4. Difficult polypectomy

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Synopsis

This chapter describes various techniques that can be employed to assist in the removal of colon polyps that are considered to be large or ‘difficult.’ Size alone is only one of the features that may cause some hesitation in making the decision to attempt polyp removal. Other factors that are related to the perceived level of difficulty are polyps that are flat and only slightly elevated above the mucosal surface, location on a wall of the colon that is not accessible to the snare, a polyp in a segment of severe diverticular disease or wrapped around a fold in clam-shell fashion. A polyp situated behind a fold can be difficult to approach, and those in the cecum hidden behind the ileocecal valve present a special challenge for resection. These and other problems will be addressed in this chapter as will the localization of lesions or polypectomy sites for future surgery (in the case of malignant polyps) or for reevaluation following total or incomplete polyp removal. The impossible polyp is one which the endoscopist feels cannot be removed. The feeling of futility when faced with such a polyp is directly dependent on the training, experience, and courage of the endoscopist. What may be ‘impossible’ for one endoscopist may be a relatively ‘routine’ polypectomy for another. In general, there are three criteria that make a polyp ‘impossible’, and when the three occur in the same lesion, then the polyp may be ‘really impossible’. The three factors which by themselves or in combination with others may place the polyp in an ‘impossible’ category are size, location of the polyp, and configuration.

Factors suggesting difficulty in polypectomy

Polyp size

It is fortunate that polyps over three centimetres in diameter are not commonly found during colonoscopy. During the last 30 years, only few publications [1–8] have reported on endoscopic removal of large colorectal polyps (Fig. 1). Christie et al. [3] found in 1977 that only 58% of colorectal polyps measuring 20–60 mm were amenable to endoscopic polypectomy. Bedogni et al. [9] reported in 1986 that in their experience 75% of colorectal polyps larger than 30 mm were endoscopically removable (66% of the removed polyps were sessile). Lower malignancy rates of less than 15% in large colorectal polyps have been reported irrespective of their macroscopic and histologic growth pattern [2,10].

Malignant potential

When large sessile polyps are identified, several decisions will impact upon the probability of its removal. The first factor to consider is whether the polyp is benign or malignant. A question that arises is whether to perform a biopsy and then bring the patient back for polypectomy based on the subsequent results of biopsy or to depend on the visual impression of whether the polyp is benign.

There are no studies on the visual criteria which can be applied to a polyp to determine the presence of malignancy, however, endoscopists in a tertiary referral center in Hamburg, Germany [2] have stated that a benign polyp does not have any of the following features: ulceration, induration, or friability. Japanese endoscopists [6] who endeavored to remove large polyps noted that large flat polyps were usually benign, and that invasive carcinoma was only seen in elevated sessile polyps.
These visual characteristics may not always be accurate, but biopsies are notoriously erroneous for the diagnosis of invasive carcinoma within a polyp because the depth of tissue obtained is usually limited and because high-grade dysplasia on biopsy (which used to be called non-invasive carcinoma or carcinoma in situ) is histologically identical to invasive carcinoma.

In addition, the amount of tissue sampled by biopsying a large polyp represents only a fragment of the total polyp volume submitted for histopathology. Most colonoscopists base the decision as to whether a large polyp is benign or malignant on the visual impression when it is identified.

If the assessment is that the polyp is benign, the decision for removal should be based on other visual criteria; if it looks like it can be removed, an attempt should be made to resect it (Fig. 2).

There is a general reluctance among endoscopists to remove large polyps because of the possibility of invasive carcinoma. One report stated a 40% incidence of invasive carcinoma in large polyps, but this finding was based on the pathologist's finding of carcinoma in surgical specimens that were sent to the pathology laboratory, not polyps which were removed endoscopically [11]. Endoscopically resected polyps, which meet the visual criteria of being benign, will actually have an incidence of about 10–15% of invasive malignancy [2,6,9,10].

**Configuration ▲▼**

Assuming the polyp appears to be benign macroscopically, the average endoscopist (as opposed to the expert) will have greater difficulty if any of three features [12] are present.

- The polyp occupies more than one-third of the circumference of the colon wall.
- The polyp crosses over two interhastral septae.
- The polyp encircles and actually involves the base of the appendix.

**More than one-third of the circumference ▲▼**

The polyp which extends more than one-third the circumference of the colon wall will create a large mucosal defect if it is removed. It is possible that polyps of this size could be removed by an expert endoscopist (Fig. 3), but even the expert may elect to send such a patient for surgical resection rather than face the possibility of multiple colonoscopic examinations, particularly if the colonoscopic approach to the polyp was extremely difficult and demanding.

**Polyps crossing two haustral septae ▲▼**

Polyps that cross over two interhastral septae present another problem in their total removal, since it may be almost impossible to remove the entire polyp, especially the portion that lies in the valley between two interhastral septae.

