4
Endoscopy

Kurt Davis and Michael A. Valente

Key Concepts

- The endoscopic examination is critical for patients with colorectal complaints and is a key component of the complete colorectal examination.
- The anoscopic examination is the best way to adequately evaluate the anoderm, dentate line and evaluate for internal and external hemorrhoids, and anal masses.
- Multiple bowel preparation regimens exist, but regardless of which prep is chosen, splitting the timing into the half the day prior to and half the day of the procedure results in a better prep.
- There is no ideal sedation medication, but the endoscopist must be familiar with the side effect profile of any medications being used and be prepared and comfortable with any reversal agents.
- Adjunctive maneuvers employed with endoscopy serve as the markers between seasoned experts and novices: these include abdominal pressure, adjusting position, torqueing, and dithering.
- PillCam endoscopy allows the clinician to evaluate the small bowel for occult gastrointestinal bleeding, insipient tumors, polyposis syndromes, or Crohn's disease.

Introduction

The endoscopic evaluation of the patient with colorectal complaints forms the keystone of the physical examination. It allows the physician to visually assess the entirety of the intestinal tract from the mouth to the anus and allows for the diagnosis, treatment, and monitoring of the effectiveness of any therapy. It is imperative for all physicians treating patients with colorectal diseases to be facile in the more common endoscopic diagnostic and therapeutic techniques.

The Complete Anorectal Examination

While performing any anorectal or endoscopic examination, an anxiety-free and modest environment must be created. Most patients will exhibit nervousness, and apprehension, which can cause anal or gluteal spasm that will preclude an accurate assessment. The examiner must reassure the patient and keep anxiety and embarrassment to a minimum. This can be accomplished by effective communication, keeping the patient covered as much as possible, keeping ancillary personnel in the room to a minimum and not rushing through the examination. Physicians should strive to actively communicate with the patient as the examination is progressing.

Before a discussion on endoscopic techniques, a thorough understanding of the initial steps of the anorectal examination is compulsory for success and patient well-being and satisfaction. Before any instrument is inserted, a focused history must be obtained coupled with a local examination. The local examination is an important precursor to any endoscopic examination and consists of: proper patient positioning, visual inspection, and manual palpation of the anorectal region followed by the digital rectal examination. Once this stepwise examination is complete, then inspection of the colon, rectum, and anus can commence.

Patient Position

There are two positions that may be used for effective anorectal examination. The choice of position may depend on several variables including available equipment, patient age and comorbid status, and physician preference. Regardless of the position chosen, both the patient and the examiner must be comfortable in order to carry out an effective anorectal and endoscopic evaluation.

S.R. Steele et al. (eds.), *The ASCRS Textbook of Colon and Rectal Surgery*, DOI 10.1007/978-3-319-25970-3_4

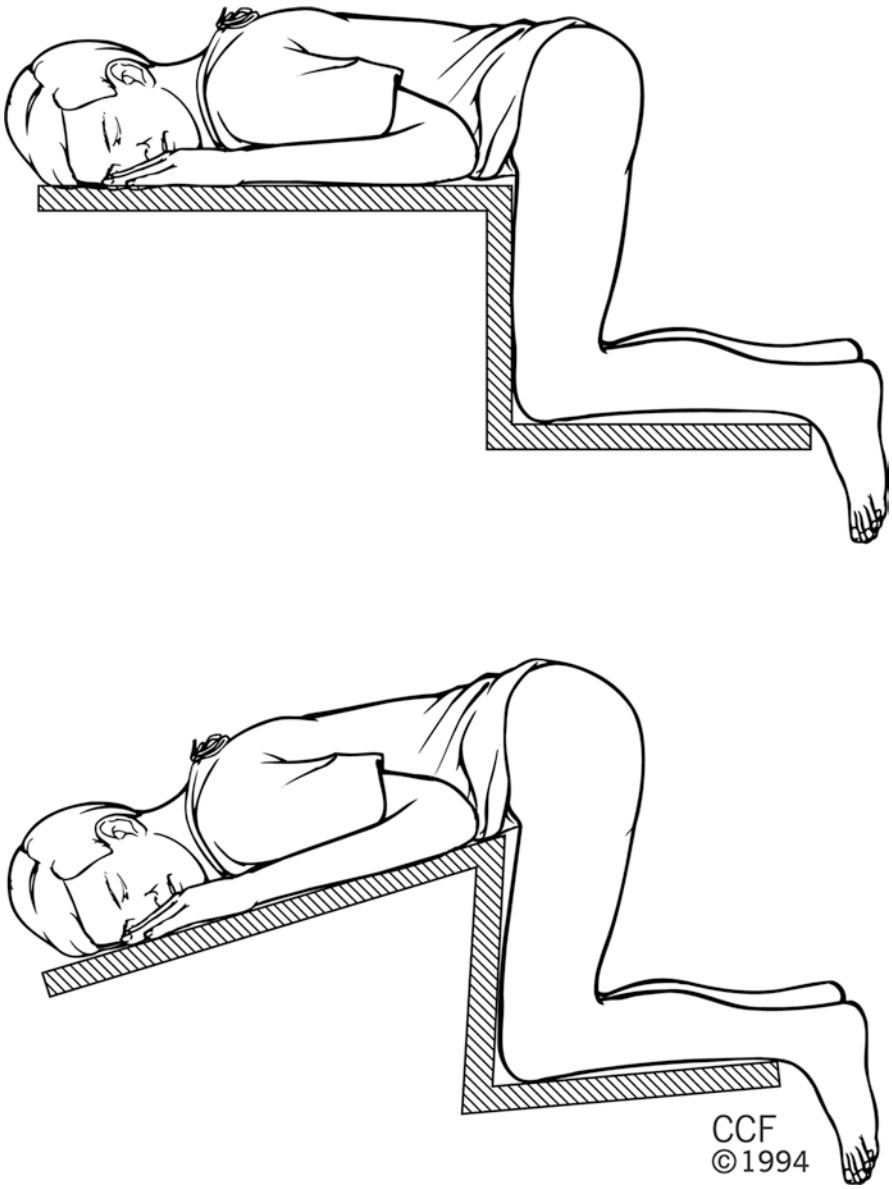

FIGURE 4-1. Prone jackknife position. Reprinted with permission, Cleveland Clinic Center for Medical Art & Photography ©2015. All Rights Reserved.

Prone Jackknife

The prone jackknife position (knee-chest), performed with the aid of a specialized proctoscopic table is commonly employed and allows for excellent visualization of the entire anus and perianal and perineal region, as well as the sacrococcygeal region. The patient kneels on the padded portion of the table and leans forward with their trunk and arms extended forward (Figure 4-1). The table is angled forward gradually so that the patient's buttocks and perineum are superior, while the head and feet are inferior. This is a comfortable position for the examiner and also allows for easy insertion of the anoscope, proctoscope, or flexible sigmoidoscope. This position is well tolerated by most patients, but should be avoided in various situations, such as debilitated patients, recent abdominal surgery, cardiopulmonary issues, various arthritic/rheumatologic conditions, or late pregnancy.

Left Lateral

The left lateral recumbent (Sims') position is also widely used, especially if a specialty bed is not readily available (Figure 4-2). This position is very well tolerated and is well suited for elderly or debilitated patients. The patient lies on their left side and the thighs are flexed as to form a 90° angle with the trunk. It is imperative that the buttocks project slightly beyond the edge of the examining table. This position will allow for excellent visualization of the perianal and sacral regions, but the anterior perineum is often obscured and requires the retraction of the buttock by an assistant. Anoscopic or endoscopic evaluation is easily performed in this position.

Inspection and Palpation

Proper stepwise visual inspection of the perineum, anal canal, rectum, and vagina should precede any other examination.

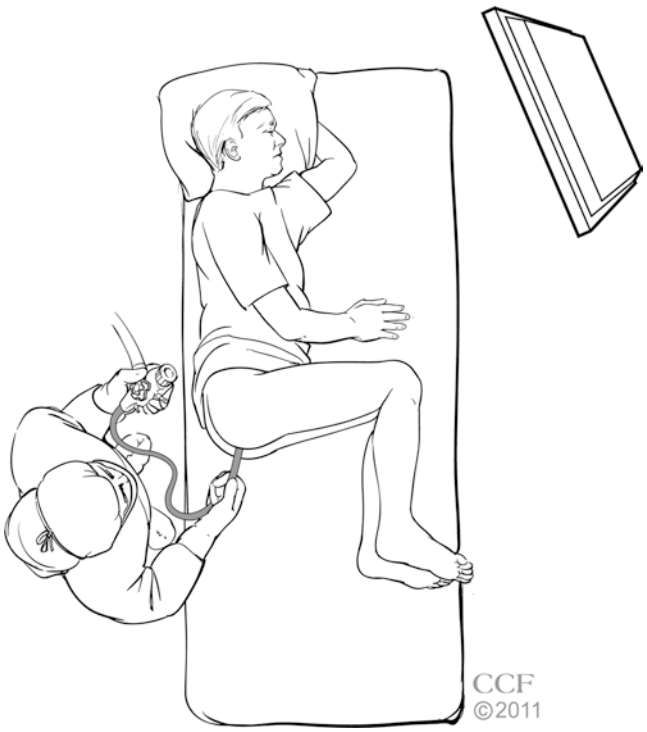

FIGURE 4-2. Left lateral (Sims') position. Reprinted with permission, Cleveland Clinic Center for Medical Art & Photography ©2015. All Rights Reserved.

Proper lighting is essential, and various light sources are commercially available, including overhead lights, gooseneck lamps, or headlamps. It should be noted that the "clockface" nomenclature is not recommended for localizing anorectal findings. This nomenclature is dependent upon the position of the patient, and hence different interpretations of the true location may differ from examiner to examiner. It is more proper to delineate anatomical location using the cardinal quadrants (i.e., left lateral, right anterior, right posterior). This is the practice most commonly employed by colorectal surgeons.

An overall assessment of the shape of the buttock and inspection of the lower sacrococcygeal area is undertaken. This is followed by the gentle spreading of the buttocks to gain proper exposure. A great deal of information can be gained from visualization. The physician should examine for and document any scarring, fecal soiling, purulence, blood or mucous drainage, excoriations, erythema, anal sphincter shape, perineal body bulk, hemorrhoidal disease, skin tags, overt signs of inflammatory bowel disease, external fistulous openings, rectal prolapse, neoplasm, and any evidence of previous anorectal surgery. Next, the patient is asked to strain (Valsalva maneuver) to help determine and assess for perineal descent, uterine, vaginal, or bladder prolapse, or rectal prolapse. It should be noted that the best position to evaluate rectal prolapse is in the sitting position on the toilet or commode after an enema has been administered. Gentle and directed palpation of the anorectal region also gives the examiner a great detail of information. Gently touching the anal verge will elicit the anocutaneous reflex (anal wink), which is indicative of an intact pudendal nerve. Additionally, gentle spreading of the anus will help elicit an anal fissure or ulceration. Palpation of the gluteal region can help identify an abscess, external opening of a fistulous tract, or possibly a mass.

Digital Rectal Examination

The digital rectal examination (DRE) is simple and is typically well tolerated and should be performed before all endoscopy of the rectum and colon. A well-performed DRE will provide information regarding the contents and potential pathology of the anal canal, distal rectum, and adjacent organs. The DRE may also permit an assessment of the neurological function of the muscles of fecal continence. While the medical school maxim of the only patient not receiving a DRE is the one that lacks an anus is obviously excessive—there are relative contraindications to performing this portion of the exam. These include painful lesions such as an anal fissure, thrombosed external hemorrhoids, grade IV internal hemorrhoids, and neutropenic patients. The keys to a successful DRE can be summarized by simple rules: adequate lubrication, gentleness, and attention to detail [1]. It is important to minimize pain during DRE as this may affect patient cooperation during endoscopy.

After proper communication with the patient, a well-lubricated index finger is placed across the anus to lubricate the general area. The fingertip is then gently inserted into the anal opening. Lubrication should be warmed if possible, and lidocaine jelly should also be available. If the patient's response is an involuntary spasm of the internal sphincter, the examiner should withdraw their fingertip and gently try again. Ask the patient to bear down as to pass a stool. This maneuver will cause relaxation of the entire sphincter complex and should facilitate an easy digital insertion [2]. The finger should be gradually and slowly advanced. The distal rectum and anal canal along with surrounding structures should be investigated in an organized and stepwise fashion. Resting anal tone followed by squeeze tone should be assessed. Assessment should be made of the entire circumference of the lumen by gently sweeping around the entire anus and distal rectum. Anteriorly in a male, the prostate should be palpated and assessed for nodularity, hypertrophy and firmness. In the female, anteriorly palpate for a rectocele. The cervix and uterus can also be palpated. Posteriorly, the presence of a presacral (retrorectal) mass may be palpated. Bimanual examination may be necessary when examining a female patient in order to adequately examine the rectovaginal septum and associated adnexal structures. Redundant rectal mucosa may be palpated as well as a stricture or narrowing. Induration or a fibrous cord, representing an internal fistulous opening, may also be felt on DRE. Exclusion of any masses should be carefully performed. The patient should be asked to perform a Valsalva maneuver to potentially bring any lesions of the upper rectum or the rectosigmoid into the examiners reach. If a mass is palpated, its size, position,

FIGURE 4-3. Various beveled anoscopes. From *top* to *bottom*: Large Hirschmann (short bevel); Buie-Hirschmann anoscope (long bevel); small (pediatric) Hirschmann anoscope.

characteristics (sessile, polypoid, ulcerated), mobility (mobile, tethered, fixed), and relationship to other structures (distance from the anal verge, distance for the anorectal ring) must be accurately recorded.

The levator ani/puborectalis muscles can also be assessed on DRE with evaluation of both the strength and function of these muscles, along with any tenderness on direct palpation, indicating a possible pelvic pain disorder. When a patient with good sphincter function is asked to squeeze these muscles, the examiner's finger will feel the muscle tighten and will have his finger pulled up into the rectum. Additionally, when the examiner pulls posteriorly on these muscles, the anal opening should gape and then return to normal, representing an intact reflex pathway to the thoracolumbar spinal cord.

Anoscopy/Proctoscopy

The anorectal examination in most cases should be followed with some component of an endoscopic investigation to complete the workup. This may include anoscopy, proctoscopy, or flexible endoscopy. Anoscopy and proctoscopy are typically performed in the clinic setting without sedation or mechanical bowel preparation and are tolerated quite well by the patient.

It should be noted that the term proctoscopy will be used as to describe the rigid scope implemented to evaluate the rectum and the distal sigmoid colon. Therefore, "rigid proctosigmoioscope" or "proctosigmoidoscopy" will be referred to as "rigid proctoscopy" or "proctoscopy." Sigmoidoscopy refers to the use of the flexible sigmoidoscope.

Anoscopy

Anoscopy is the examination of the anal canal and the distal rectum. Anoscopy offers the best way to adequately evaluate the anoderm, dentate line, internal and external hemorrhoids, papillae, fissures, anal masses, and distal rectal mucosa.

The anoscope is a relatively simple instrument consisting of an obturator, the scope itself, and a light source. There exist several variations in type, size, and length of anoscopes available. Additionally, commercially available anoscopes include slotted or beveled styles, reusable or disposable, and lighted or unlighted. The particular type of instrument and light source used are based on individual preference, expense, and prior training (Figure 4-3).

Regardless of the choice of instrument used, the examination is initiated only after a DRE has been performed (if a DRE is unable to be performed secondary to pain, spasm, or stenosis, an anoscopic exam should not be attempted). For most instances, cleansing of the anorectum with an enema is not warranted. The anoscope (with obturator in place) is liberally lubricated and gently and gradually advanced until the instrument is fully inserted. It is important to align the anoscope along the anterior–posterior axis of the anus. If unsuccessful due to patient intolerance, remove the scope, reapply lubrication and try again. After successful insertion, the obturator is removed and examination of the anorectum undertaken. The obturator should then be reinserted while the scope still in the anus, and the anoscope is gently rotated to examine a new area.

The prone jackknife position offers good visualization and ease of insertion as well does the lateral position, however, an assistant must retract the buttock if the lateral position is utilized. During the examination, the patient is asked to strain while the anoscope is withdrawn to visualize any prolapsing anorectal mucosa or hemorrhoidal tissue. During the anoscopic examination, hemorrhoids may be banded or sclerosing agents injected and biopsies of any suspicious lesions may be obtained. Complications are rare, but may include occasional bleeding from hemorrhoids or inadvertently tearing the anoderm.

Proctoscopy

Rigid proctoscopy is suitable to examine the rectum, and in some patients, the distal sigmoid colon may also be evaluated. Similar to the anoscope, the proctoscope consists of an obturator, the scope itself, and a light source. Illumination is supplied by a built-in light source and a lens is attached to the external orifice of the scope after the obturator is removed. The main difference between an anoscope is that a proctoscope needs to hold air so the rectum can be distended. This is achieved by having a bellows attached to the scope, which allows for insufflation of air to gain better visualization and negotiation of the scope proximally through the rectum. A suction device or cotton tipped swabs can be used to remove any endoluminal debris or fluid or to enhance visualization (Figure 4-4). Ideally, the patient should receive an enema preparation within 2 h of

FIGURE 4-4. Proctoscopy suction catheter and long cotton-tipped applicators for clearing small amounts of fecal debris. The cotton-tipped swaps are also used for manipulating the rectal and anal mucosa during anoscopy and proctoscopy.

