-laparoscopic surgery

Author	Year	Patients	Polyps	Polyp size, (cm)	Frozen section	Operating time (min)	Intraoperative complications (%)	Postoperative complications,%	Mortality (%)	LOS (days)	Tis (%)	Submucosal cancer (%)	Successful endoscopic resection (%)	Conversion to open surgery (%)	Prognosis (m = months)
Goh	2014	30	30	1.4	–	105 (75–125)	0	13.3	0	2.0	HGD 26.7	6.7	73	0	no recurrence at 20m
SW Lee	2013	75	75	3 (1–7)	if needed	145 (50–249)	0	9.2	0	1	HGD 9.3	6.7	74	3	10% recurrence at 65m
Wood	2011	13	16	3 (2–5)	all	NA	0	15	0	2	7.7		77	0	NA
Grunhagen	2011	11	12	2 (0.6–4.5)	–	45 (15–80)	0	18.1	0	1	9	0	82	0	no recurrences at 11m
Cruz	2011	25	25	2.4 (1–4)	–	92.7 (60–145)	0	8	0	1.5	8	4	76	0	NA
Agrawal	2010	19	19	0.6–6	all	35.3–37	0	5.6	0	0–14	5.3		58	NA	no recurrences at 3m
Wilhelm	2009	146	154	NA	–	100 (40–272)	1	25	0.7	8	11		73	5	Local recurrence of adenoma 0.9% at 35m
Franklin	2009	176	251	3.7 (2–6)	all	96.5	0	10	0	1.1	10.2		91	0	no recurrences at 65m

NA not available, *HGD* high grade dysplasia, *Tis* carcinoma in situ, *LOS* length of stay

colonoscopy has been shown to be safe and can remedy this issue. CO_2 gas is absorbed approximately 150-times faster than room air so there is minimal unwanted distention of the colon providing excellent simultaneous endoscopic and laparoscopic visualization [70].

Consideration for CELS starts by reviewing the initial procedure report and photographs looking for any concerning signs of malignancy, such as ulceration and hypervascularity. Presence of high-grade dysplasia is concerning for malignancy but is not necessarily a contraindication to performing CELS. In our practice, prior to obtaining laparoscopic access to the abdomen, colonoscopy is performed and at that point, decision is made whether the polyp is resectable using colonoscopy alone or if laparoscopic assistance is needed (Video 5.1). If laparoscopic assistance is needed, then abdominal access is performed. The exact location of the polyp is determined by visualizing the tattoo mark and manipulating the polyp laparoscopically while visualizing the polyp endoscopically. For laterally and retroperitoneally located polyps, the colon needs to be mobilized. Polyps located on the mesenteric side may be difficulty to visualize and laparoscopically repair in case of perforation. Once the polyp is identified intraluminally, using laparoscopic manipulation, the base of the polyp is exposed. The lesion can then be elevated further with submucosal injection. Malignancy is suspected with specific morphology (ulceration, central umbilication, or a vascular pattern on narrow-band imaging) or if the polyp does not lift up with injection. If there is no suspicion of malignancy, polypectomy is performed using snare and electrocautery. The wall of the colon can be invaginated laparoscopically to aid in optimal snaring of the polyp. While polypectomy is performed, the serosal aspect of the colon can be monitored for thermal related changes. If a full-thickness burn of perforation is even suspected, repair can be done intracorporeally. An air leak test can also be performed using insufflation with the colonoscope. If the polyp feels firm on palpation or seems in any way suspicious for malignancy after excision, an intraoperative frozen section can be performed. In select patients with cecal or right colon polyps, if the polyp is located on the anti-mesenteric side of the colon, a colonoscopic assisted laparoscopic wall excision can be performed using a laparoscopic stapler. When the stapler is placed across the bowel wall, colonoscopy can be used to monitor the margins of excision and the ileocecal valve when in the cecum.

Several published studies have similarly addressed this combined technique, considering it a safe and effective method to avoid colectomy and remove difficult polyps in many cases (Table 5-5). A large study describing a 10-year experience with the technique of combined laparoscopic endoscopic resection reported results on 146 patients with 156 lesions. The authors performed four separate techniques combining endoscopy and laparoscopy but only eight patients (5.4%) had laparoscopic-assisted endoscopic resection. Most of the patients (76.7%) underwent either an endoscopic-assisted transluminal resection, which was done through a colotomy. In addition, the mean length of stay was 8 days, which is long compared with other studies. This may have been due to the nature of the resections. There was also a 25% complication rate, which may have contributed to the prolonged length of stay. Although there was only a 0.9% local recurrence rate, with a follow up of 2.9 years [65]. One of the largest studies to date was reported by Franklin and Portillo describing the technique of laparoscopic-monitored colonoscopic polypectomy in 176 patients with excision of 251 polyps. The procedure was performed successfully in all but four patients (97.8%). This study was an update of two previous publications from their group in 2000 and 2007. In their practice, all specimens were sent for frozen section and ultimately, 18 (10.2%) patients required colectomy for cancer [71].

Overall, technical success rates for CELS are consistently reported between 74 and 97%. Postoperative complications are typically minor and less than 5%. Recurrence rates are low, reported in 10–15% and can typically be approached endoscopically or with CELS [65, 69, 70].

Conclusion

Polypectomy is fundamental to the practice of colonoscopy. A range of techniques is available and the choice of technique should be tailored to the size, site, and morphology of the polyp. There is a wide variation in practice. Advanced endoscopic techniques such as EMR, ESD, and combined endolaparoscopic techniques provide options for patients with benign polyps not amenable to traditional endoscopic removal that would have otherwise undergone colon resection. Although polyp removal using these advanced techniques may be an effective alternative in select patients, they require both experience and expertise to become an available option in a surgeon's armamentarium [66, 70, 71].

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