**Polyps involving the appendiceal orifice ▲▼**

Polyps that involve the appendiceal orifice may extend into the appendix, and, although this phenomenon is rare, total removal of this type of polyp is problematic (Fig. 4).
**Bleeding risk**

Large pedunculated polyps have a large nutrient artery, and may bleed during or after polypectomy. Injection of epinephrine into the stalk may decrease the risk of bleeding. Other measures are application of endoloops; or a technique of using one disposable snare to cut off the blood supply and another to perform the resection \([13,14](Fig. 5)\).

**Practice issues for difficult polyps**

**Risks and consent**

When the decision is made by the endoscopist to attempt removal of large polyps, it is necessary to obtain the patient's agreement with repeated endoscopy sessions and follow-up endoscopies. Complete resection of large sessile polyps may require several sessions, and since high rates of local recurrences are reported \([4,8,9]\), it is mandatory to confirm complete removal by follow-up examinations.

Much of the reluctance to remove large polyps is related to the fear of complications. The actual incidence of perforation in removal of large polyps is low, with 2 series \([2,6]\) of large polypectomies reporting that no patients required surgical intervention, there were no perforations, and when bleeding during polypectomy occurred in 10% and 24% \([2]\) of patients it was successfully handled. The published rate of complications indicates that bleeding occurs in 1.4% of polypectomies and perforation in 0.3% of patients \([5]\).

**Ambulatory or in-patient polypectomy**

Most diagnostic colonoscopies are performed on an ambulatory basis. When a large polyp is encountered that meets the criteria for removal, the endoscopist must decide whether the patient should be admitted to the hospital, or, to do the polypectomy in a hospital out-patient setting, or whether it is safe to perform the procedure in an office facility remote from a hospital? Literature supports the safety of ambulatory polypectomy \([15]\), and only 1 of 170 patients who had large polyps removed required immediate hospitalization for suspected perforation \([2]\).

**Which colonoscope for difficult polyps?**

For difficult polypectomy, a therapeutic colonoscope with a 4.2-mm working channel and an additional channel for a water pump is recommended. This allows for sufficient simultaneous suction during the procedure which is particularly helpful in the face of severe bleeding. An additional small-bore channel connected to a water pump provides a strong water jet for cleansing the mucosa surface, e.g. in case of oozing during EMR or piecemeal resection. Many endoscopists use a standard colonoscope for removal of large polyps.

**Sometimes a thinner endoscope is helpful**

A pediatric colonoscope is useful, but not generally available. A standard upper intestinal gastroscope has been demonstrated to be of benefit \([35]\). The major attributes of the gastroscope is that it has a tighter bending radius of the tip than does a colonoscope and the tip beyond the bending portion is shorter in length. This will frequently allow easy snare positioning in the same location where the colonoscope was both cumbersome and difficult. There is a growing awareness among endoscopists
that gastroscopes can easily and readily be used in the colon to intubate difficult and narrowed segments, to be passed through strictures, and to render a previously inaccessible polyp more readily manageable. The upper intestinal endoscope can be of use even in the rectum, where it may not be possible to snare a polyp on the proximal surface of one of the rectal valves. In this circumstance, the bending section of the colonoscope may be too long to permit a tight turn, whereas a gastroscope with its greater tip deflection capability and shorter ‘nose’ (or straight portion beyond the bending section) may permit easy visualization and removal of polyps.

**Which snare? ▲▼**

**Types of snares ▲▼**

For resection of difficult polyps there is probably no significant difference between snares made of braided and monofilament wire. A braided wire creates more coagulation effect than a monofilament wire. Bleeding may be less frequent with braided wire, but it may carry a higher risk of perforation due to greater thermal penetration depth. In our experience, a monofilament snare made of 0.5 mm steel wire is stiffer and provides greater stability for ensnaring flat polyps (Fig. 6). The standard Erlangen polypectomy snare (Grosse Co., Daldorf, Germany) is 5 × 3 cm of size. In a narrowed bowel lumen such as encountered in diverticulosis, a smaller floppy snare made of braided wire may be useful.

**Use of the mini snare ▲▼**

Even after total colonoscopy has been performed and the colonoscope has been straightened, there may still be difficulty in the sigmoid colon when attempting to capture a polyp because of narrowing by diverticula and thickened hypertrophic folds. There are two maneuvers which may permit easier endoscopic polypectomy.

The first is to use a mini snare, which will allow a full extension of the snare within a short segment of the bowel. The standard regular-sized polypectomy snare may not be able to capture a small polyp in a difficult and ‘tight’ location where there is not sufficient distance for the wire loop to open sufficiently wide to be placed over a polyp.