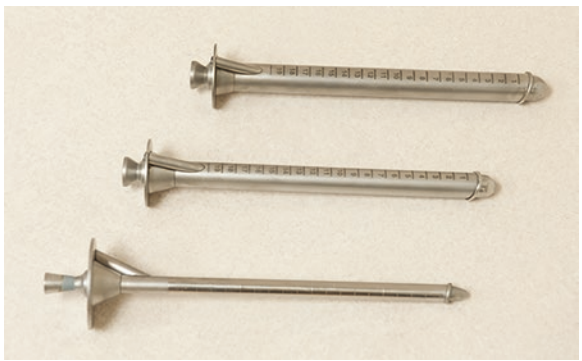

FIGURE 4-5. Proctoscopes. From *top* to *bottom*: large proctoscope, length 25 cm, diameter 19 mm; standard proctoscope, length 25 cm, diameter 15 mm; pediatric proctoscope, length 25 cm, diameter 11 mm.

the procedure in order to clear any stool, which may make passage of the scope and visualization difficult.

Proctoscopes are available in three sizes, all 25 cm in length. Different luminal diameters include 11, 15, and 19 mm (Figure 4-5). The largest scope is suited best for polypectomy or biopsies in which electrocoagulation may be needed. In most patients, the 15 mm × 25 cm scope is ideal for a general inspection. There is also a disposable plastic, self-lighted proctoscope which is available for use.

The procedure can be performed in either the prone jackknife or left lateral position as previously described. When properly performed, the patient feels little to no discomfort. Pain may occur with stretching of the rectosigmoid mesentery due to over insufflation of air or the scope hitting the rectal wall. An overzealous examiner trying to advance the scope too quickly or too proximal is the main cause of patient discomfort. Unfortunately, the art of using the rigid proctoscope has declined in recent years due to the ubiquity of flexible endoscopy. The proctoscope however, still has important indications, especially in the identification and precise localization of rectal lesions or in the evaluation of rectal bleeding. Contraindications are similar to anoscopy and include painful anorectal condition such as acute fissure, incarcerated hemorrhoids, recent anorectal surgery (<1 month), or anal stenosis.

After adequate lubrication, while the obturator is held in place with the right thumb, the instrument is gently inserted into the anal canal and advanced approximately 4–5 cm in the general direction of the umbilicus. The scope is then aimed toward the sacrum and advanced for an additional 4–5 cm. The obturator is then removed and the viewing lens is placed. Minimal air insufflation is used in order to open the bowel lumen and gently withdrawing and advancing the scope to straighten out angulations proximally aids in achieving successful navigation. It should be noted that the distal extent reached on proctoscopic examinations averages approximately 17–20 cm and very rarely can the scope be inserted to its full length [3]. If at any time the insertion becomes difficult or painful to the patient, the procedure should be terminated and the farthest extend reached should be recorded.

As the proctoscope is withdrawn from the farthest extent reached, careful examination is performed of the entire circumference of the rectal wall with minimal air insufflation and rotation of the scope. The valves of Houston are flattened out with the tip of the scope to reveal areas just proximal to the folds. If any lesions are found, accurate measurements and descriptions are necessary. These include: size of the lesion, the exact distance from the anal verge, appearance, and location on the bowel wall. Several different types of biopsy forceps are available (Figure 4-6) and biopsies can be done in the office setting with or without the use of electrocautery. Additionally, polyps or small lesions can be snared (Figure 4-7) or fulgurated. Proper suction, electrocautery and irrigation devices should be readily available in the examining room for these purposes (Figure 4-8).

FIGURE 4-6. Turell angulated biopsy forceps. A curved upper jaw allows for 360° rotation. A variety of jaw sizes and types are available.

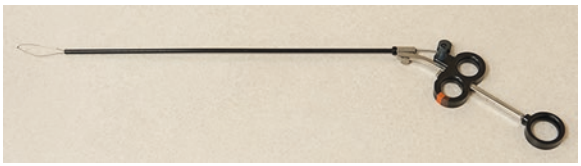

FIGURE 4-7. Rigid-wire (Frankfelt) snare. This snare allows for polypectomy or tumor debulking via the anoscope or proctoscope.

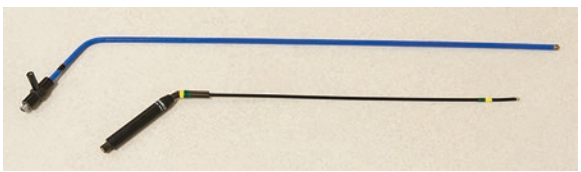

FIGURE 4-8. Suction catheter/electrocoagulation catheter. From *top* to *bottom*: an insulated catheter for combining suction and electrocautery, and an electrocoagulation catheter.

Serious complications during rigid proctoscopy are rare, with bleeding the most common, especially after biopsy or polypectomy. Perforation is a very rare occurrence and should not happen with proper technique. Before the introduction of flexible endoscopy, rigid proctoscopy was the standard technique to evaluate the distal sigmoid and rectum and large series of patients have shown minimal to no complications [4, 5]. Perforation of a normal rectum or sigmoid colon is a rare occurrence, but passing a scope or excess insufflation in a diseased or inflamed rectosigmoid may prove hazardous and caution must be undertaken in patients with inflammatory bowel disease, radiation proctitis, diverticulosis/diverticulitis, volvulus, or malignancy.

Anal and Rectal Ultrasound

Endoanal ultrasonography (EUS) is a highly reliable and reproducible imaging modality that provides information on the anatomy and function of pelvic floor structures, anorectal disease processes, and anorectal tumors. In experienced hands, EUS is accurate, with high sensitivity and specificity for detecting anal sphincter injuries. Advantages of EUS include the relatively inexpensive cost to perform and its widespread availability. One obvious disadvantage of EUS is that like all ultrasound examinations, it is an operator-dependent test, with varied published results for the same disease process.

Circumferential assessment of the anal canal and distal rectum is made possible by a 360° rotating transducer that is either a 7 or 10 megaHertz (MHz) probe for two-dimensional (2D) units or a 13 MHz probe for three-dimensional (3D) (Figure 4-9). In recent years, the use of 3D units has increased, with a similar sensitivity in detecting both external and internal sphincter defects, but it has been demonstrated that with the 3D units, intra-observer variation is decreased and thereby the diagnosis of pathology has been increased [6].

Prior to testing, patients receive an enema to clear the anorectum of any stool that may interfere with images due to artifact. Additionally, as with rigid proctoscopy above, EUS should not be performed on patients diagnosed with anal stenosis or fissure-in-ano, as this will undoubtedly render the test uncomfortable for the patient and difficult for the examiner to perform. EUS is most commonly performed with the patient in the left lateral recumbent position. After a gentle DRE, the well-lubricated ultrasound probe is inserted and slowly advanced and then withdrawn to view the entire area of the anal canal/rectum (in modern systems, a crystal moves up and down along the transducer to acquire images while the probe is held stationary).

The anal canal is divided into three levels on EUS: upper, middle, and lower based on anatomic landmarks. The upper anal canal is defined by the U-shaped puborectalis muscle; the middle canal has both EAS and IAS muscles visible (this is also where the IAS is at maximum width); and in the lower anal canal, only the most distal external sphincter fibers are visualized (Figures 4-10, 4-11, and 4-12). Highly reflective tissue on EUS reveals a hyperechoic (white) image, while poorly reflective tissues are hypoechoic (black). Thus, the smooth muscle-based IAS, which has higher water content, shows up black on EUS. In post-obstetrical sphincter injuries, the defect is usually located anteriorly and encompasses the EAS and may involve the IAS as well. In cases of postsurgical or posttraumatic injuries of the anal sphincters, defects can involve either or both muscles and may be unifocal or multifocal in nature (Figure 4-13). The accuracy of EUS compared to surgical findings has been reported to be as high as 90–100% by some authors and additionally, EUS has been used after operative sphincter repair to show the overlap of the muscles and to confirm a proper repair has been performed.

Flexible Endoscopy

Flexible Endoscopic Insertion Techniques

Due to the fact that no two colons are the same, the techniques described here are generalizations and guidelines to help navigate the flexible endoscope to its completion. The technique of performing an endoscopic examination, like any invasive procedure, is best learned under the watchful eye of a seasoned mentor, rather than reading a text; however, there are some points that can be generalized.

The keys to a comfortable and efficient endoscopic examination include a mastery of the insertion techniques described here to maintain a straight scope while keeping pain and trauma to the patient at a minimum. The skilled endoscopist must be able to use torque, tip deflection, dithering/jiggle, and push and pullback techniques as second nature in order to successfully achieve these goals. The techniques described here apply to both sigmoidoscopy and colonoscopy.

Torque

The twisting motion applied to the shaft of the scope by the endoscopist's right hand is called torque (Figure 4-14). Torque is an essential technique that allows for a stiffening of the scope and alters the direction in which the tip deflection controls work. Torque also has the ability to increase the scopes resistance to avoid troublesome loops. Torque can be to the right (clockwise) or left (counterclockwise) based on whichever direction seems to work best for the task at hand. Gentle torque is used while keeping the scope straight and a more forceful torque is used when removing or following a loop.

Tip Deflection

The tip of the endoscope should always be kept in the middle of the bowel lumen. The techniques of torque, pull/push, and

FIGURE 4-9. B-K Medical (Herlev, Denmark) three-dimensional anorectal ultrasound equipment.

dithering-jiggle will tend to move the tip in several directions. The endoscopist should bring the tip back by controlling both the outer and inner controls with their left hand. With practice, the endoscopist should be able to control and use both tip deflection control knobs in different directions with only the thumb of the left hand. The preference of locking one or both of the knobs is operator dependent. It should be noted, however, that the endoscopist should strive to keep their right hand on the shaft and their left hand on the tip deflection controls throughout the examination in order to maintain proper feel of the scope and to not miss opportunities for advancement and also to avoid "losing ground" by having the scope slide retrograde.

Dithering/Jiggle

The rapid up-and-down, side-to-side, and to-and-fro movements of the shaft of the scope are referred to as dithering or jiggle (Figure 4-15). This technique can be combined with rapid torqueing and rapid in-and-out movements of the scope. The object of this important maneuver is to pleat the colon onto the shaft of the endoscope in order to shorten the colon and to keep the scope straight. Every endoscopist should employ this technique throughout the entire insertion, even when scope advancement appears easy in a straight portion of the colon, especially the descending and transverse colon.

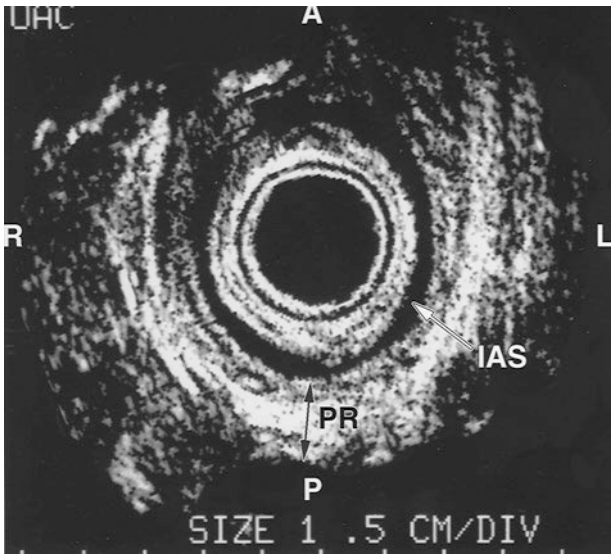

FIGURE 4-10. Two-dimensional endoanal ultrasound view of the U-shaped puborectalis muscle (PR). *IAS* internal anal sphincter.

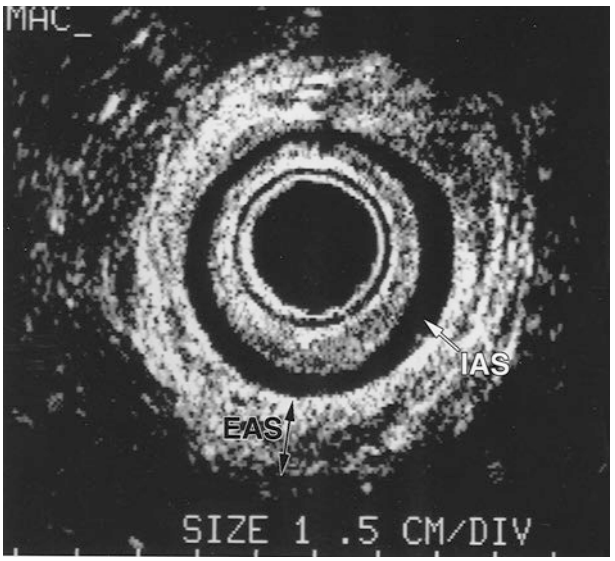

FIGURE 4-11. Two-dimensional ultrasound from the mid-anal canal. This ultrasound image represents normal, intact internal anal sphincter (IAS) (hypoechoic) and external anal sphincter (EAS), (hyperechoic).

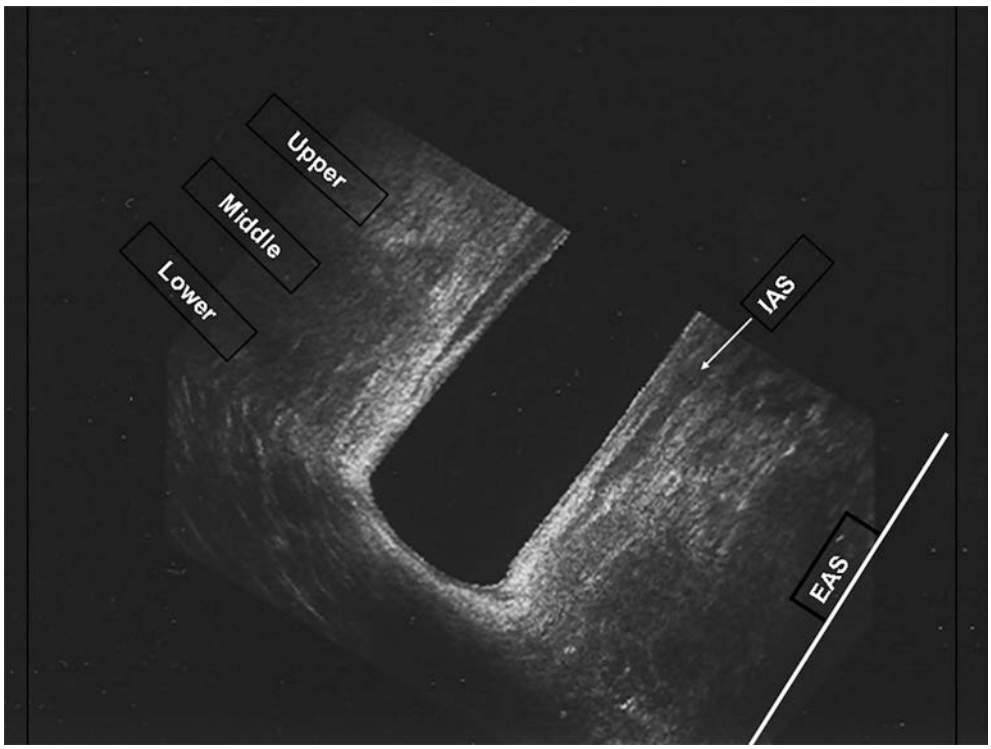

FIGURE 4-12. Three-dimensional coronal view of the upper, middle, and lower anal canal. *EAS* external anal sphincter, *IAS* internal anal sphincter.

Aspiration of Air and Breath Holding

As insufflation of air accumulates during the procedure, the colon becomes distended and elongates, thereby making the goal of reaching the cecum farther away and often causing discomfort to the patient. The judicious and cautious use of air is important during the examination, but thoughtful and calculated aspiration/suction of air is an important adjunct insertion technique. Aspiration of air can allow the scope to

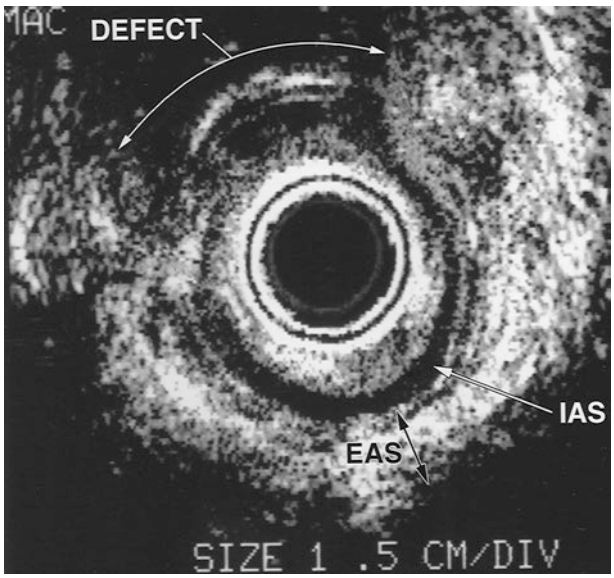

FIGURE 4-13. Anteriorly located defect of both the EAS and IAS in the mid anal canal.

FIGURE 4-14. Torque—a twisting motion of the endoscopist's right hand to the left (counterclockwise) or right (clockwise). Reprinted with permission, Cleveland Clinic Center for Medical Art & Photography ©2015. All Rights Reserved.

advance the tip past a turn (especially at the hepatic flexure) without needed to push the scope forward and likely forming a loop. Once the tip of the scope is past the turn, advancement is much easier due to the straightness of the scope.