A problem with the standard snare is that it must be completely extended to its full length of 6 cm in order for the loop to completely expand. During colonoscopy, it often occurs that the wire loop can only be extended a few centimeters beyond the scope because of a tight bend or because the tip of the loop impacts on an adjacent wall of the colon. When the snare loop cannot be fully extended, the two partially open parallel wires may not sufficiently spread apart to enable polyp capture. In this circumstance, a ‘mini’ snare 3 cm in length and 1.0 cm in width [33,34] is extremely valuable. This snare will open fully when extended only 3 cm beyond the sheath making it useful in areas where multiple bends are present (such as in the sigmoid narrowed with diverticulosis), or when polyps are located in the depth between intrahaustral folds. Since the vast majority of colon polyps are less than 1.0 cm in diameter, they are within the limits of this mini-snare.

**Submucosal injection for polypectomy (SIP) ▲▼**

The submucosal injection technique is often used for removal of large sessile adenomas [16,17]. Deyhle et al. first performed submucosal injection to raise flat mucosal lesions facilitating ensnaring in 1973. Saline or epinephrine solution (1 : 20 000) is injected from the margins of the polyp. Submucosal injection may be useful to lift parts of the polyp located in the appendiceal orifice or behind a haustral fold. However, submucosal injection even with large amounts of saline solution may not avoid
perforation, if too large pieces of polyp are ensnared and resected [18]. Diluted epinephrine solution is used to prevent bleeding during polypectomy. However, a possible drawback of this precaution may be delayed bleeding due to the short-lasting vasoconstrictive effect of epinephrine.

Endoscopic mucosal resection (EMR) using a double-channel endoscope was introduced by Tada et al. in 1993 [19] to remove large sessile and flat polyps. The lesion is lifted by using a forceps to enable ensnaring (‘lift and cut’ technique). Several modifications of EMR technique have been introduced in the management of early cancer of the stomach and esophagus [20].

In the colon and rectum, EMR is widely performed using the simple snare resection technique. The colon wall is 1.5–2.2 mm in total thickness, and thermal damage to deep layers of the colon is frequently encountered [21]. Injection of fluid into the submucosa beneath the polyp will increase the distance between the base of the polyp and the serosa. When current is then applied via a polypectomy snare, the lesion can be more safely removed because of a large submucosal ‘cushion’ of fluid which lessens the likelihood of thermal injury to the serosal surface.

It is permissible to remove a much larger piece with this technique than one would ordinarily resect when in the right colon without a ‘cushion’ of fluid. The pieces should probably not be larger than 2 cm in diameter [6]. With the fluid as protection against deep thermal tissue injury, it is possible to fulgurate the base of the resection site with devices such as a hot biopsy forceps, the tip of the snare, the argon plasma coagulator, or any other thermal device which delivers heat to the residual polyp site.

**Injection fluid ▲▼**

The fluid, injected through a long and stiff sclerotherapy needle, may be saline (normal or hypertonic) [22], with or without methylene blue to enhance visualization and with or without epinephrine [23]. Most endoscopists use normal saline only. Hypertonic saline solution and epinephrine are used to retain the fluid at the site for a longer period, but submucosal saline lasts for 10–15 minutes, which is sufficient time for removal of most polyps. A viscous mucinous solution of 0.5% sodium hyaluronate has been used (via a 21 gauge needle) to elevate large flat polyps for endoscopic mucosal resection [24]. This solution is isotonic and remains at the injection site longer than saline.

Further studies need to be performed to assess the practicality of various injection solutions. There is a theoretical advantage to the injection of dilute epinephrine, to prevent bleeding at the time of polypectomy or to prevent delayed bleeding (Fig. 7). However, the incidence of immediate bleeding is low (1 out of 100 procedures) [25], and the long-term effect is nil because the vasoconstrictive action is measured in hours, not days.

**Injection site ▲▼**

The injection needle may be placed into the submucosa just at the edge of a polyp, or if the polyp is large and flat, multiple injections may be given around the polyp or directly into the middle of the polyp. If a bleb does not form at the injection site when 1 mL of fluid has been given, the needle should be withdrawn since the tip may have penetrated the wall and pierced the serosal surface. When the needle is in the submucosal plane, continuous injection of saline will result in submucosal infiltration of fluid. A large localized fluid collection is the desired endpoint, with marked elevation of the polyp.

When the tissues expand in response to fluid injection, the fluid is being deposited in the areolar tissue of the submucosal layer since neither the mucosa, muscularis propria or the serosa will accept injected substance.
If the needle placement is too superficial, the fluid will leak out from the beveled edge and spill into the lumen. This spilling is especially noticeable when a colored fluid is used, such as methylene blue or India ink. Multiple repeated needle placements and attempts at injection may be required to locate the correct plane for polyp elevation. If possible, the approach by the needle injection should be tangential and not perpendicular to the mucosal surface. Polyps up to 2 cm in diameter may be removed with one application of the snare, but larger polyps may require several transections in piecemeal fashion [26].

**Polyps behind folds**

When part of the polyp is either hidden from view behind a fold or wrapped around a fold in clamshell fashion, injection of the part nearest to the colonoscope may elevate that portion, but can cause interference with polypectomy because the mound of saline will block vision. The solution to this problem when the proximal edge of the polyp is hidden is to inject the far side of the polyp. This is accomplished by passing the scope beyond the far edge of the polyp. While deflecting the tip toward the polyp, the injection should be made into the normal mucosa just at or near the edge of the polyp (or into the proximal edge of the polyp).