Another technique to help the scope around the flexure is the "breath-hold" maneuver. While negotiating difficult turns and bends (especially the hepatic and splenic flexure), have the patient take a deep breath in and hold it. This causes the diaphragm to drop and pushes the flexures over the scope and thereby allows the scope to pass [7]. Aspiration of air and breath holding can be used in conjunction along with precise abdominal pressure techniques.

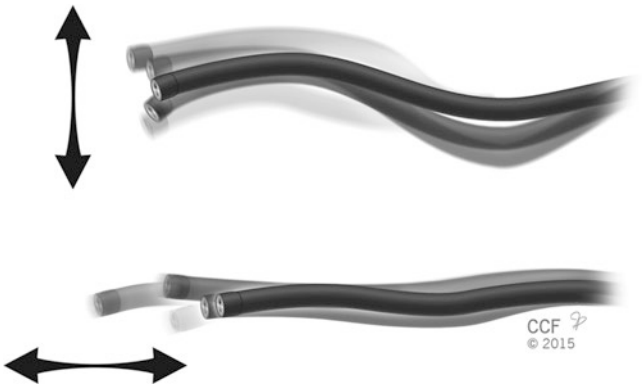

FIGURE 4-15. Jiggle (Dithering)—rapid side-to-side, up-and-down, and to-and-fro movements of the endoscope in order to pleat or "accordion" the colon onto the scope's shaft. Reprinted with permission, Cleveland Clinic Center for Medical Art & Photography ©2015. All Rights Reserved.

Slide-By

The technique of pushing blindly into a turn or bend with maximum tip deflection and without full visualization of the colon lumen to guide the scope along the curvature of the bowel wall to advance the scope past the turn is termed a slide-by technique. Slide-by is a controversial technique that should never be used by unsupervised trainees or novice endoscopists due to the potential dangers and complications that may occur, namely perforation. Slide-by should be terminated if there is any resistance to forward advancement or the mucosa becomes blanched at the tip of the scope. Slide-by can be very painful to the patient because it causes tension on the bowel mesentery and will need to be terminated if not tolerated by the patient. Once the slide-by is successful, the scope needs to be straightened and any loops need to be reduced. Modern endoscopes have a great deal of tip deflection and thus, slide-by is not as commonly employed as when endoscopy was in its infancy (Fig. 4.16).

Adjunctive Maneuvers for More Difficult Examinations

The adjunctive maneuvers employed with endoscopy often serve as the markers between seasoned experts and novices. There are several different maneuvers including abdominal pressure and other external manipulation provided by an assistant under the direct supervision of the endoscopist. In addition it is possible to adjust the position of the patient to either the supine or prone positions. There are also commercially produced overtubes, which are seldom required now with the advent of adjustable stiffness endoscopes. All of these adjunctive maneuvers are designed to reduce the loop formation of the endoscope or to prevent it from reforming

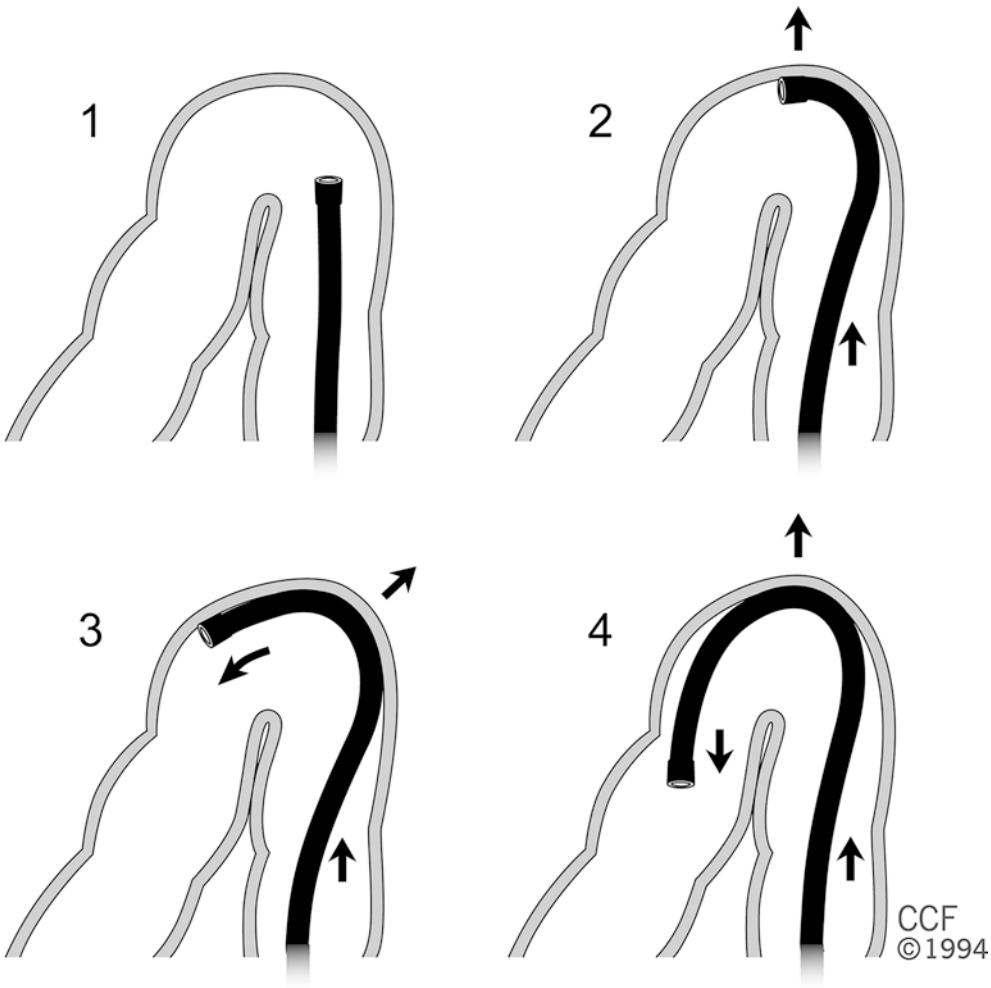

FIGURE 4-16. Slide-by technique. The colonoscope is blindly pushed around a bend, guided by the curve of the scope and the curvature of the bowel wall. Slide-by should be terminated with excessive patient pain or blanching of the mucosa occurs. This technique should be avoided in diseased bowel or in the presence of diverticuli. Reprinted with permission, Cleveland Clinic Center for Medical Art & Photography ©2015. All Rights Reserved.

once it has been reduced. In one study evaluating the use of ancillary techniques, directed abdominal pressure was used in 56% of colonoscopies, while turning to the left and right was performed in 17% and 23% of exams respectively [7]. Like all techniques, however, they are best learned under the supervision of a seasoned endoscopist.

The most likely cause of a difficult examination is the formation of a loop, which makes further advancement of the scope impossible, painful, and potentially harmful. It should be remembered that when facing a difficult-to-negotiate area of the colon, a different technique must be employed to facilitate success. It is the authors' opinion that once a technique has failed twice, a new technique should be employed. The technique of withdrawing the scope all the back to the rectosigmoid and starting the procedure over is a valuable maneuver and again should not be overlooked. It may be necessary during a difficult examination to "take a few steps backwards in order to move forward."

Patient Position

While the procedure starts with the patient on their left side, transitioning to a supine position may ease the navigation of the sigmoid, sigmoid/descending, splenic flexure, and hepatic flexure. Alternatively, if the patient begins supine, turning to the left lateral will help achieve the same goal. While the patient is being moved with the assistance of the endoscopy team, the endoscopist should keep their eye on the screen and attempt to maintain the scope in the middle of the lumen, as it is common for the scope to lose its position during patient movement. Turning the patient to their right side is a technique that is especially useful when the examination has reached the ascending colon and it cannot be advanced into the cecum. Placing the patient into a prone position can also be performed, but this position is often difficult and cumbersome for the staff and the patient. Patient safety must be maintained during this maneuver. The authors

finds this technique useful very occasionally to help the scope navigate in more obese individuals, as the act of having their abdomen on the bed supplies abdominal pressure.

Abdominal Pressure

The technique of splinting certain redundant areas of the colon with external pressure via the abdominal wall may help reduction in loop formation. However, this technique is most effective when a known loop is present and the endoscopist can guide the staff to apply pressure in the correct location. The most common areas of looping are the sigmoid and transverse colon, but simply pressing on different areas of the abdomen will often clue the examiner where the problem exists. Initial attempts at "blind pressure" should be from superior and right of the umbilicus directed toward the left lower quadrant. This has the effect of stabilizing the sigmoid colon and giving counter-pressure to the scope. However, pressure may need to be applied to different areas of the abdomen in order to successfully reduce the loop. The scope should be in the middle of the lumen and as straight as possible before pressure is asserted. This technique should be performed gently and it should not cause the patient any discomfort.

Turning the Scope

During the navigation of a very difficult or acute turn, it may help to change the entire angle of approach of the scope. This is accomplished by torqueing the shaft 180°, while keeping the tip of the scope stabilized in the middle with the help of the deflection knobs (Figure 4-17).

Sigmoidoscopy

The use of the flexible sigmoidoscopy (FS) in the office setting has increased in popularity due to its many applications, ease of use and high yield of findings over conventional rigid proctoscopy. In approximately 50–85% of patients, the entire sigmoid colon can be evaluated and in some patients, the splenic flexure can be reached as well. The flexible sigmoidoscope is easier to handle and the technique is easier to learn than colonoscopy, but nonetheless, supervised training is compulsory. In terms of selective screening purposes, the flexible sigmoidoscope offers a three to sixfold increase in the yield of findings, especially neoplasms, in the rectum and sigmoid colon compared to rigid proctoscopy. It should be noted, however, that FS is not an adequate substitute to colonoscopy for detection of colonic polyps and neoplasms.

The flexible sigmoidoscope is available from various companies with minor variations between them. In general, the channel size ranges between 2.6 and 3.8 mm, the diameter of the scope ranges between 12 and 14 mm and the length varies from 60 to 71 cm (Figure 4-18). As with most instruments in a surgeon's armamentarium, the exact instrument selected is based on surgeon preference in regards to availability, cost and surgeon experience.

The indications for FS in the office setting are broad. FS is an excellent tool to evaluate the patient with bright red rectal bleeding as well as a myriad of other conditions such as in radiation proctitis, nonspecific proctitis, rectal ulcer, anorectal Crohn's disease, or suspected distal neoplasms. FS also

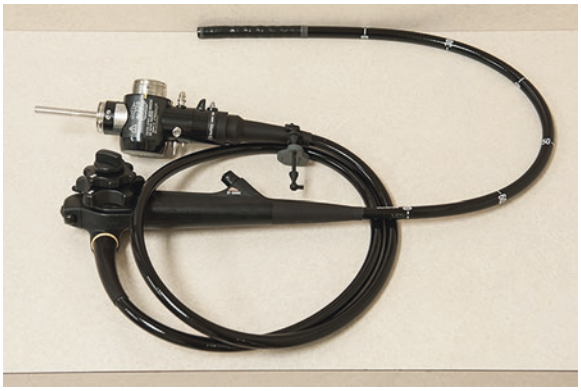

FIGURE 4-18. Flexible sigmoidoscope.

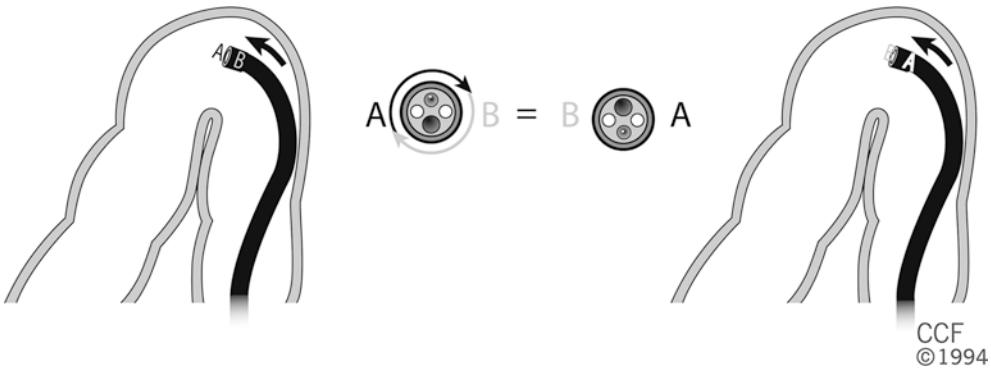

FIGURE 4-17. Turning the scope. This maneuver allows the examiner to change the angle of approach to a turn. Scope torque of 180° is accomplished while the deflection controls keep the tip centered in the lumen. Reprinted with permission, Cleveland Clinic Center for Medical Art & Photography ©2015. All Rights Reserved.

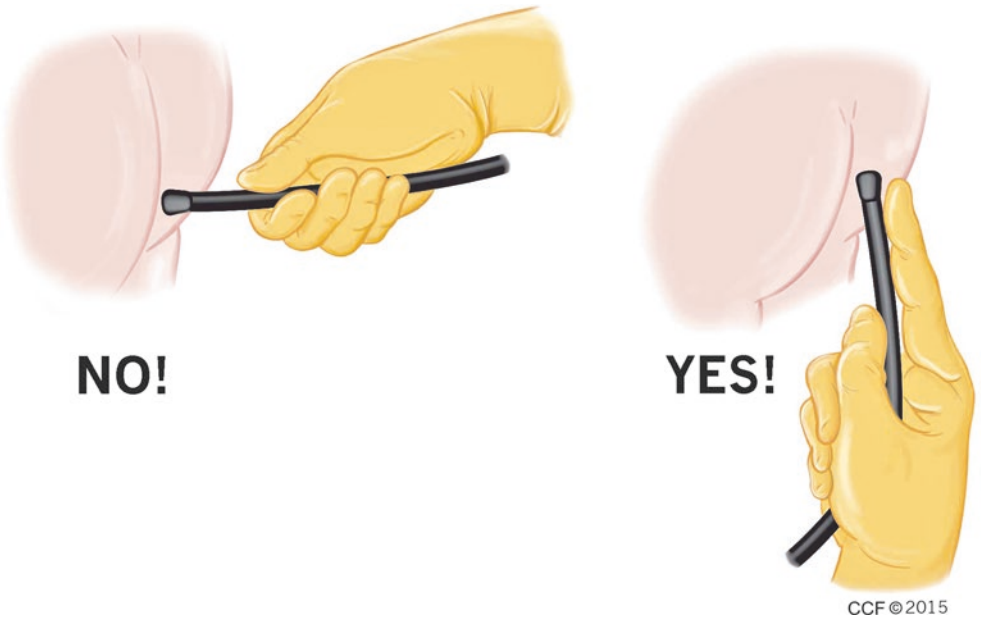

FIGURE 4-19. The flexible endoscope should be inserted "side first" for less painful passage through the anal canal. Reprinted with permission, Cleveland Clinic Center for Medical Art & Photography ©2015. All Rights Reserved.

has utility in examining and acquiring cultures or biopsies of the distal colorectum in diarrheal states, ruling out *Clostridium difficile*, infectious and ischemic colitis. Radiographical abnormalities can be confirmed with the use FS as well as diagnosing or for the follow-up of inflammatory bowel disease. Additionally, postoperative evaluation of distal anastomoses can rapidly be performed, evaluating for stricture or recurrence of cancer as well as recurrences after local excision.

Patients are typically given one to two enemas prior to the procedure and generally do not require oral laxatives or dietary restrictions. The position that offers the easiest approach is the left lateral recumbent but the prone jackknife position can also be used. Sedation is not typically necessary in the vast majority of patients.

The well lubricated scope is inserted "side first" rather than "end on" which allows for the edge of the endoscope to act as a leading point and avoids pushing the blunt end "*en face*" against the anal sphincter with subsequent trauma and pain (Figure 4-19) [2]. After proper insertion of the scope, gentle air insufflation is achieved and the scope is advanced under direct visualization to approximately 10–12 cm. The instrument is then passed into the sigmoid colon by a combination of torqueing in either the clockwise or counterclockwise direction and short advancement and withdrawal (dithering). These maneuvers are used to advance the scope as far as the splenic flexure, if amendable. The endoscopist should use a combination of these techniques along with air insufflation, suction and irrigation to successfully advance the scope. After the scope has been advanced to its extent, careful and thoughtful withdrawal is achieved slowly, in order to evaluate the entire mucosal surface. Any lesions that are detected can be biopsied or have brush cytology performed to establish a diagnosis. Additionally, small polyps can be removed with cold or hot biopsy forceps. Larger polyp removal may be best suited during a subsequent colonoscopy when a full bowel preparation has been achieved. It is important to remember that FS is excellent at examining the proximal and mid rectum as well as the left and sigmoid colon, but is suboptimal for the most distal anorectal disorders, and therefore, another method such as anoscopy should be employed to visualize this area.

Complications of FS are uncommon but may be serious or life threatening when they do occur. Over distention of air will cause abdominal pain and patient discomfort or possibly perforation due to barotrauma. Perforation is most common at the distal sigmoid where it angulates from the relatively fixed rectum at the sacral promontory. It is critical for the endoscopist to be aware of any patient discomfort during the procedure, to use as little insufflation as necessary and abort the procedure if necessary. Electrocoagulation should be avoided or used very judiciously in biopsies or snare techniques unless the patient has received a full mechanical bowel preparation to reduce the risk of explosion due to the presence of hydrogen and methane gas present within the bowel lumen.

Colonoscopy

The colonoscopic examination is often at the center of the evaluation and treatment of many patients with intestinal complaints. A thorough colonoscopy allows the physician to completely evaluate the mucosa of the terminal ileum, colon,

and rectum as well as to obtain biopsies or photodocumentation of any abnormalities identified. The colonoscopy also remains at the forefront of the screening for colorectal carcinoma. The procedure also plays a central part of the clinical practice of most colon and rectal surgeons. Over 90% of colon and rectal surgeons reported performing colonoscopies as part of their regular practice, with these surgeons reporting an average of over 40 endoscopic procedures a month. Clearly the performance of colonoscopy plays a central role in the training and practice of colorectal surgeons across the world [8].

Indications and Contraindications

The specific indications for performing a colonoscopy are multiple and the endoscopic evaluation and management of these conditions is covered in the appropriate sections elsewhere in this text. There does exist some debate regarding the appropriateness of performing the procedure in varying clinical scenarios and an attempt to ensure the appropriateness of the procedure has been sought. In 2000, the American Society for Gastrointestinal Endoscopy and in 2008 the European Panel on the Appropriateness of Gastrointestinal Endoscopy was revised to EPAGE II [9]. Each published their respective appropriateness guidelines regarding when to perform a colonoscopy. The EPAGE II guidelines are intended to serve as a guide for referring physicians and is available to the clinician online at: http://www.epage.ch/, allowing the consulting physician to ensure the procedure is indicated prior to making the referral to an endoscopist. Despite the existence of these guidelines, they have not been widely accepted [10].

Using either of these two sets of guidelines, there are numerous publications demonstrating that many colonoscopies are indeed inappropriate. Using the ASGE guidelines there have been reports ranging from a 13% inappropriate procedure rate [11] to 18% [12]. These are even higher when the European criteria are utilized. Inappropriate procedure rates of 30% are reported [13], and these percentages have been confirmed in several multi-institutional studies [14, 15]. One reason for these high numbers is that an open access practice pattern is common among many physicians who perform endoscopy [16]. Indeed, these guidelines are designed primarily for the open access endoscopy scenario, where the endoscopist serves more as a technician: performing and interpreting the procedure for the physician ordering the procedure. These studies show that it is often surgeons that fall outside the ordering guidelines. Since colon and rectal surgeons seldom perform endoscopy in these open access systems, there are no studies evaluating the appropriateness of colonoscopies performed by these subspecialty surgeons.

The only absolute contraindication for performing a colonoscopy is in a patient who requires immediate operative intervention. All other contraindications are relative and are at the discretion of the endoscopist. Patients with active colitis or those with a recent intestinal anastomosis are at higher risk for complications but a careful endoscopic examination can be safely conducted in these patients [17]. As with any procedure being performed, the benefits must outweigh the risks.

Bowel Preparation

Unlike in elective colon surgery there is no controversy surrounding the necessity of mechanical bowel preparation prior to a colonoscopy. The bowel prep is of critical importance in order to be able to adequately examine the entire colon, with inadequate cleaning reported in up to 27% of patients [18]. It is often considered the most unpleasant part of the procedure on the part of the patient and a great deal of research has gone into making it more effective and the process more palatable for the patient. Despite this, the optimal regimen has yet to be determined [19]. While many practitioners add additional dietary restrictions such as protein restriction or a low residue diet for 2–3 days prior to the procedure but there are no studies that validate these practices.

There remain numerous options for bowel preparation prior to the procedure with three broad categories of agents in use: osmotic agents, polyethylene glycol (PEG) solutions and stimulants. The choice is somewhat practice-dependent, although more practitioners use PEG-based preparations in their practices than the osmotic agents. Osmotic agents such as Sodium Phosphate and Magnesium Citrate work by increasing the passage of extracellular fluid across the bowel wall. Following the FDA alert regarding renal damage associated with oral sodium phosphate with bowel cleansing prior to colonoscopy in 2008, its use declined precipitously in the USA [20, 21], yet it remains a viable option [22]. The potential side effects associated with its use include nephropathy and renal insufficiency resulting from the tubular deposition of phosphate [23]. These side effects are uncommon; yet, with many and potentially better options, most practitioners including the authors forgo using it in clinical practice. Stimulants such as Senna and Bisacodyl increase bowel wall smooth muscle activity, and are primarily used as adjuncts to one of the other preps rather than as a stand-alone prep [24].

There is also good evidence to suggest that regardless which agent is chosen, splitting the timing into the half-day prior to and half-day of the procedure results in an overall better cleansing [25]. The majority of patients seem willing to comply with this split preparation and this results in an improvement in the number of satisfactory bowel preparations [26]. At least one meta-analysis demonstrates that a 4-L split-dose PEG is superior to other preparation strategies [27]. It is also critical that the instructions that are given to the patient are understood. It is beneficial if the language is tailored to the individual and instructions should include commonly asked questions, as this will increase patient understanding and compliance with whichever agent(s) is chosen [28].

The reporting of the quality of the bowel prep is both an important part of documentation of the procedure as well as a standard of quality. An adequate bowel preparation should be achieved and documented in greater than 85% of procedures [29]. There are numerous scales for grading the adequacy of the bowel prep, yet none is proven superior. The Aronchick scale grades the overall quality on a scale of 5 (excellent) to 0 (inadequate) [30]. The Ottawa [31], Boston [32] and Chicago [33] scales grade the preparation quality in different anatomic areas of the colon adding them together to form a total score. These scores range up to 9 for the Boston, 14 for the Ottawa and 36 for the Chicago. The easiest and therefore the most commonly employed is the 4-point scale of excellent, good, fair, and poor. Regardless of which scale is chosen, they are all subjective and therefore subject to bias.

Special Considerations

The Difficult-to-Prep Patient

With the high number of patients with an inadequate bowel prep, as above, it is not uncommon to encounter patients with a prior history of a poor bowel prep presenting for a repeat evaluation. It is recommend that patients undergo early repeat colonoscopy when the bowel preparation quality is deemed inadequate, defined as the inability to detect polyps smaller than 5 mm [34]. Adenomas and high-risk lesions are frequently detected on repeat colonoscopy in these inadequate prep patients, suggesting that these lesions were likely missed at the time of the initial evaluation [35].

There are no prospective studies dealing with this patient population and the practices are individualized. Some practitioners either increase the amount of liquid diet by 1 day or add an osmotic or cathartic agent to the existing regimen. In addition antiemetics or anxiolytics may be added in an attempt to make the prep more palatable to the patient. It has also been demonstrated that patients tolerate a larger volume PEG prep solution [36]. In hospitalized patients it has also been demonstrated that the prep can be administered via a gastroscope the day prior to colonoscopy, improving patient tolerance and the subsequent quality of bowel preparation for colonoscopy [37]. Ultimately the clinician is left to their best clinical judgment.

The Patient Requiring Antibiotics

The data regarding the need for prophylactic antibiotics for patients undergoing a colonoscopy is lacking. While there are case reports of endocarditis following colonoscopy, the need for antibiotic prophylaxis for patients undergoing elective endoscopy is rare. Antibiotic prophylaxis against infective endocarditis is not routinely recommended for colonoscopy although there is some evidence suggesting that infective endocarditis due to *Streptococcus* and *Enterococcus* species may indeed warrant prophylaxis in these patients [38] Based upon current guidelines antibiotic prophylaxis is reserved for individuals with cardiac valvular disease at high risk of infective endocarditis. There has been a small but significant increase in the incidence of infective endocarditis since 2008, when the more restrictive guidelines regarding the lack of need for prophylaxis were issued [39], but the clinical significance remains unclear at this time [40, 41].

The ASGE guidelines published in 2003 and revised in 2008 (Table 4-1) divide the patients into high, moderate, and low risk based upon the cardiac risk factors [42]. However, even high-risk patients are not required to have antimicrobial prophylaxis prior to endoscopic procedures. In patients who fall into the high-risk category, a frank discussion with the patient's cardiologist or infectious disease specialist is warranted.

TABLE 4-1. Antibiotic prophylaxis for elective colonoscopy ± biopsy

Conditions	Patient risk	Antibiotics
Prosthetic heart valves	High-risk patients	Prophylaxis is optional
History of endocarditis		
Systemic-pulmonary shunt		
Complex cyanotic congenital heart disease		
Cardiac Transplant with valvulopathy		
Other congenital cardiac abnormalities	Moderate-risk patients	Prophylaxis is not recommended
Mitral valve prolapse with regurgitation		
Rheumatic heart disease		
Hypertrophic cardiomyopathy		
CABG	Low-risk patients	Prophylaxis is not recommended
Defibrillators		
Pacemakers		
Repaired septal defect or PDA		
Physiologic heart murmurs		
Mitral valve prolapse without regurgitation		
Prosthetic joints <6 months	Patients to consider prophylaxis	Consider prophylaxis
Peritoneal dialysis		
Vascular grafts	Insufficient data	Consider prophylaxis

The Anticoagulated Patient

The anticoagulated patient poses an even larger dilemma for the endoscopist. As the number of anticoagulation medications and the number of patients receiving these medications increase coupled with the rising number of colonoscopies performed, this clinical scenario is frequently encountered, and can be expected to increase. While a diagnostic colonoscopy itself poses little bleeding risk, the possibility of biopsies or polypectomy must be considered. It is imperative that the endoscopist weighs the risk of possible thrombotic events if any medication is withdrawn against those of bleeding. This must often be done prior to the procedure, when knowledge of any pathology or whether any biopsy or polypectomy does not exist.

According to the 2005 ASGE guidelines [43], a diagnostic colonoscopy or a colonoscopy with biopsy is considered a low-risk procedure for causing hemorrhage. A polypectomy however is considered to be a high-risk procedure and any anticoagulant medications should be adjusted according to the medication that is being taken (Table 4-2) [44–47]. These decisions will often need to be coordinated with the physician monitoring the anticoagulant, as it is often not within the purview of the endoscopist to evaluate the thrombotic risk. When to reinitiate anticoagulation is another difficult issue that must take into account what was performed at the time of the endoscopy, with the recommendation being to reinitiate the therapy as soon as hemostasis has been confirmed, which is obviously difficult [48]. The incidence of post-polypectomy hemorrhage peaks at 4–6 days and this risk extends to at least 14 days. In general, the morbidity of a thromboembolic event is greater than that of hemorrhage—therefore, resuming anticoagulation as soon as possible and treating hemorrhagic complications as they occur seems to be the most prudent management strategy.

Incomplete Colonoscopy

A complete colonoscopy examination to the cecum should be achieved in >95% for screening cases and is considered a major benchmark of quality. The slight decrease in colorectal cancer incidence over the past several decades is attributed in part to early detection and removal of colorectal polyps before they progress to invasive malignancy [49]. This decrease is attributed mostly to left sided lesions versus right sided lesions due to potential genetic factors, missed lesions, poor bowel preparation, and incomplete examinations [50]. Right-sided colon lesions tend to more flat and depressed which undoubtedly contributes to missing these lesions.

Rates of incomplete colonoscopy range from 5 to 25% and reasons are varied [49, 51]. Whatever the reason for incompletion, a secondary examination must be offered to the patient. The dilemma of what to do after an incomplete colonoscopy is best approached by delineating what was the specific reason for the incomplete exam.

TABLE 4-2. Management of anticoagulation medications for elective lower GI endoscopy

↑ Risk procedures			↓ Risk procedures
Polypectomy >1 cm			Diagnostic endoscopy
Endoscopic dilatation			Flexible sigmoidoscopy/colonoscopy ± biopsy
			Stent placement without dilation
Medications			
Medication	Risk	Medication instructions	Medication restart
Warfarin		Hold 3–5 days prior	
A-fib		Hold warfarin and start UFH or LMWH when INR ≤2.0	
A-fib w h/o embolic event		Hold warfarin and start UFH or LMWH when INR ≤2.0	
Mechanical valvular heart disease			
Low molecular weight heparin (LMWH)	↓	No medication adjustment necessary	
	↑	D/C 8 h prior to procedure	Restarting medication Individualized
Bridging LMWH: to replace Heparin Window D/C Warfarin 3–5 days prior to procedure		Consider 1 mg/kg q 12 h	D/C as above
Thienopyridines: clopidogrel/ticlopidine	↓	No change necessary	
	↑	D/C 7–10 days prior to procedure, consider continuing aspirin if on dual therapy	Restarting individualized
Dipridamole	↓	If no preexisting bleeding disorder, no change necessary	
	↑	Unknown	
GIIb/IIIa inhibitor		Medication not usually used in patients undergoing elective procedures. Consult with Prescribing Physician or Cardiology	

Patients who had an incomplete colonoscopy due to an unsatisfactory or poor prep must be re-educated on the preparation process, as above. A repeat colonoscopy in this situation is the most logical and effective approach [52, 53]. In patients whom the procedure was terminated secondary to tortuosity or pain, a repeat colonoscopy under alternate analgesia or a repeat colonoscopy with a more experienced endoscopist may be appropriate [49, 53]. Alternatively, CT colonoscopy (virtual colonoscopy) may also be performed with good success. It should be noted that any lesion >6 mm found on CT colonoscopy will require a standard colonoscopy as follow-up. As a final option, a double (air and ingested contrast) barium enema can be considered. Even though barium enema has been available for decades and is an accepted screening tool for colorectal carcinoma, a recent large population-based study showed a cancer miss rate of 22%, which makes this a very poor second test to either standard or CT colonoscopy [54].

In patients in whom the colonoscopy was incomplete secondary to stricture or an obstructing lesion, options include on-table colonoscopy at the time of resection, preoperative CT colonoscopy, or postoperative colonoscopy [49].

Procedure

The Endoscopy Suite

Unlike the flexible sigmoidoscopic examination that can be adequately performed in the office, a full colonoscopy typically requires a larger space with more equipment. The endoscopy suite should provide an adequate amount of space for the necessary endoscopic equipment and patient stretcher as well as allow adequate egress of staff and equipment. It is important that clear and unobstructed sight lines are maintained for all of the personnel in the endoscopy suite such that adequate visualization on the patient as well as any monitoring equipment is maintained at all times. It is dark in the endoscopy suite and the endoscopist is concentrating on the procedure therefore it is imperative to have a designated person, who's primary responsibility is for monitoring the patient throughout the procedure.

If sedation is to be used, as is most commonly performed in the USA, it is important that oxygen and routine EKG monitoring are performed. A consensus statement states that patients who are having their procedure performed under moderate or deep sedation "must have continuous monitoring before, during, and after the administration of sedatives." Monitoring may detect early signs of patient distress, such as changes in cardiovascular or pulmonary parameters prior to any clinically significant compromise. Standard monitoring of sedated patients undergoing GI endoscopic procedures includes recording the heart rate, blood pressure, respiratory rate, and oxygen saturation. Although electronic monitoring equipment often facilitates assessment of patient status, it does not replace a well-trained and vigilant assistant [55].

Instruments

As with flexible sigmoidoscopes above, there are numerous manufacturers of colonoscopes that typically vary from 130 to 168 cm in length. There are also pediatric colonoscopes that are smaller in diameter than the typical adult endoscope: 11.3 mm versus 12.8 mm. The basic colonoscope consists of a suction channel, an air/water channel, and fiber-optic bundles for light transmission, along with a biopsy port, which is connected into the suction channel (Figure 4-20a, b). Modern colonoscopes commonly possess variable stiffness controls that allow the endoscopist to vary the rigidity of the endoscope dependent on the clinical situation. It is hypothesized that this ability decreases the need for external over the tube stiffeners, and they have been proven to decrease procedure-related pain and the doses of sedative medications during colonoscopy [56].

Sedation

There are numerous studies evaluating the optimal method in which to sedate the patient for colonoscopy procedures and there is ample dogma employed as well. As with a bowel prep, there is no perfect sedation regimen but the endoscopist must be familiar with the side effect profile of medications being used and be prepared and comfortable with any reversal agents. While there is literature demonstrating that colonoscopy can be performed adequately and safely on the un-sedated patient, the practice in the USA is rare. In one study, less than half of the endoscopists polled practiced unsedated colonoscopy, listing a lack of patient acceptance as the most common reason for not offering it [57]. In an evaluation of Canadian gastroenterologists and colon and rectal surgeons, the endoscopists reported using sedation for more than 90% of colonoscopies they performed. The most common sedation regimen was a combination of midazolam and fentanyl [58]. While the combination of a narcotic with a benzodiazepine remains popular for providing colonoscopy sedation, several alternate medications have been evaluated.

Nitrous Oxide

Nitrous oxide is one medication that has been found effective in several studies to be effective for colonoscopic sedation. While some studies show that it is not an effective substitution for intravenous sedation and analgesics [59], there are several studies that show it to work well in that setting. In a review of seven randomized trials using nitrous oxide for colonoscopy, four showed that nitrous oxide is as good at controlling pain as conventional methods, while another showed that sedation was actually improved [60]. Despite this it is unlikely that Nitrous Oxide will become widely used in clinical practice.