Injection into the wall on the far side of the polyp will raise that portion up on the fluid mound, rendering snare application easier (Fig. 8). Depending on the polyp size, several injections may be required to elevate the polyp so that snare placement is more readily accomplished. After the back portion of the polyp has been removed, then saline may be injected into the area closest to the scope to assist in completing the polypectomy.

**Injection volume**

When attempting SIP, there is not a specific volume of fluid which is used, but rather, the desired end point is a large submucosal swelling beneath the polyp and adjacent portions of the mucosa. Elevation of the polyp may take 3–4 mL of saline given in several places, although some authors use up to 30 mL of fluid [6].

**The non-lifting sign**

In general, malignant tumors should not be removed by the submucosal injection technique. If a polyp fails to elevate (the ‘non-lifting sign’) [27], it may be an indication of infiltration by cancer into the submucosa, with fixation by tumor limiting the expansion of the submucosal layer [28]. Although deep or superficial needle placement may be the cause for failure to raise a bleb under a polyp, a submucosal bulging or bleb on one side of a polyp in response to injection without any visible elevation of the tumor itself is a clue that there is fixation into the submucosa. This phenomenon may also be caused by a prior attempt at polypectomy with healing and scarring of the mucosa and submucosa, preventing their separation by fluid injection.

**Tumor tracking**

There is a theoretic possibility that injection through a malignant tumor may cause tracking of cancer cells into and even through the bowel wall. The risk of this happening is minimal, with experience gained from direct percutaneous needle aspiration of malignant tumors in other sites throughout the body. In the latter instances, the risk of tumor tracking is 1 in 10 000–1 in 20 000 cases [29].

Parenthetically, it seems that any tumor which can be elevated with submucosal injection of fluid may be totally removed by endoscopic resection, even if invasive cancer is found on tissue examination. The
ability to elevate a tumor indicates that there is only a limited degree of fixation to the submucosal layer, with the possibility of complete removal.

**Cap assisted polypectomy**

A suction cap may be attached to the colonoscope tip, and a preloaded snare can be placed at the mouth of the cap. Once the polyp elevated with SIP has been aspirated into the cap, a sizable portion of the wall can be removed using coagulation current. Caution is urged for using this technique above the peritoneal reflection [30]. Endoluminal full-thickness resection using a rigid instrument was introduced by Buess et al. to remove sessile and/or malignant polyps in the rectum (Buess et al. 1984) [31]. This technique may offer a better alternative to endoscopic piecemeal resection or resective surgery in selected cases. However, it does not allow for lymphadenectomy, and has therefore a limited use in malignant lesions that cannot be treated endoscopically. Furthermore, it is questionable whether a recently introduced system will allow polypectomy in the proximal colon.

**Polyp resection technique**

When complete visualization is not possible as the loop is being closed, the assistant should close until resistance is met, or, if no closure sensation, then stop at the line on the snare sheath. Once closed, the catheter sheath should be jiggled to and fro at the biopsy port while observing the colon walls around the polyp. If extraneous portions of the mucosa are not caught, the polyp will be seen to move independently of the surrounding colon walls as the sheath is jiggled. If the polyp and the surrounding wall move simultaneously, there is a strong probability that a portion of adjacent mucosa has been captured within the snare loop. Complete removal of the snare or partially opening the loop for repositioning is advisable before application of electrocautery current. Transection of a large fragment of inadvertently captured normal mucosa is not a desirable outcome of polypectomy and may lead to perforation. If extra tissue is captured, there is no assurance that it will only consist of mucosa, for submucosa may also be entrapped, and when electrocautery current is applied, a deep burn may result.

**Piecemeal polypectomy**

When removing a sessile polyp, the characteristic whitening at the site of wire placement when electrocautery current is applied often cannot be observed because the wire is embedded in the polyp. After a few seconds of current, the wire snare should be slowly closed until separation occurs. During piecemeal polypectomy, the next placement of the snare may be immediately adjacent to the first, with the edge of the wire positioned into the denuded area just created by removal of the previous piece (Fig. 9). In this fashion, multiple portions can be sequentially resected in an orderly fashion, with removal of each succeeding piece being facilitated by its predecessor. Several applications may be required, removing fragments until satisfactory polypectomy is achieved [7,32]. The polyp fragments may be removed by suction into a trap if they are small or retrieved with a Roth basket or, less effectively, with a dormia basket or a tripod grasper. One or two fragments may be captured in a snare loop for removal.