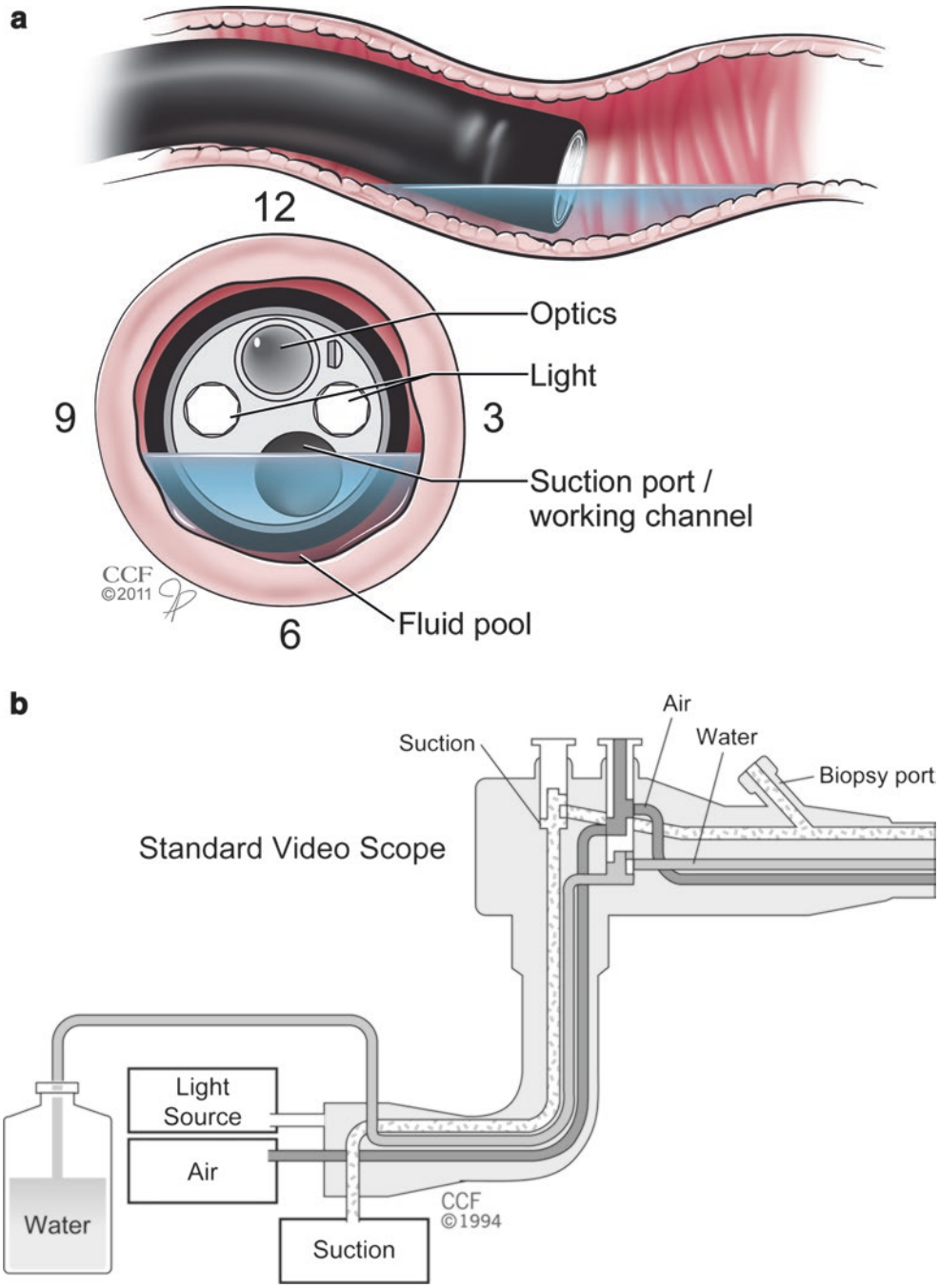

FIGURE 4-20. (**a**) End-on view of the endoscopic tip, showing suction/biopsy channel, air/water channel, lens, and light source. (**b**) Basic endoscope design. Reprinted with permission, Cleveland Clinic Center for Medical Art & Photography ©2015. All Rights Reserved.

Ketamine

Ketamine is another medication that has demonstrated beneficial in colonoscopy. In one study, the addition of low-dose ketamine to a standard sedation regimen resulted in more rapid and better quality of sedation with stable hemodynamic status, and similar recovery times [61]. Due to a lack of familiarity with the medication and concerns regarding central nervous system alteration this medication is also unlikely to receive widespread use for endoscopic sedation.

Propofol

By far, the preponderance of the recent literature involving sedation for endoscopy involves the use of propofol, which has increased substantially among endoscopists [62]. In a Cochrane Review of the randomized controlled studies comparing propofol with standard sedation of a narcotic and benzodiazepine, the findings were that recovery and discharge times were shorter with the use of propofol. In addition, there was higher patient satisfaction with use of propofol. No difference in the procedure time, the cecal intubation rate

or the incidence of complications was noted [63]. A later meta-analysis confirmed these findings [64].

One criticism of the use of propofol is that an anesthesia provider is typically required to administer the agent—thereby increasing the cost associated with the procedure. It has been demonstrated that the medication can be delivered in a patient controlled setting [65] or by a nurse under the supervision of the endoscopist [66]. These methods are likely to remain in the minority, however, and the question remains unanswered in an era of cost containment whether the benefits listed above justify its use.

Colonoscopy Technique

Colonoscopy is the most challenging endoscopic examination, and appropriate training, practice, attention to detail, and patience is needed in order to successfully complete this examination. The act of negotiating a 5–6 ft flexible tube through a tortuous colon painlessly and efficiently while performing detailed surveillance and therapeutic maneuvers is a difficult task. This section will describe successful navigation to the full extent of the colonoscopy relying on the principles mentioned prior.

Anal Intubation

The well-lubricated colonoscope is inserted as previously described for sigmoidoscopy. The examiner must make sure that the scope is brought over to the patient straight without any twists or loops from the endoscopy tower.

The Rectum and Rectosigmoid

Once the endoscope is placed into the anus, it is advanced into the rectum while insufflating an appropriate amount of air to distend the rectum. The distensibility of the rectum is an easy way to evaluate rectal compliance based on how easily and how much the rectum distends. Negotiating through the rectum is usually not difficult, but if difficulty is encountered going through the three valves of Houston (Figure 4-21), torque can be employed to reach the rectosigmoid.

The rectosigmoid can pose extreme difficulty and is often one of the more challenging areas of the colonoscopy. There is often an acute angle at this junction from a redundant and floppy sigmoid colon. If the patient has undergone prior pelvic surgery, especially hysterectomy, the sigmoid may become fixed and adherent which makes negotiation of the turn difficult and often painful. In other patients (usually males) this turn is obtuse and very easy to advance. In situations where the turn is difficult, a combination of all the basic maneuvers discussed should be employed. The scope should be kept as straight as possible as a combination of short advancements—withdrawals with jiggle and a slight clockwise

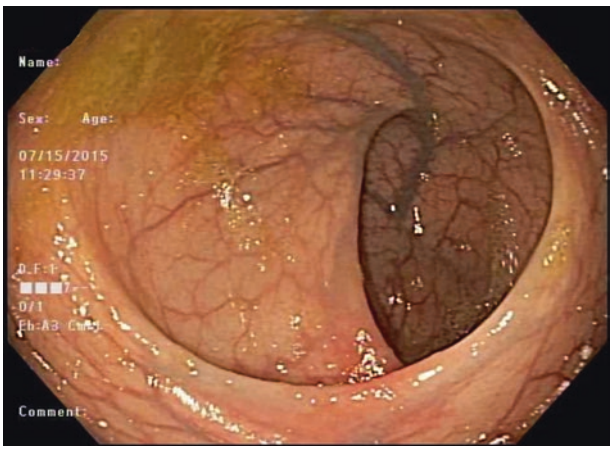

FIGURE 4-21. The first and second rectal valves of Houston. Note the large submucosal venous plexus.

torque (this torque may be considerable in certain individuals) should be employed to advance the scope into the sigmoid colon. This portion of the exam requires adequate patient sedation and relaxation. For the most acute angles, multiple small advancing steps toward getting the tip of the scope past the angle with tip deflection and torque are needed. Slide-by maneuvers should not be routinely performed.

Once the scope advances into the sigmoid, tip deflection and some torque will help reduce any loops. If this is not possible, the scope can be carefully inserted farther into the sigmoid with the loop still in place as long as this does not cause too much patient discomfort. Once the descending colon comes into view, any loops should be reduced with withdrawal and torqueing maneuvers. This may require a substantial torque with the right hand and usually the endoscopist can feel the scope reduce and any patient discomfort or pain will usually abate at this time. It should be noted that successful completion of the procedure is quite low if the rectosigmoid loop is not reduced [67].

Sigmoid Colon

The sigmoid colon is the most tortuous segment of the colon with associated high muscular tone, spasm, and a higher incidence of diverticulosis (Figure 4-22). The sigmoid colon is not fixed and can be very redundant and elongated. The sigmoid readily accepts the endoscope and a considerable length of scope can be inserted. All of these factors contribute to making this a difficult-to-navigate segment requiring insertion-pull back, jiggle, and a variable amount of torque (usually clockwise). These maneuvers will allow the sigmoid to "accordion" over the scope, which allows for efficient advancement and the prevention of loop formation.

Diverticula, when present, can be of various sizes and the larger ones can be dangerous as they can be mistaken for the true bowel lumen. Careful navigation around a diverticula

FIGURE 4-22. The sigmoid colon has variable degrees of tortuosity, spasm, diverticular disease, and muscular tone.

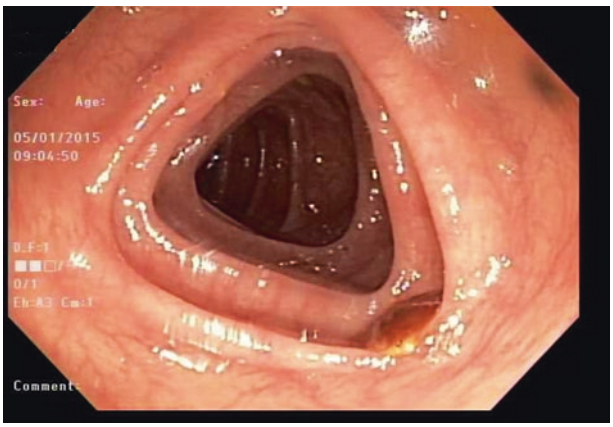

FIGURE 4-23. Transverse colon: note the common triangular appearance of the lumen.

laden sigmoid requires patience and the pull back techniques in order to gain a broader view of the colon. Perforation of a diverticulum can occur if too forceful or blind advancement (slide-by) is incorporated.

Sigmoid-Descending Junction

The junction of the sigmoid and descending colon can be difficult if a sigmoid loop is present or has only been partially reduced. Keeping the scope straight and gently advancing and withdrawing 1–2 cm at a time usually works, as opposed to pushing through the loop which will undoubtedly cause pain. One can also attempt to apply abdominal pressure at this point or turn the patient position to supine (or lateral) in attempts to advance into the descending colon.

Descending Colon

The descending colon is usually straighter and less muscular than the sigmoid colon. It should be noted that even though this segment of the colon is easier to advance, jiggle, torque, air suction, and push and pullback techniques should still be employed to pleat the colon over the scope.

Splenic Flexure

After advancing through the descending colon, the splenic flexure is the next obstacle. The splenic flexure is identified by the strong cardiac pulsations often seen and occasionally the blue shadow from the spleen itself. Often, this is a simple 90° turn that can be easily negotiated with some tip deflection and torque and other times, the splenic flexure may be a series of turns and twists in multiple planes. A difficult splenic flexure should be treated as already described using tip deflection, torque and push and pull techniques. Often, changing patient position or externally splinting the sigmoid with abdominal pressure can achieve flexure passage as well. It should be noted that the straighter the sigmoid colon is, the easier the splenic flexure will be. A sigmoid loop can form during this portion of the exam if forward push is used to get past the flexure.

Transverse Colon

The transverse colon is characterized by the triangular appearance formed by the taenia coli (Figure 4-23). If no proximal loop has been formed, the scope will advance readily through this segment. If a loop is formed in the splenic flexure or the sigmoid, application of abdominal pressure at the sigmoid coupled with a strong torque (left or right) will usually reduce the loop and allow for a one-to-one advancement rather than a paradoxical advance. It should be remembered that torque, jiggle, and push-pull should be employed even when this segment is straight.

One area of difficulty may be in the mid-transverse colon. The mid transverse colon may exhibit ptosis and descend down into the pelvis and could be fixed with adhesions, especially following pelvic surgery. Loops are commonly created during this part of the exam, and external pressure and changing the patient position to either right lateral or supine will help with advancement.

Hepatic Flexure

The hepatic flexure is often recognized by the large blue shadow from the liver (especially in thin patients) (Figure 4-24). As one advances through the transverse colon, the hepatic flexure comes into view, often with a variable amount of pooling liquid stool. If the flexure turn is very acute, the novice endoscopist often mistakes this “fools cecum” for the true one, believing that they are at the end of

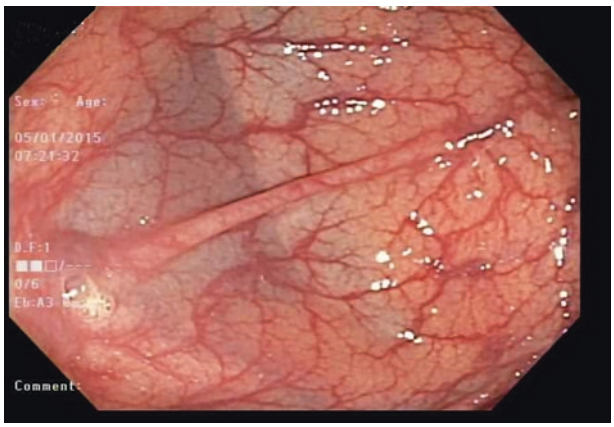

FIGURE 4-24. Hepatic flexure: note the *blue shadow* from the liver. There is usually a sharp turn which can be quite difficult to negotiate.

the colon. As with any other turn or flexure, if the scope is straight, advancement will be easier than if a loop is formed proximally. Often, one can gently push through a loop and get into the ascending colon and then reduce the loop. At other times, the examiner may find it useful to use air suction and abdominal pressure techniques to negotiate this turn. Another technique previously mentioned, involves having the patient take a deep breath of air to push the diaphragm down, and thus, the scope down into the ascending colon.

Ascending Colon and Ileocecal Valve

As the scope advances past the hepatic flexure into the ascending colon, prevention of a new loop is critical, as any proximal loop at this point will make further advancement of the scope extremely difficult. Pushing through a loop in the ascending colon is not as successful as it is on the left side of the colon since there are many bowel loops to accommodate before push pressure is transmitted to the end of the scope [67]. It can be very common to have the entire length of the scope inserted and there is still additional colon to traverse, due to inappropriate or minimal pleating techniques and the presence of loops. A change in patient position to either supine, right lateral, or prone coupled with the basic insertion techniques will prove to be extremely important in these situations and help advance the scope to the cecum.

The ileocecal valve is a fold at the base of the ascending colon that may appear as an obvious polypoid-like yellowish mass or can be totally hidden (Figure 4-25a, b). When the valve is not easily recognizable, the presence of gas, stool, or bile flowing from it is helpful to aid in its identification.

Cecum

The complete colonoscopic examination is ensured when the cecum has been reached. This blind sac is characterized by the "crow's foot" which is made up of the muscular arrangement of the colonic wall and the crescent or circular shaped appendicle orifice (Figure 4-26a, b). These landmarks are extremely important in quality assurance of a complete examination and photodocumentation is mandatory. Relying on trans-illumination of the scope through the abdominal wall in the right lower quadrant can be deceptive and is inadequate evidence of a complete examination. Careful and detailed examination of the entire cecum is important due to the fact that many cecal lesions, including serrated adenomas are flat or recessed and can be quite deceptive and easily missed with a casual examination.

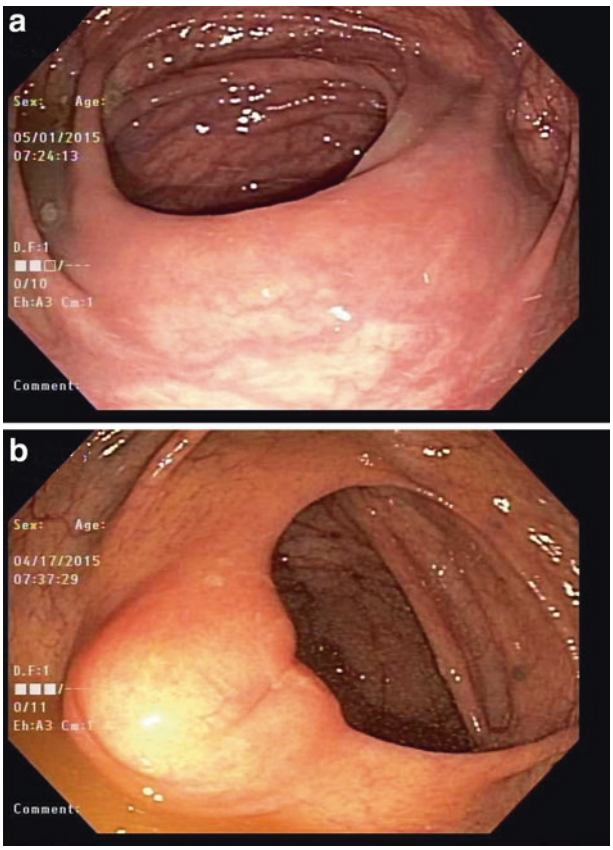

FIGURE 4-25. Different appearance of the ileocecal valve. (**a**) Flat and subtle. (**b**) Polypoid and obvious.