The fulcrum technique may be used for the endoscopic treatment of laterally spreading polyps. The tip of the opened snare is impacted against the colonic wall behind the polyp. By keeping the tip fixed, slightly advancing the snare, and bending the endoscope tip to left or right the snare is pivoted to either side (Figs 10 and 11). If the tip of the opened snare is placed in front of the polyp, it can be flexed backwards along its long axis by advancing the snare and the tip of the endoscope (Fig. 12). To prevent
perforation, the wire loop should be pressed flat against the bowel wall to ensnare the mucosal and submucosal layers only.

**Positioning the polyp**

Whenever a polyp is to be removed, snare placement is facilitated by rotation of the colonoscope to bring the polyp to the 5 o'clock position. Rotation of the scope is necessary to reposition the instrument tip in relation to the polyp.

Rotation of the scope may be difficult during intubation when the instrument shaft has loops and bends. Advantageous positioning may be best accomplished when the colonoscope shaft is straight, because a straight instrument transmits torque to the tip, whereas a loop in the shaft tends to absorb rotational motions applied to the scope. It is often difficult to capture a sigmoid polyp during intubation, when the obligatory sigmoid loop is present. It may not be possible to straighten the scope in the sigmoid during the intubation phase because rotation and loop withdrawal often results in losing the scope's position. With a loop in the scope, the dial controls may no longer work effectively to turn the instrument tip because the cables which transmit motion are maximally stretched by the loop.

These two negative forces, the inability to torque effectively and the loss of cable-controlled tip deflection, combine to create a difficult situation when attempting to maneuver the snare into position around a polyp. Snare placement can be made considerably easier by passing the scope far beyond the polyp, even to the cecum (and thus visualize the rest of the colon) and attempt capture during the withdrawal phase of the examination. As the scope is withdrawn, the loops are removed and the polyp which proved difficult to position during intubation may be quite easily ensnared because both torque and tip deflection are responsive when the shaft is straight.

**Clamshell polyps**

Large sessile polyps wrapped around a fold in a ‘clamshell’ fashion usually permit the distal portion to be readily removed, but resection of the proximal portion on the far side of the fold may be considerably more difficult. This type of polyp is often located in the right colon and should be removed in piecemeal fashion (Fig. 13).

The piecemeal technique usually requires rotation of the colonoscope to place the polyp at the 5–6 o'clock position. Although it would be ideal to resect the total polyp at one session, it may only be possible to remove the portion nearest to the scope, leaving some of the polyp on the far side of the fold for an interval resection. Subsequent scarring may flatten the polypectomy site, bringing the residual polyp into a favorable location for subsequent polypectomy. Often, an injection of fluid (SIP) into the mucosa on the far side of the polyp will facilitate its removal, as previously described.

If it is elected to attempt total polypectomy at the first session, the stiffness of the plastic snare catheter can be used as a probe. After endoscopic transection of the portion closest to the scope, and with the loop extended, the tip of the catheter can be positioned on the ridge of the fold in the polypectomy site where a portion of the polyp has just been removed. By a combination of torque and rotation of the large control knob, downward pressure on the ridge at the site of the polypectomy divot will often depress it sufficiently so that a portion of the residual adenoma will extend into the loop permitting capture under direct vision (Fig. 14).

Several repeated snare applications and transections of this type will usually result in complete polypectomy. The tip of the instrument must be close to the polypectomy site for this technique to be
effective, since the plastic polypectomy sheath becomes quite flexible when it is extended more than a few centimeters beyond the colonoscope. The sheath, with its tip barely protruded from the faceplate of the scope, is stiff and will depress a fold when torque or tip deflection is applied to the colonoscope shaft. A stiff monofilament snare may be used to flatten the fold exposing the entire polyp. Pushing on a fresh polypectomy site in this manner is not associated with any adverse results.

**Retroversion**

An alternative technique for removal of a polyp located on the far side of a fold is to perform a U-turn maneuver. With standard instruments, this can only be accomplished in the cecum, ascending colon, and sometimes in the transverse colon although it is somewhat easier with pediatric colonoscopes. It is difficult but not impossible to resect a polyp in a U-turn mode because the tip deflection responses are opposite to those usually expected (Fig. 15).

**Flat polyps**

In spite of the knowledge and skill of modern endoscopists, not all colon polyps can be successfully removed with a colonoscope. Among these are carpet-like polyps which extend over several centimeters. An attempt can be made to fulgurate the surface of such polyps with the shank of the monopolar biopsy forceps, a BICAP probe, a laser, or the argon plasma coagulator.

A helpful maneuver to be considered when the lesion appears too flat to capture with the snare loop is to aspirate air from the colon with the snare device in place. This will collapse the distended colon, causing a decrease in the circumference of the colon wall and as that occurs, the polyp flattened against the stretched wall, will become thicker and more elevated, rendering capture relatively easy so that piecemeal type resection may be performed.

Alternate possibilities include submucosal injection of fluid to elevate the polyp for safer transection and use of a two-channel colonoscope where a forceps can be passed through one channel to grasp the polyp over which the opened snare has been positioned. Once the forceps lifts up the polyp, the snare is tightened to capture the polyp.