Ileocecal Valve Intubation

It is common for some endoscopists to routinely advance the endoscope into the terminal ileum. While it is considered a critical assessment when performing either an initial evaluation or follow-up for Crohn's disease, or in a search for obscure bleeding, it is unclear the precise role of routine visualization of the terminal ileum on colonoscopy. It is a skill, and the ability of the endoscopist to perform the maneuver improves with practice. The technique involves first removing any loops from the colonoscope, as significant looping of the instrument make entering the ileum much more technically challenging. The edge of the ileocecal valve is hooked

with the curved endoscope and the scope is then gently inserted into the ileum when the lumen is visualized (Figure 4-27). The intubation of the ileum confirms a complete colonoscopic evaluation and this confirmation can often be a frustrating endeavor for beginning endoscopist [68].

In an assessment of the ileal intubation learning curve, 50 procedures was the benchmark, but once learned could be accomplished in most patients in less than 1 min [69]. The addition of routine ileoscopy to screening colonoscopy has been demonstrated to detect asymptomatic small bowel carcinoid tumors and has led some to argue that this should be considered part of the endoscopic examination [70]. A large study at the Mayo Clinic involving over 6000 patients however did not validate this. Terminal ileum intubation showed gross abnormalities in only 1% of the patients, and pathologic abnormalities were identified for only 0.3% of the patients. These authors concluded that intubation of the terminal ileum should not be a required part of screening colonoscopy [71].

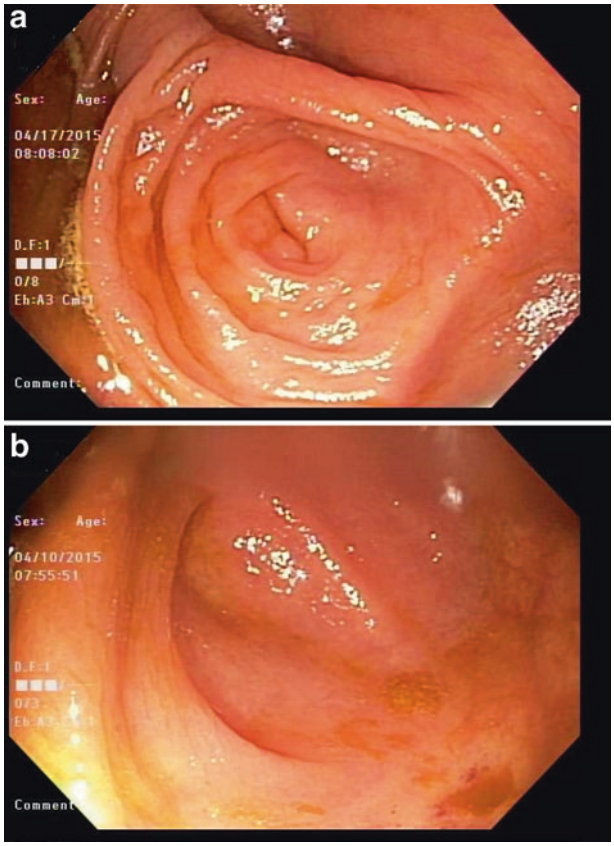

FIGURE 4-26. Reaching and proper identification of the cecum is compulsory for a complete examination. (**a**) Round appendiceal orifice with associated crow's foot. (**b**) Crescent shaped appendiceal orifice.

Terminal Ileum

If the endoscopist chooses to intubate the ileum, it is easily recognizable by its granular appearance and its increased motility (Figure 4-28). Quite often in younger patients, there will be innumerable lymphoid follicles that may resemble small polyps. The scope should be advanced as far as it is

FIGURE 4-28. Terminal ileum: note the granular mucosa and the fine muscular folds.

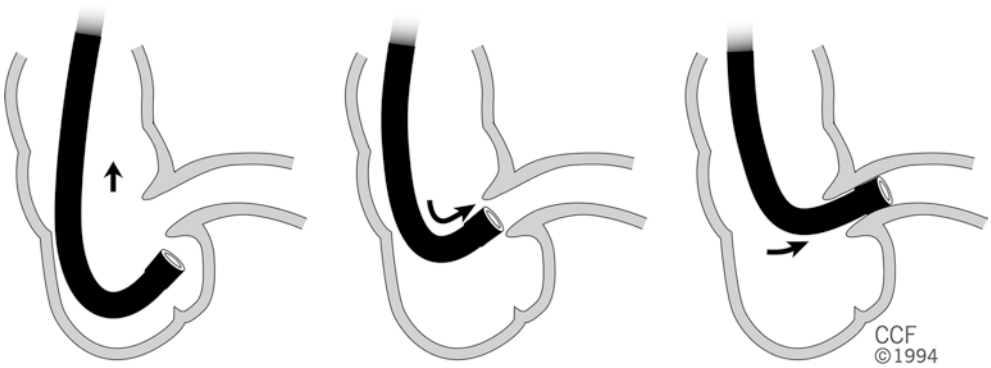

FIGURE 4-27. Intubation of the ileocecal valve: identification of the orifice, impacting the scope while giving air insufflation and then waiting for the bowel to relax before advancement into the terminal ileum. Reprinted with permission, Cleveland Clinic Center for Medical Art & Photography ©2015. All Rights Reserved.

comfortable and appropriate biopsies taken when needed. One should try to keep air insufflation to a minimum during this portion of the examination.

Alternate Techniques

CO_2 Insufflation

Two alternatives to traditional air infusion colonoscopy are water-assisted colonoscopy and insufflation with Carbon Dioxide. Due to the fact that CO_2 is more rapidly expelled from the colon than air, the hypothesis is that due to this rapid diffusion, there will be decreased pain associated with CO_2 infusion compared to air. Some evaluations have been consistent with this [72] hypothesis, while others have not shared these findings [73]. Due to the paucity of literature documenting efficacy, the technique must be considered experimental at this point.

Water Insufflation

The second method shows more promise. It involves the infusion of water without air and subsequent suctioning either during the insertion or withdrawal of the endoscope [74]. It has been demonstrated in limited studies that the use of water-assisted colonoscopy has a positive effect on patients, predominantly with lower levels of pain during the procedure [75, 76]. In addition, one study demonstrated that water immersion colonoscopy prevented loop formation in the sigmoid colon [77]. In a meta-analysis of nine studies, warm water infusion was demonstrated to be less painful than standard air insufflation, while reducing the need for sedation or analgesia during the procedure. There is a higher incomplete colonoscopy rate with this technique, however, and the endoscopist must consider this if considering employing this technique [78]. Interestingly when the methods of water insufflation and CO_2 insufflation are compared to each other, there is no significant reduction in either moderate or severe pain with either technique, compared with patients receiving no sedation [79].

Chromocolonoscopy (Chromoendoscopy)

Chromocolonoscopy involves the use of dye with spray catheters to spray coat the colonic mucosa in an attempt to increase the visualization of the mucosa. The dye enhances delineation, thereby aiding the endoscopist in differentiating between small structures, especially small and flat neoplastic lesions that are hard to recognize with traditional endoscopy. There has been some demonstrated benefit with this technology in high-risk populations such as those with inflammatory bowel disease or those with known genetic disorders [80, 81], due to the difficulty in differentiating abnormal from normal mucosa in some of these patients. The technology has primarily demonstrated an increase in the yield of small polyps in the general population, however. Due to this lack of clinical significance in the population as a whole, there is a questioning of the necessity for widespread application of the technique [82].

High Definition/NBI Endoscopy

High definition endoscopes with wider angle viewing capability have the ability to increase the magnification and the visualization in endoscopy. High definition endoscopy has not proven superior in the ability to detect additional colon neoplasms, however [83]. Narrow Bandwidth Imaging (NBI) uses a filter to narrow the blue and green wave light and eliminates the red wavelength from standard white light. This leads to an accentuation of the microvasculature and improved visualization of pathology. The endoscopist is able to rapidly switch between white light and NBI views with the use of a foot pedal [84]. It has been noted in small studies that using NBI technology there is an increase in the number of adenomatous polyps detected [85]. In addition surface patterns differentiation between hyperplastic and adenomatous polyps is enhanced [86]. Due to this ability to better predict histology, NBI technology may play a role in the future resection and discarding of diminutive polyps, but it has not received widespread acceptance.

Full Spectrum Endoscopy

Full spectrum endoscopy uses three cameras, with the two additional cameras located adjacent to the scope's tip. This allows simultaneous viewing of all three cameras, which the endoscopist has from three adjacently located monitors. This colonoscopy platform has been demonstrated to be feasible, usable, and safe [87]. Despite the impressive visualization that is gained from the additional cameras, at this point, there is no proven benefit regarding increased adenoma detection, making it only a viable alternative to traditional endoscope technology [88].

Retroflexion

Many endoscopists routinely perform retroflexion, or the turning of the endoscope back upon itself in a U shape, in order to obtain a better view than with straight viewing. There is sparse data on either the benefits or the risks associated with the routine use of retroflexion of the endoscope in the rectum. There is one study that using the retroflexion technique with sigmoidoscopy increases adenoma detection [89]. Other studies cast some doubt on this. In one study of over 450 patients, in only 9 cases did the retroflex view identifiable pathology—predominantly hyperplastic polyps [90]. In another study of over 1500 patients, only 7 polyps were visualized solely by retroflexion. Six of these were hyperplastic and one was a

4 mm sessile tubular adenoma [91]. More concerning than a low yield is a higher rectal perforation rate reported associated with the technique [92]. The procedure can undoubtedly be performed safely, and some experts tout that it provides valuable information and photodocumentation of benign disease at the rectal outlet such as hemorrhoids [93]. It is unclear if the limited data is worth any added risk.

There is some data that retroflexion performed in the ascending colon, may offer benefit, however. One study evaluating routine retroflexion in the right colon showed that it could be safely achieved in the majority of patients undergoing screening colonoscopy [94]. In addition retroflexion identified additional polyps, predominantly adenomas, increasing the polyp yield as well as the adenoma detection rate in one study [95]. Due to the concerns regarding missed lesions in the right colon, retroflexion in patients with polyps identified on initial forward viewing should be considered.

Complications

While the performance of colonoscopy is very safe with several million procedures performed every year with no untoward events—it is an invasive procedure and complications are possible. These should be discussed with the patient frankly and documented prior to the procedure. The complications can be broadly grouped into those relating directly form the procedure such as bleeding and perforation and those relating to the sedation involved with the procedure—primarily cardiac and pulmonary complications. The exact incidence of complications varies widely in the literature, from 4.0 for 10,000 colonoscopies [96] to 17.8 per 1000 procedures [97]. The incidence varies somewhat depending on what exactly is considered a complication, and looking only at serious complications, defined as those resulting in hospital admission within 30 days of the procedure occur with a rate of 1 per 1000 [98–100] to 5.0 per 1000 exams [101, 102].

Sedation Complications

There are obviously risks associated with the administration of any medication, particularly sedative medications. The reason for the monitoring guidelines outlined above is to monitor for just these risks [103]. The primary concerns regarding the administration of sedation revolve around the cardiac and pulmonary complications associated with these medicines.

Vasovagal/Cardiac Arrhythmia

A vasovagal reaction is a slowing of the heart rate, often accompanied by a drop in blood pressure. This is believed to reflect the stimulation of the vagus nerve. It is common during colonoscopy and has been reported to occur in up to 16% of cases [104]. It is most likely not related to sedation, however, as the occurrence is unrelated to sedative medication administration and [105] it more likely results from the distension of the bowel or from a relative hypovolemic state resulting from the bowel prep. A vasovagal reaction is typically self-limited, but should be addressed by colonoscopic aspiration of air and/or reduction of loops. It typically requires no medical intervention other than monitoring and IV fluid administration. True cardiac arrhythmias are uncommon in association with colonoscopy. While there are reports of life threatening cardiac dysrhythmias during the procedure, these are primarily from case reports [106, 107]. Cardiac arrhythmias occur in approximately 2% of patients while undergoing endoscopic procedures [108] but the vast majority of these require no medical intervention [109].

The administration of sedative medications, particularly midazolam does cause transient hypotension in 20% of patients, with ST-segment depression in 7% of them [110]. It has also been noted in patients undergoing endoscopy that there is evidence of cardiac arrhythmias in 16%, with ischemic changes noted in 4% of those [108]. The clinical significance of these changes is unclear, however, as these are only electrocardiographic abnormalities. When comparing patients not having a colonoscopy, the incidence of myocardial infarction or stroke is similar to patients undergoing colonoscopy [111], implying that the procedure does not place the patient at increased risk for a cardiac event. In addition, it has been demonstrated that endoscopic procedures are safe and beneficial in patients after recent MI and should be performed if necessary in this patient population [112]. Colonoscopy in patients with a recent myocardial infarction is associated with a higher rate of minor, transient, and primarily cardiovascular complications compared with control patients but is infrequently associated with major complications [113].

Pulmonary

The incidence of pulmonary complications is even less common than for cardiac events, and any evidence of pulmonary issues following a colonoscopy should prompt the endoscopist to consider the abdomen as the ultimate source. The majority of patients that are undergoing colonoscopy are older and patients over 80 have not surprisingly demonstrated higher rates of pulmonary complications [111]. There are reports of aspiration following the administration of sedative medications for colonoscopy [114], but this is a very uncommon event. In addition, there are also numerous reports of pneumothorax or pneumomediastinum, following a colonoscopy [115]. These events are most commonly related to an intra-abdominal perforation, however, and should prompt a quick investigation for that possibility [116].

Procedural Complications

Procedural complications such as bleeding, perforation, and post-polypectomy syndrome serve as the other broad classification of complications. There are reports of unusual occurrences such as colonoscopes becoming incarcerated in either inguinal or ventral hernias [117, 118], but these are extremely uncommon events and serve primarily to warn the practitioner that there is always something else that can go wrong with any procedure. All endoscopists should be aware of the more common risks associated with the endoscopy and attempt to mitigate them.

Splenic Injury

The incidence of splenic injury in association with a colonoscopy is uncommon but is something that many endoscopists will encounter. A comprehensive literature search identified just over 100 patients worldwide with this complication [119]. It is likely that it is a much more common occurrence, however, as most of the cases in the literature are severe and the patients reported typically are managed with splenectomy [120]. There are likely many more cases that are not reported that are managed nonoperatively or even go unrecognized. It is believed that the etiology of this injury is from traction and subsequent tearing of the splenocolic ligament during the procedure, with subcapsular hematoma the most common injury pattern seen [121]. Splenic rupture at colonoscopy usually presents with abdominal pain developing within the first 24 h [122], although patients can present anywhere from a few hours to several days following the procedure [123]. Selection criteria for operative management may be extrapolated from those used for the management of traumatic splenic injury, but while there are reports of using splenic embolization [124], as mentioned above, the majority of patients in the literature have required splenectomy.

Perforation

A perforation of the colon during a colonoscopy can be a devastating complication that can result in serious morbidity or mortality. While it is uncommon, endoscopists will likely encounter it at some point in their career. The exact incidence of perforation is difficult to precisely define, but it is much less than 1/1000 procedures, with rates of 0.012% [125] to 0.016% reported in large studies [126]. It is believed to be more common when the procedure is performed in a diseased colon such as in inflammatory bowel disease patients, but a large study of IBD patients showed a low perforation rate of 0.16% [127]. In most series attempting to examine the etiology of the complication, the incidence is as common when a biopsy is performed as from a diagnostic endoscopy alone [99, 128, 129].

There are three mechanisms believed to be responsible for colonoscopic perforation. The first is believed to be a mechanical perforation resulting from direct trauma from the colonoscope itself [130]. The most common anatomic site for perforation is the sigmoid colon, occurring in up to [131] 74% in some series [132]. This would be consistent with direct trauma, as the sigmoid is the narrowest and most tortuous section of the colon. The second mechanism is believed to be a result of barotrauma from air insufflation, and the ascending colon or cecum, which would be the most susceptible to this mechanism, is the second most common location for a perforation. However, one series that examined specifically patients that had a cecal perforation found that cecal pathology such as inflammation or ulceration contributed to the perforation in most of these patients [133]. The final etiology of perforation is believed to be from therapeutic procedures such as polypectomy or the dilation of strictures.

The management depends not only on the condition of the patient, but on what the etiology of the perforation is felt to be. If the patient presents acutely and has peritonitis, the management is relatively clear and the patient warrants an emergent celiotomy. If the patient had a therapeutic endoscopy, and is clinically stable, then an attempt at nonoperative management is acceptable. The management with bowel rest and IV antibiotics has been demonstrated to be successful in 13/21 patients in one series of patients, all of whom had a perforation resulting from a therapeutic colonoscopy [134]. Perforations from a diagnostic colonoscopy are likely larger and are less successfully managed with nonoperative treatment [135]. The operative management of colonoscopic perforations has evolved as well. As in the trauma literature, if the patient requires surgical intervention, primary repair or resection with a primary anastomosis has proven to be an effective management strategy [132].

One emerging technology is the use of clips to manage a perforation that is either identified endoscopically or as prophylaxis when the endoscopist feels that the tissue has been thinned to the point that a perforation is likely. There are several case series reported in the literature with good results. A literature review of perforations managed with this technology show that if the clips were placed for a perforation during therapeutic colonoscopy it is successful in 69–93% of cases [136]. In one cohort of 27 patients with perforation from a therapeutic colonoscopy, the placement of clips resulted in successful nonoperative management in 25 of these patients [137]. In another review of 28 visible or suspected perforations, 13/19 evident and 8/9 suspected perforations underwent successful endoscopic closure with clips [138]. Clearly this technology has a place in the endoscopist's armamentarium, but should also be employed with surgical consultation, so that early decisions regarding operative management can be made.

Post-polypectomy Syndrome

Post-polypectomy syndrome is a spectrum of symptoms including abdominal pain, fever, leukocytosis, peritoneal tenderness, and guarding, following a colonoscopic polypectomy.

It is believed to be the result of an electrocoagulation injury to the colonic wall, thereby creating a transmural burn with localized peritoneal inflammation, but without evidence of perforation. It has carried several other monikers as well, including post-polypectomy coagulation syndrome and transmural burn syndrome. Typically patients present several days following a colonoscopy with fever, localized abdominal pain, and leukocytosis and may have localized peritoneal signs on physical examination. The majority of these patients do not require surgical treatment and are usually adequately managed with bowel rest, intravenous hydration, broad-spectrum parenteral antibiotics until symptoms resolution [139]. In one series, all patients were successfully managed medically without the need for surgery, with a median hospitalization of 5 days [140]. In an attempt to identify risk factors, one study found that polyp size greater than 2 cm and the presence of hypertension were the largest risk factors [141], but any patient who undergoes a polypectomy with cautery is at risk.

Bleeding

Bleeding following a polypectomy is the most common serious complication following a colonoscopy and patients should be given specific written instructions regarding the actions they should take if it should occur. It is estimated that significant bleeding, requiring a patient to seek medical care, occurs in over [142] 3% of all colonoscopic polypectomies, with significant bleeding in over 1% [143–146]. While bleeding can happen immediately when the polyp is removed, this is typically dealt with by the endoscopist at the time of the procedure [147]. Clinically significant hemorrhage typically manifests itself 4–6 days following the procedure when there is clot dissolution [145].

There have been several studies attempting to elucidate those patients at higher risk for this complication. A difficult colonoscopy with procedural bleeding is one group of patients at higher risk [148]. Hypertension has also been noted to be not only a risk for bleeding, but for increasing the interval between the polypectomy and hemorrhage [149] In addition, patients on anticoagulation medications are not surprisingly at higher risk, with 34% of patients in one series having been recently restarted on their anticoagulant medications [145]. While there is an increased risk with anticoagulants, surprisingly, this risk is not seen with aspirin, NSAIDS, or other antiplatelet medications [150]. The size of the polyps excised is the most consistent predictor of delayed hemorrhage after a polypectomy [151]. It is much more common with larger polyps. Polyps greater than 2.0 cm diameter were noted to experience bleeding 3.8% of the time, compared to 0.3% when the polyps removed were smaller than 2 cm in one study [148]. In addition to the absolute size, the risk is noted to increase by 13% for every 1 mm increase in polyp diameter. While polyp size correlates with bleeding, the type of polyp either sessile or pedunculated has not been demonstrated to be a risk factor [152]. The location of the polyp has, however, with polyps located in the right colon more susceptible to bleeding [153]. Microscopic examination of the vascular supply of resected polyps reveal that sessile and thick-stalked pedunculated polyps are supplied with more vessels than other polyps. Patients with polyps larger than 17 mm, pedunculated polyps with a stalk diameter >5 mm obviously place the patient at higher risk [154]. The endoscopist should obviously recognize those patients that are at highest risk for post-procedural bleeding and counsel them appropriately.

The initial management of a patient with post-polypectomy bleeding is identical to any other patient with intestinal bleeding. The patient should have coagulation parameters measured and resuscitation should be based upon hemodynamic parameters. There are no specific transfusion triggers with post-polypectomy bleeding, but advanced age is predictive of a patient receiving a transfusion [155]. Almost all patients can be managed with a repeat endoscopy and rarely are operative or other interventions necessary, although angiographic embolization has been demonstrated to be effective in the management of post-polypectomy bleeding [156]. The endoscopist should be familiar with advanced endoscopic hemostatic techniques for these procedures, or consult an experienced colleague.

As with the management of perforation above, endoscopic clipping has been demonstrated beneficial in patients at increased risk for post-polypectomy hemorrhage. In one evaluation of polyps 2 cm or larger, there was a significantly decreased rate of post-procedure bleeding when the site was prophylactically clipped [157]. In addition, clipping has been shown to be beneficial in anticoagulated patients with lesions larger than 1 cm who were able to undergo successful polypectomy without interrupting the anticoagulation or antiplatelet medications [158].

Infectious Complications

A word of caution should be made regarding the extremely rare infectious complications associated with endoscopy. Although it is uncommon, it is associated with sensationalistic press coverage when it does occur. The endoscopist should have a basic understanding of the process involved in the cleaning of the endoscopes and endoscopic equipment, as the majority of infectious complications result from breaches in cleaning procedures. In one survey of endoscopy centers, it was found that a significant number of centers did not conform to guidelines regarding the cleaning, processing and care of endoscopes [159]. A separate study found that several of the guidelines are inconsistent with one another, making it difficult to determine which guideline to follow [160]. *Salmonella*, *Pseudomonas*, and *Mycobacterium* species are the most commonly transmitted organisms associated with endoscopic equipment [161] and the ability of these bacteria to form biofilms on the inner channel surfaces is believed to contribute to their ability to survive the decon-

tamination process [162]. There have recently been reports of Carbapenem-resistant organisms associated with endoscopy as well [163]. The endoscopist should always be vigilant regarding the equipment used and ensure that proper protocols are in place and are being followed.

Training and the Use of Simulation

The training of medical personnel to safely and adequately perform colonoscopy is obviously critical. The criteria of what constitutes adequate training is controversial, however. Gastroenterologists perform the vast majority of colonoscopies and there are understandably differences in the manner in which different specialists, either gastroenterologists or surgeons educate and evaluate their trainees in performing procedures. Most of the literature on the topic involves gastroenterology fellows, and tends to focus on the number of procedures necessary in order to achieve competency. Surgical trainees obviously spend more time throughout their education learning procedural skills and it is doubtful that the two groups can be adequately compared regarding the speed or alacrity with which they learn procedures. It is unlikely that there will ever be a consensus on what constitutes adequate training. What is clear is that colonoscopy is a critical element in the treatment of the patient with colorectal disease and the colorectal surgeon must continue to be involved and have a voice in the education of the next generation of endoscopists.

The ability to perform a colonoscopy is undoubtedly a skill and as with any skill, the ability to perform it improves with repetition. It is a point of contention exactly how many of these repetitions a trainee must perform. In evaluating first year gastroenterology fellows, it was found that the ability to intubate the cecum successfully improved and reached the requisite standard of competence—defined as completing the task greater than 90% of the time and within 20 min after 150 procedures had been performed [164]. When comparing first and third year gastroenterology fellows, it was found that competence improved throughout training but an independent completion rate of 90% was not obtained until after 500 colonoscopies were performed [165]. As with the ability to technically perform the procedure, quality metrics improve with experience as well. In one study, the adenoma detection rate (ADR) increased by year of training [166]. Another study however showed that from the beginning of their education, trainees were able to provide high-quality investigations, again using ADR as the quality indicator benchmark [167]. In one of the few comparisons between gastroenterology and surgery trainees, there was a disparity in endoscopic performance between trainees favoring the gastroenterology trainees [168]. A different study showed that following the use of endoscopy simulation surgery residents were capable of performing colonoscopy equivalent to their gastroenterology counterparts using quality metrics as the benchmark [169].

Simulation

The practice of endoscopy lends itself well to simulation, yet it has not been fully embraced. While surgical simulation is difficult to portray, basic endoscopy skills are well illustrated. Due to the myriad of surgical procedures that are performed and the manner in which they are performed, it is difficult to incorporate surgical simulation into the educational curriculum. Endoscopy, lends itself much better to simulation. The improvement of trainees using simulation is most noticeable during the beginning of their endoscopic experience [170]. Following a 6-h colonoscopy simulation, trainees were noted to significantly outperform those who did not have the training but these advantages are negligible after approximately 30 procedures on patients [171].

Despite this reported advantage, the technology has not received widespread adoption in gastroenterology training. In a survey of active gastroenterology fellows, they noted that while half of the programs have endoscopic simulators, only 15% are required to use them prior to performing endoscopy on patients [172]. In a review of program directors, this was confirmed with 15% requiring their fellows to use simulation prior to clinical cases, with only one program having a minimum number of hours required in simulation training. The majority of the program directors felt that there is a need for endoscopic simulator training [173]. The reasons for a lack of embracing simulation are unclear. An attractive method to increase the quality of colonoscopy performance and to increase the skill levels of trainees without excessive numbers of procedures is the incorporation of endoscopy simulation into the curriculum of training programs that train endoscopists.

Documentation and Quality

Documentation

After completion of the procedure it is important to adequately document any findings as well as any adjunctive procedures that were performed at the time. It is imperative to photodocument any lesions or areas that were biopsied, as well as the endoscopists interpretation of these lesions. An attempt to place the location anatomically should be made, as the distance of the inserted colonoscopy can vary greatly depending upon looping and can vary depending on whether the measurement was taken on insertion or while the endoscope was being withdrawn. In addition, if any lesion was biopsied, or if a polyp was excised, the note should document whether the excision was complete or whether there was grossly abnormal tissue remaining.

A Multi-Society Task Force on Colorectal Cancer developed a consensus-based set of data points that reflected what should be included in any colonoscopy report (Table 4-3) [174].

TABLE 4-3. Recommended elements in standard colonoscopy report

Documentation of informed consent
Facility where endoscopy performed
Patient demographics and history
Age/sex
Receiving anticoagulation: if yes, document management plan
Need for antibiotic prophylaxis: if yes, document reason and management plan
Assessment of patient risk and comorbidity
ASA classification
Indication(s) for procedure
Procedure: technical description
Procedure date and time
Procedure performed with additional qualifiers (CPT codes, polypectomy, etc.)
Sedation: medications given and by the type of provider responsible
Level of sedation (conscious, deep, general anesthesia)
Extent of examination by anatomic segment: cecum, ascending colon, etc.
If cecum is not reached, provide reason
Method of documentation: i.e., photo of ileocecal valve and/or appendiceal orifice
Time of examination: scope was inserted, withdrawal started, when withdrawn from patient
Retroflexion in rectum (yes/no)
Bowel prep: type of preparation, quality, adequate or inadequate to detect polyps >5 mm
Technical performance: not technically difficult or examination difficult
Patient discomfort/looping/need for special maneuvers including turning patient
Type of instrument used: model and instrument number
Colonoscopic findings
Colonic masses or polyp(s)
Anatomic location: length/size (mm)
Descriptors: pedunculated/sessile/flat/obstructive (% of lumen reduced)/ulcerated
Biopsy obtained: hot/cold or snare/tattoo (if performed)
Fulguration or ablation with cautery
Completely removed (yes/no)/retrieved (yes/no)/sent to pathology (yes/no)
Mucosal abnormality
Suspected diagnosis: ulcerative colitis, Crohn's, ischemia, infection
Anatomic location/extent/pathology obtained (yes/no)
Other findings
Diverticulosis/arteriovenous malformations/hemorrhoids
Assessment
Follow-up plan
Immediate follow-up/further tests, referrals/medication changes
Follow-up appointments and recommendation for follow-up colonoscopy and tests
Documentation of communication directly to the patient and referring physician
Pathology
Pathology results reviewed, communicated with referring provider with recommendation for follow-up and communicated with patient

Adapted from Lieberman D, Nadel M et al. Standardized colonoscopy reporting and data system: report of the Quality Assurance Task Group of the National Colorectal Cancer Roundtable. Gastrointest Endosc 2007 May;65(6):757–66 (17)

There are numerous commercially available software programs that allow rapid and accurate documentation and these guidelines will look familiar to any provider who has utilized these systems. Unfortunately, the very ease of these programs and their check-box design allow trainees or busy professionals to perform documentation that is inadequate. In one study involving both community hospitals and academic centers several deficiencies in reporting were identified. For example, bowel preparation quality was reported in only 20%, but more concerning, the description of polyp appearance was present in only in 34% of notes [175]. In another study, photodocumentation was often missing and the size and morphology of polyps was present in only slightly more than 60% of cases [176]. Other studies show a consistent lack of documenting the quality of the bowel preparation, lack of documentation of the cecal landmarks as well as poor procedural interpretation [177, 178]. Clearly physicians who perform these procedures must not only ensure that the

procedure is done well and safely, but that it is properly documented and these findings are relayed to the patient and any other treating physicians.

Quality

There is increasing attention to quantifiable measures of quality in medicine, and colonoscopy lends itself well to metric analysis and therefore there has been a great deal of attention paid to these performance measures [179]. Almost 14 million colonoscopies are performed annually in the USA and there is understandably a great deal of attention paid to quality associated with the procedure. The five most frequently cited quality measures are cecal intubation rate, adherence to recommended screening and surveillance interval, adenoma detection rate, quality of bowel preparation, and colonoscopy withdrawal time [180]. While some of these elements are addressed elsewhere in this text, is imperative that surgeons remain involved in these discussions and the continuing quest for quality improvement for our profession and for our patients.

PillCam Endoscopy

The advent of PillCam endoscopy (PCE) has revolutionized the evaluation of the small intestine. It allows the clinician to evaluate this portion of the intestine that was previously relegated to inaccurate or uncomfortable studies such as small bowel radiographic series or enteroclysis. The procedure is most commonly used in patients with occult gastrointestinal bleeding or in the search for other small bowel pathology, such as insipient tumors, polyposis syndromes, or Crohn's disease [181]. It typically is performed after an upper and lower endoscopic examination has already been completed; however, it can complement the latter as well, as in at least one study 28% of abnormalities identified on PCE were within the area normally covered by an endoscopic exam [182]. The use of PillCam endoscopy is easy to perform and learn and is a natural adjunct in the endoscopists' armamentarium. Capsule endoscopy does not require a bowel preparation, but most patients are instructed to remain either NPO or on a clear liquid diet for 10–12 h prior to the procedure. The patient swallows the disposable capsule, which then transmits images wirelessly to a recorder, and the clinician can review the images at a time when it is convenient to spend the 15–60 min, on average, for image viewing and documentation [183].

PillCam endoscopy has been demonstrated to play a significant role in Crohn's disease, where the small intestine is difficult to visualize radiographically. While there are concerns for evaluating patients with stricturing Crohn's disease, as the capsule can be retained at the location of a stricture [184, 185], this is typically less of a concern for a surgeon contemplating operative management and can serve as a marker of stricture location enabling the procedure to be performed with minimally invasive techniques. PCE has resulted in medication changes in up to 60% of patients in some studies and [186] has proven superior to other imaging modalities in identifying obscure sources of intestinal bleeding and is beneficial in the localization of small bowel neoplasms [187, 188]. In addition, there is data that PCE may play a role in screening for colonic neoplasm, or in the evaluation of large intestinal inflammatory bowel disease. It is clear that the uses for this technology will only expand and physicians who treat intestinal disease will have to be familiar with the technology [189].

Summary

The endoscopic evaluation of the patient with colorectal complaints is essential in both the diagnosis and management of the patient. It allows the physician to visually assess the entirety of the intestinal tract and should not be thought of as a separate entity, but as an adjunct in the examination of the colorectal patient. These techniques should be familiar to the colorectal surgeon, and surgeons should continue to play a role in the testing, training, and advancement of endoscopic techniques and technology.

References

1. Ashburn J, Church J. Open sesame revisited. Am J Gastroenterol. 2013;108(1):143. doi:10.1038/ajg.2012.382.
2. Farmer KC, Church JM. Open sesame: tips for traversing the anal canal. Dis Colon Rectum. 1992;35(11):1092–3.
3. Nivatvongs S, Fryd DS. How far does the proctosigmoidoscope reach? A prospective study of 1000 patients. N Engl J Med. 1980;303(7):380–2.
4. Gibertson VA. Proctosigmoidoscopy and polypectomy in reducing the incidence of rectal cancer. Cancer. 1974;34(3 suppl):936–9.
5. Nelson RL, Abcarian H, Prasad ML. Iatrogenic perforation of the colon and rectum. Dis Colon Rectum. 1982;25(4):305–8.
6. Christensen AF, Nyhuus B, Nielsen MB, Christensen H. Three-dimensional anal endosonography may improve diagnostic confidence of detecting damage to the anal sphincter complex. Br J Radiol. 2005;78(928):308–11.
7. Xhaja X, Church J. The use of ancillary techniques to aid colonoscope insertion. Surg Endosc. 2014;28(6):1936–9.
8. Kann BR, Margolin DA, Brill SA, et al. The importance of colonoscopy in colorectal surgeons' practices: results of a survey. Dis Colon Rectum. 2006;49(11):1763–7.
9. Juillerat P, et al. EPAGE II. Presentation of methodology, general results and analysis of complications. Endoscopy. 2009;41:240–6.
10. Gimeno-García AZ, Quintero E. Colonoscopy appropriateness: really needed or a waste of time? World J Gastrointest Endosc. 2015;7(2):94–101.
11. Chan TH, Goh KL. Appropriateness of colonoscopy using the ASGE guidelines: experience in a large Asian hospital. Chin J Dig Dis. 2006;7(1):24–32.