**Residual fragments of adenoma after polypectomy**

Often the base of a large polyp which was resected in piecemeal fashion has some residual adenomatous tissue at the edge or in the middle of the polypectomy site. If residual tissue is seen at the base, there will be adenomatous tissue at that site on follow-up colonoscopy. The site of polyp resection heals concentrically, from the edges toward the center, so that usually only one polypoid excrescence will be present upon complete healing of the site, whether or not several small islands of adenoma remained at the periphery of the initial resection base. If the polypectomy was adequate, the residual polyp will be smaller than the original size of the polyp, and can be easily removed.

The application of thermal energy to the fragments of adenoma remaining at the base and edges of a fresh polypectomy site can reduce the incidence of residual polyp (Fig. 16). This has been studied with the argon plasma coagulator (APC), with reduction of adenoma on follow-up from 100% to 50% when residual tissue at the fresh base is destroyed [36,37].
Judging and marking the location of lesion

There are several reasons to mark an area of the colon for future localization. Most of the time, the endoscopist desires to have a precise identification of the site where a polyp was removed. When large polyps are resected in piecemeal fashion, even though the endoscopist considered that it was totally removed, there is a strong possibility that residual adenoma will be present at a follow-up examination. It may be difficult to find the exact place where a polyp was removed, as the initial placement of the site was wrong, the scar is behind a fold, or the residual is small. Of equal importance is the knowledge that the polyp was indeed completely resected at the original session, and the site can be declared free of residual adenoma.

Now that laparoscopic-assisted surgical colonic resection is becoming as well accepted as primary colonoscopy, there is even greater urgency to have precise lesion location, since the laparoscopist does not have the capability of palpating the colon between the fingers at exploratory laparotomy. For the laparoscopist, it is of great importance to have an easily visible marker which can be seen through the telescopic lens of the laparoscope. It is not acceptable for the endoscopist to state that ‘a lesion is in the transverse colon’, since a more specific localization is needed to avoid a subsequent open surgery to find the lesion.

Even under circumstances when open laparotomy is to be performed, site identification becomes necessary when a specific portion of the large bowel requires resection and the lesion may not be readily apparent by visual or palpatory exploration. Following endoscopic removal of a malignant adenoma, the site may heal completely in eight weeks, and a locator mark may assist both the surgeon and the pathologist in identifying the place where the lesion had been.

Location by depth of insertion

Localization by measurement of centimeters of instrument introduced into the rectum is an extremely poor method for tip localization. During introduction of the instrument, when loops are common, it is possible to advance the full length of a long colonoscope (180 cm) into the rectum, yet the tip may still be at the sigmoid/descending colon junction. On the other hand, it is possible, by repositioning the instrument, removal of loops, and straightening, to reach the cecum in that same patient with a total length of only 60 cm of instrument. The actual number of centimeters inserted may bear no relationship with the actual tip location within the colon.

A report from a previous examiner that ‘a polyp was found at 100cm’ is meaningless for surgical localization. With the current knowledge of intraluminal landmarks—the splenic flexure, transverse colon, hepatic flexure—it is much better to identify the approximate area of the lesion. During withdrawal, there is usually a good correlation between length of scope inserted and tip localization since the loops are removed and the instrument is straightened. It is usual, on withdrawal, to have the splenic flexure at 40–50 cm and the upper sigmoid at 30–35 cm. Because of sigmoid looping, shaft measurements during withdrawal are not usually helpful until the splenic flexure has been reached.

Endoscopic landmarks

Landmarks are notoriously imprecise for exact localization of areas between the rectum and cecum. Even the most experienced colonoscopists may err in their estimate of tip location. Indeed, in a large tortuous sigmoid colon, it may be difficult to localize a lesion to even the mid- or upper sigmoid colon. Similarly, a lesion estimated by the endoscopist to be near the splenic flexure may be
under the diaphragm, could be either proximal or distal to the flexure, or may even be actually located at the sigmoid descending colon junction. Precise location may be impossible because of tortuosity and multiple bends in that area of the colon. The only invariable localizing landmarks are when a lesion is located within 15 cm of the anus, there is no doubt that it is close to or in the rectum, and a lesion near the endoscopically identified ileocecal valve can be easily found by the surgeon. The problem in the latter case revolves about the endoscopist's ability to recognize beyond a doubt that the cecum was indeed reached.

Clipping

Clips may be placed through the colonoscope and onto the mucosa at any location. These will assist in radiographic or ultrasonographic location of the marked segment. However, clips tend to fall off at an average of approximately 10 days [43], with some falling off earlier and some maintaining their attachment for longer intervals. Although it has been suggested that clips may be a helpful marker for surgical localization, it has been found that the clip devices are quite small to be palpated easily. In addition, the surgeon cannot be assured that a palpable clip had not been spontaneously detached just prior to surgery and is at some distance from the original placement during endoscopy. If, indeed, a surgeon palpates a clip in the sigmoid colon and resects that segment, it is possible that the clip actually had been placed at a location near the splenic flexure, had become detached, and migrated distally. A report of eight patients with prelaparoscopic clip placement by colonoscopy stated that intraoperative ultrasound readily located the marked areas for surgical resection [44].

Marker injections into the colon wall

The ideal method for lesion localization is to have an easily identifiable marker which will immediately draw the attention of the surgeon or endoscopist [42]. This can be achieved with injection of dye solutions. An experimental study demonstrated that, of eight different dyes injected into the colon wall in experimental animals, only two persisted for more than 24 hours [53]. These were indocyanine green and India ink. The indocyanine green was visible up to seven days after injection, and it is known that India ink is a permanent marker which lasts for the life of the patient by virtue of submucosal injection of carbon particles. Other dyes, such as methylene blue, indigo carmine, toluidine blue, lymphazurine, hematoxylin, and eosin, all were absorbed within 24 hours, leaving no residual stain at the injection site. Indocyanine green is approved by the FDA for human use, but India ink has not been so approved. A new surgical marker has been FDA approved, and consists of pure carbon in suspension. It is marketed as a prediluted sterile compound in preloaded syringe [54].

Indocyanine green

Indocyanine green is not associated with any significant tissue reaction, and is relatively non-toxic, but ulceration of the injection sites have been reported in an animal model [53,55]. Clinical experience with indocyanine green tattoo in 12 patients demonstrated that the dye was easily visualized on the serosal surface of the colon at surgery within 36 hours following injection [56] and may remain visible for up to seven days [53]. Animal experimental models have shown that the dye was not visible after one day [55] or lasted up to two weeks [57]. The problem with a marker having such a relatively short visible span is that the decision to operate after removal of a malignant polyp may require a few weeks, with slide reviews and multiple consultations. An injection at the time of polypectomy will have disappeared whereas the site itself may become more difficult to localize with the passage of time.
India ink

Most experience with dye injection technique has been accumulated with India ink as a permanent marker [58,59]. The stain lasts for at least 10 years with no diminution in intensity at that duration. A permanent marker may be worthwhile for several reasons. A lesion requiring surgery may be injected and, for clinical reasons, surgery may be postponed for several weeks at which time a vital dye such as indocyanine green will have been absorbed, leaving the operating surgeon with no visible evidence of its having been injected. Sometimes it is desirable to mark the site of a resected polyp for subsequent endoscopic localization when it is anticipated that the area will be difficult to find on a follow-up examination, especially when the lesion is located around a fold or behind a haustral septum.

A stain with a permanent marker such as India ink will draw immediate attention to the site, enabling a more accurate and complete assessment. For the surgeon, a locator stain will aid immeasurably the efforts to seek and resect an area of the bowel containing the site of the lesion. When the lesion is relatively small, such as a flat cancer or a previously endoscopically resected malignant polyp which requires surgical resection, the site may not be evident from the serosal surface and may not even be palpable. If the area to be resected is in a redundant sigmoid colon or near the splenic flexure, it may be impossible to locate by either visual means or by palpation. Occasionally, even large lesions may not be palpable by the surgeon if they are soft and compressible [60]. As previously mentioned, visible marking can assist in precise surgical intervention for laparoscopic-assisted colon resections, or clips may be detected by an ultrasound probe.

There have been reported complications with India ink injection, but clinical symptoms resulting from the injection are relatively rare [61,62]. Tissue inflammation has been reported in an animal model [55]. The complications may in part be related to the wide variety of organic and inorganic compounds contained in the ink solution, such as carriers, stabilizers, binders, and fungicides [63]. It is possible that the toxic properties of India ink may be partially ameliorated by marked dilution of the ink. Ink diluted to 1:100 with saline produces as dark a spectrophotometric pattern as undiluted India ink, and in clinical tests, the tattoo made by 1:100 diluted India ink is readily visible by the endoscopist and by the operating surgeon. A small volume injection (0.5 mL) may increase the safety of the procedure [55,64].

India ink is black drawing ink made with carbon particles. Permanent fountain pen ink is not an acceptable substitute. India ink is available from any stationery store, although it is supplied for medical use in non-sterile form as a stain to enhance the diagnosis of cryptococcosis in the cerebrospinal fluid. The India ink may be sterilized in an autoclave following dilution or can be rendered bacteriologically sterile by passing the diluted solution through a 0.22 micron Millipore filter which is interposed between the syringe containing the dilute solution of India ink and the injection needle [65]. The preparation of India ink, prior to injecting the carbon particles into the submucosa is not required of a new compound of sterile micronized carbon particles [54].

A standard sclerotherapy needle is utilized of sufficient length to traverse the accessory channel of a 168-cm colonoscope, and stiff enough so that the plastic sheath will not crinkle up as it is being forced through the biopsy port when the tip of the instrument is deep in the colon and the colonoscope shaft has several convolutions and loops. Ideally, the needle should enter the mucosa at an angle to permit injections into the submucosa, rather than to have the needle pierce the bowel wall. The edges of intrahastral folds should be targeted (Fig. 17). If during an injection a submucosal bleb is not immediately seen, the needle should be pulled back slightly, since the needle tip may have penetrated the full thickness of the wall and the ink may be squirting into the peritoneal cavity. An intracavity injection is not a clinical problem [45,46], but can scatter black carbon particles around the abdominal
cavity, which may be somewhat disconcerting for the surgeon. A prior submucosal injection of saline may aid the colonoscopist in depositing the carbon suspension in that layer, without risk of injecting either deep or superficial (Fig. 18) [66].

Since the colonoscopist cannot know which portion of the bowel is the superior aspect, multiple injections should be made circumferentially in the wall around a lesion to prevent a single injection site from being located in a ‘sanctuary’ site, hidden from the surgeon as the abdomen is opened with the patient lying supine [67]. Each injection should be of sufficient volume to raise a bluish-black bleb within the submucosa at the injection site. The injection volume may vary from 0.1 to 0.5 mL. If injections are made a few centimeters from the lesion, the surgeon should be informed whether the injections are proximal or distal to the site. With the proper dilution of India ink, endoscopic visualization is still possible should some of the ink spill into the lumen, whereas, with the more concentrated solutions, the endoscopic picture becomes totally black when ink covers the bowel walls [45].

Most endoscopists who use India ink to mark colonic lesions do not prescribe antibiotics prior to its use, although it has been suggested that prophylactic antibiotics be given before injections of indocyanine green [56].

Injection of carbon particles provides a permanent marker, with endoscopic visualization of the tattoo site being possible in every case on follow up examination without diminution in color up to an interval of 10 years following initial injection (Fig. 19). Several reports have attested as to its safety as well as its efficacy [61,68,69].

**Intraoperative colonoscopy ▲▼**

It is possible to localize the site of a tumor, or a resected polypectomy site, by performing intraoperative colonoscopy [50,51]. This technique has been avoided by most endoscopists because of the need to perform an endoscopic examination in the operating room with all the constraints of positioning the patient, handling the scope, and trying to use maneuvers such as torque and straightening techniques with the abdomen open. The amount of air insufflated for colonoscopy can create problems with surgical techniques once the endoscopist has completed the necessary localization. Because the site of a polypectomy may heal within a few weeks, there is a possibility that a polypectomy site may not be seen during an intraoperative endoscopy. Lesion identification can also be accomplished by colonoscopy and submucosal injection of radioactive labeled albumin microaggregates [52] just prior to surgery. The surgeon can localize the precise area with detection by a gamma probe during laparotomy or laparoscopy.

**Radiological methods of localization ▲▼**

**Barium enema ▲▼**

The barium enema is still an acceptable method for determining the location of polyps or cancers [41], but small lesions may not be readily identified on the barium enema X-ray examination. Certainly, if a malignant polyp were endoscopically resected, it may be extremely difficult to then try to locate the area where the polyp was removed, since only a small puckering may be present [41,45], or the site may be almost completely healed within three weeks.

During colonoscopy in a suite where radiographic imaging is possible, either fluoroscopy or an X-ray of the abdomen during endoscopy may assist in locating the site of a lesion. Unfortunately, it may be
difficult, with the instrument in a straightened configuration, to state that the tip of the colonoscope is in the distal descending colon or in the mid-portion of a long redundant sigmoid loop.

**Magnetic imaging ▲▼**

New methods of inductive sensing with a low-intensity magnetic field may aid in the moment-to-moment localization of the tip of the fiberoptic colonoscope as it progresses through the colon. The magnetic sensors are attracted to electromagnets within the sheath of the colonoscope (or on a wand-like device inserted into the biopsy channel) [46,47]. These methods have replaced such devices as metal detectors for localization of the instrument tip [48]. Unlike a fluoroscopic image which demonstrates both the scope and air in the colon as a contrast media, the electromagnetic field method only shows the colonoscope itself, but is capable of a three-dimensional format. This technique may be of benefit in localizing the site of a colonic tumor or polyp [49].

**The extremely difficult colonoscopy ▲▼**

If passage to the right colon has been arduous and prolonged, with the discovery of a large sessile polyp having a broad attachment that would require several attempts at piecemeal polypectomy, the wisest approach may be to suggest surgical resection. The risk–benefit ratio will depend on the location of the polyp: the right colon is somewhat thinner than the left, increasing the risk of colonoscopic removal. Also there are some patients with limited physiological reserves, who may be unacceptable operative risks.

The advent of laparoscopic-assisted partial colectomy may markedly change the attitude of adventurous colonoscopists who attempt removal of large polyps, especially in the right colon [70]. The ease of laparoscopic resection may reduce the willingness of both the patient and the endoscopist to embark on the repetitive number of colonoscopies required. Both the risks and benefits of an aggressive endoscopic approach will need to be reevaluated.

**References ▲**