12. Suriani R, Rizzetto M, Mazzucco D, et al. Appropriateness of colonoscopy in a digestive endoscopy unit: a prospective study using ASGE guidelines. J Eval Clin Pract. 2009;15(1):41–5.
13. Gimeno García AZ, González Y, Quintero E, et al. Clinical validation of the European Panel on the Appropriateness of Gastrointestinal Endoscopy (EPAGE) II criteria in an open-access unit: a prospective study. Endoscopy. 2012;44(1):32–7.
14. Petruzziello L, Hassan C, Alvaro D, et al. Appropriateness of the indication for colonoscopy: is the endoscopist the 'gold standard'? J Clin Gastroenterol. 2012;46(7):590–4.
15. Eskeland SL, Dalén E, Sponheim J, et al. European panel on the appropriateness of gastrointestinal endoscopy II guidelines help in selecting and prioritizing patients referred to colonoscopy—a quality control study. Scand J Gastroenterol. 2014; 49(4):492–500.
16. Zuccaro G. Treatment and referral guidelines in gastroenterology. Gastroenterol Clin North Am. 1997;26:845–57.
17. Cappell MS, Ghandi D, Huh C. A study of the safety and clinical efficacy of flexible sigmoidoscopy and colonoscopy after recent colonic surgery in 52 patients. Am J Gastroenterol. 1995;90:1130–4.
18. Froelich F, Wietlisbach V, Gonvers JJ, et al. Impact of colonic cleansing on quality and diagnostic yield of colonoscopy: the European Panel of Appropriateness of Gastrointestinal Endoscopy European multicenter study. Gastrointest Endosc. 2005;61(3):378–84.
19. Kao D, Lalor E, Sandha G, et al. A randomized controlled trial of four precolonoscopy bowel cleansing regimens. Can J Gastroenterol. 2011;25(12):657–62.
20. Markowitz GS, Stokes MB, Radhakrishnan J, et al. Acute phosphate nephropathy following oral sodium phosphate bowel purgative: an underrecognized cause of chronic renal failure. J Am Soc Nephrol. 2005;16:3389–96.
21. Markowitz GS, Perazella MA. Acute phosphate nephropathy. Kidney Int. 2009;76:1027–34.
22. Cohen LB. Advances in bowel preparation for colonoscopy. Gastrointest Endosc Clin N Am. 2015;25(2):183–97.
23. Brunelli SM, Lewis JD, Gupta M, et al. Risk of kidney injury following oral phosphosoda bowel preparations. J Am Soc Nephrol. 2007;18:3199–205.
24. Hookey LC, Depew WT, Vanner SJ. A prospective randomized trial comparing low-dose oral sodium phosphate plus stimulant laxatives with large volume polyethylene glycol solution for colon cleansing. Am J Gastroenterol. 2004;99(11):2217–22.
25. Gurudu SR, Ramirez FC, Harrison ME, et al. Increased adenoma detection rate with system-wide implementation of a split-dose preparation for colonoscopy. Gastrointest Endosc. 2012;76(3):603–8.e1.
26. Kilgore TW, Abdinoor AA, Szary NM, et al. Bowel preparation with split-dose polyethylene glycol before colonoscopy: a meta-analysis of randomized controlled trials. Gastrointest Endosc. 2011;73(6):1240–5.
27. Enestvedt BK, Tofani C, Laine LA, et al. 4-Liter split-dose polyethylene glycol is superior to other bowel preparations, based on systematic review and meta-analysis. Clin Gastroenterol Hepatol. 2012;10(11):1225–31.
28. Abuksis G, Mor M, Segal N, et al. A patient education program is cost-effective for preventing failure of endoscopic procedures in a gastroenterology department. Am J Gastroenterol. 2001;96(6):1786–90.
29. Johnson DA, Barkun AN, Cohen LB, et al. Optimizing adequacy of bowel cleansing for colonoscopy: recommendations from the US multi-society task force on colorectal cancer. Gastroenterology. 2014;147(4):903–24.
30. Aronchick CA, Lipshutz WH, Wright SH, et al. A novel tableted purgative for colonoscopic preparation: efficacy and safety comparisons with Colyte and Fleet Phospho-Soda. Gastrointest Endosc. 2000;52:346–52.
31. Rostom A, Jolicoeur E. Validation of a new scale for the assessment of bowel preparation quality. Gastrointest Endosc. 2004;59(4):482–6.
32. Calderwood AH, Schroy PC, Lieberman DA, et al. Boston Bowel Preparation Scale scores provide a standardized definition of adequate for describing bowel cleanliness. Gastrointest Endosc. 2014;80(2):269–76.
33. Gerard DP, Foster DB, Raiser MW, et al. Validation of a new bowel preparation scale for measuring colon cleansing for colonoscopy: the Chicago bowel preparation scale. Clin Transl Gastroenterol. 2013;4:e43.
34. Clark BT, Rustagi T, Laine L. What level of bowel prep quality requires early repeat colonoscopy: systematic review and meta-analysis of the impact of preparation quality on adenoma detection rate. Am J Gastroenterol. 2014;109(11):1714–23.
35. Chokshi RV, Hovis CE, Hollander T, et al. Prevalence of missed adenomas in patients with inadequate bowel preparation on screening colonoscopy. Gastrointest Endosc. 2012;75(6):1197–203.
36. Poon CM, Lee DW, Mak SK, et al. Two liters of polyethylene glycol-electrolyte lavage solution versus sodium phosphate as bowel cleansing regimen for colonoscopy: a prospective randomized controlled trial. Endoscopy. 2002;34(7):560–3.
37. Barclay RL. Esophagogastroduodenoscopy-assisted bowel preparation for colonoscopy. World J Gastrointest Endosc. 2013;5(3):95–101.
38. Patanè S. Is there a need for bacterial endocarditis prophylaxis in patients undergoing gastrointestinal endoscopy? J Cardiovasc Transl Res. 2014;7(3):372–4.
39. Wilson W, Taubert KA, Gewitz M, et al. Prevention of infective endocarditis: guidelines from the American Heart Association: a guideline from the American Heart Association Rheumatic Fever, Endocarditis, and Kawasaki Disease Committee, Council on Cardiovascular Disease in the Young, and the Council on Clinical Cardiology, Council on Cardiovascular Surgery and Anesthesia, and the Quality of Care and Outcomes Research Interdisciplinary Working Group. Circulation. 2007;116:1736–54.
40. Duval X, Delahaye F, Alla F, et al. Temporal trends in infective endocarditis in the context of prophylaxis guideline modifications: three successive population-based surveys. J Am Coll Cardiol. 2012;59(22):1968–76.
41. Dayer MJ, Jones S, Prendergast B, et al. Incidence of infective endocarditis in England, 2000–13: a secular trend, interrupted time-series analysis. Lancet. 2014. doi:10.1016/S0140-6736(14)62007-9.
42. Banerjee S, Shen B, Baron TH, et al. Antibiotic prophylaxis for GI endoscopy. Gastrointest Endosc. 2008;67:791–8.
43. Zuckerman MJ, Hirota WK, Adler DG, et al. ASGE guideline: the management of low-molecular-weight heparin and non-aspirin antiplatelet agents for endoscopic procedures. Gastrointest Endosc. 2005;61:189–94.

44. Khashab MA, Chithadi KV, Acosta RD, et al. Antibiotic prophylaxis for GI endoscopy. Gastrointest Endosc. 2015;81(1):81–9.
45. Piraino B, Bernardini J, Brown E, et al. ISPD position statement on reducing the risks of peritoneal dialysis-related infections. Perit Dial Int. 2011;31:614–30.
46. Meyer GW, Artis AL. Antibiotic prophylaxis for orthopedic prostheses and GI procedures: report of a survey. Am J Gastroenterol. 1997;92:989–91.
47. Anderson MA, Ben-Menachem T, Gan SI, et al. Management of antithrombotic agents for endoscopic procedures. Gastrointest Endosc. 2009;70:1060.
48. Fujimoto K, Fujishiro M, Kato M, et al. Guidelines for gastroenterological endoscopy in patients undergoing antithrombotic treatment. Dig Endosc. 2014;26:1–14.
49. Ridolfi TJ, Valente MA, Church JM. Achieving a complete colonic evaluation with incomplete colonospcy is worth the effort. Dis Colon Rectum. 2014;57:383–7.
50. Baxter NN, Goldwasser MA, Paszat LF, Saskin R, Urbach DR, Rabeneck L. Association of colonoscopy and death from colorectal cancer. Ann Intern Med. 2009;150:1–8.
51. Church JM. Complete colonoscopy: how often? And if not, why not? Am J Gastroenterol. 1994;89:556–60.
52. Rizek R, Paszat LF, Stukel TA, Saskin R, Li C, Rabeneck L. Rates of complete colonic evaluation after incomplete colonoscopy and their associated factors: a population-based study. Med Care. 2009;47:48–52.
53. Kao KT, Tam M, Sekhon H, Wijeratne R, Haigh PI, Abbas MA. Should barium enema be the next step following an incomplete colonoscopy? Int J Colorectal Dis. 2010;25:1353–7.
54. Toma J, Paszat LF, Gunraj N, Rabeneck L. Rates of new or missed colorectal cancer after barium enema and their risk factors: a population-based study. Am J Gastroenterol. 2008;103:3142–8.
55. Baron JP, Hirota TH, Waring WK, et al. Guidelines for conscious sedation and monitoring during gastrointestinal endoscopy. Gastrointest Endosc. 2003;58(3):317.
56. Lee DW, Li AC, Ko CW, et al. Use of a variable-stiffness colonoscope decreases the dose of patient-controlled sedation during colonoscopy: a randomized comparison of 3 colonoscopes. Gastrointest Endosc. 2007;65(3):424–9.
57. Faulx AL, Vela S, Das A, et al. The changing landscape of practice patterns regarding unsedated endoscopy and propofol use: a national Web survey. Gastrointest Endosc. 2005;62(1):9–15.
58. Porostocky P, Chiba N, Colacino P, et al. A survey of sedation practices for colonoscopy in Canada. Can J Gastroenterol. 2011;25(5):255–60.
59. Loberg M, Furholm S, Hoff I, et al. Nitrous oxide for analgesia in colonoscopy without sedation. Gastrointest Endosc. 2011;74(6):1347–53.
60. Aboumarzouk OM, Agarwal T, Syed Nong Chek SA et al. Nitrous oxide for colonoscopy. Cochrane Database Syst Rev 2011;(8):CD008506.
61. Tuncali B, Pekcan YO, Celebi A, et al. Addition of low-dose ketamine to midazolam-fentanyl-propofol-based sedation for colonoscopy: a randomized, double-blind, controlled trial. J Clin Anesth. 2015;27:301–6.
62. Childers RE, Williams JL, Sonnenberg A. Practice patterns of sedation for colonoscopy. Gastrointest Endosc. 2015;82(3):503–11.
63. Singh H, Poluha W, Cheung M et al. Propofol for sedation during colonoscopy. Cochrane Database Syst Rev 2008;(4):CD006268.
64. Wang D, Chen C, Chen J, et al. The use of propofol as a sedative agent in gastrointestinal endoscopy: a meta-analysis. PLoS One. 2013;8(1):e53311.
65. Bright E, Roseveare C, Dalgleish D, et al. Patient-controlled sedation for colonoscopy: a randomized trial comparing patient-controlled administration of propofol and alfentanil with physician-administered midazolam and pethidine. Endoscopy. 2003;35(8):683–7.
66. Ulmer BJ, Hansen JJ, Overley CA, et al. Propofol versus midazolam/fentanyl for outpatient colonoscopy: administration by nurses supervised by endoscopists. Clin Gastroenterol Hepatol. 2003;1(6):425–32.
67. Church JM. Colonoscopy. In: Church JM, editor. Endoscopy of the colon, rectum, and anus. New York: Igaku-Shoin; 1995. p. 99–135.
68. Cirocco WC, Rusin LC. The reliability of cecal landmarks during colonoscopy. Surg Endosc. 1993;7(1):33–6.
69. Iacopini G, Frontespezi S, Vitale MA, et al. Routine ileoscopy at colonoscopy: a prospective evaluation of learning curve and skill-keeping line. Gastrointest Endosc. 2006;63(2):250–6.
70. Ten Cate EM, Wong LA, Groff WL, et al. Post-surgical surveillance of locally advanced ileal carcinoids found by routine ileal intubation during screening colonoscopy: a case series. J Med Case Rep. 2014;8:444.
71. Kennedy G, Larson D, Wolff B, et al. Routine ileal intubation during screening colonoscopy: a useful maneuver? Surg Endosc. 2008;22(12):2606–8.
72. Uraoka T, Kato J, Kuriyama M, et al. CO(2) insufflation for potentially difficult colonoscopies: efficacy when used by less experienced colonoscopists. World J Gastroenterol. 2009;15(41):5186–92.
73. Chen PJ, Li CH, Huang TY, et al. Carbon dioxide insufflation does not reduce pain scores during colonoscope insertion in unsedated patients: a randomized, controlled trial. Gastrointest Endosc. 2013;77(1):79–89.
74. Leung FW. Water-aided colonoscopy. Gastroenterol Clin North Am. 2013;42(3):507–19.
75. Church JM. Warm water irrigation for dealing with spasm during colonoscopy: simple, inexpensive, and effective. Gastrointest Endosc. 2002;56(5):672–4.
76. Miroslav V, Klemen M. Warm water immersion vs. standard air insufflation for colonoscopy: comparison of two techniques. Hepatogastroenterology. 2014;61(136):2209–11.
77. Asai S, Fujimoto N, Tanoue K, et al. Water immersion colonoscopy facilitates straight passage of the colonoscope through the sigmoid colon without loop formation: randomized controlled trial. Dig Endosc. 2015;27(3):345–53.
78. Rabenstein T, Radaelli F, Zolk O. Warm water infusion colonoscopy: a review and meta-analysis. Endoscopy. 2012;44(10):940–51.
79. Garborg K, Kaminski MF, Lindenburger W, et al. Water exchange versus carbon dioxide insufflation in unsedated colonoscopy: a multicenter randomized controlled trial. Endoscopy. 2015;47(3):192–9.
80. Bartel MJ, Picco MF, Wallace MB. Chromocolonoscopy. Gastrointest Endosc Clin N Am. 2015;25(2):243–60.
81. Huneburg R, Lammert F, Rabe C, et al. Chromocolonoscopy detects more adenomas than white light colonoscopy or

narrow band imaging colonoscopy in hereditary nonpolyposis colorectal cancer screening. Endoscopy. 2009;41(4):316–22.
82. Kahi CJ, Anderson JC, Waxman I, et al. High-definition chromocolonoscopy vs. high-definition white light colonoscopy for average-risk colorectal cancer screening. Am J Gastroenterol. 2010;105(6):1301–7.
83. Pellise M, Fernandez-Esparrach G, Cardenas A, et al. Impact of wide-angle, high-definition endoscopy in the diagnosis of colorectal neoplasia: a randomized controlled trial. Gastroenterology. 2008;135(4):1062–8.
84. Singh R, Mei SC, Sethi S. Advanced endoscopic imaging in Barrett's oesophagus: a review on current practice. World J Gastroenterol. 2011;17(38):4271–6.
85. Rastogi A, Early DS, Gupta N, et al. Randomized, controlled trial of standard-definition white-light, high-definition white-light, and narrow-band imaging colonoscopy for the detection of colon polyps and prediction of polyp histology. Gastrointest Endosc. 2011;74(3):593–602.
86. Rastogi A, Keighley J, Singh V, et al. High accuracy of narrow band imaging without magnification for the real-time characterization of polyp histology and its comparison with high-definition white light colonoscopy: a prospective study. Am J Gastroenterol. 2009;104(10):2422–30.
87. Gralnek IM, Segol O, Suissa A, et al. A prospective cohort study evaluating a novel colonoscopy platform featuring full-spectrum endoscopy. Endoscopy. 2013;45(9):697–702.
88. Gralnek IM, Siersema PD, Halpern Z, et al. Standard forward-viewing colonoscopy versus full-spectrum endoscopy: an international, multicentre, randomised, tandem colonoscopy trial. Lancet Oncol. 2014;15(3):353–60.
89. Hanson JM, Atkin WS, Cunliffe WJ, et al. Rectal retroflexion: an essential part of lower gastrointestinal endoscopic examination. Dis Colon Rectum. 2001;44(11):1706–8.
90. Cutler AF, Pop A. Fifteen years later: colonoscopic retroflexion revisited. Am J Gastroenterol. 1999;94(6):1537–8.
91. Saad A, Rex DK. Routine rectal retroflexion during colonoscopy has a low yield for neoplasia. World J Gastroenterol. 2008;14(42):6503–5.
92. Quallick MR, Brown WR. Rectal perforation during colonoscopic retroflexion: a large, prospective experience in an academic center. Gastrointest Endosc. 2009;69(4):960–3.
93. Rex DK, Vemulapalli KC. Retroflexion in colonoscopy: why? where? when? how? what value? Gastroenterology. 2013;144(5):882–3.
94. Kushnir VM, Oh YS, Hollander T, et al. Impact of retroflexion vs. second forward view examination of the right colon on adenoma detection: a comparison study. Am J Gastroenterol. 2015;110(3):415–22.
95. Chandran S, Parker F, Vaughan R, et al. Right-sided adenoma detection with retroflexion versus forward-view colonoscopy. Gastrointest Endosc. 2015;81(3):608–13.
96. Niv Y, Gershtansky Y, Kenett RS, et al. Complications in colonoscopy: analysis of 7-year physician-reported adverse events. Eur J Gastroenterol Hepatol. 2011;23(6):492–8.
97. Chan AO, Lee LN, Chan AC, Ho WN, Chan QW, Lau S, Chan JW. Predictive factors for colonoscopy complications. Hong Kong Med J. 2015;21(1):23–9.
98. Stock C, Ihle P, Sieg A, et al. Adverse events requiring hospitalization within 30 days after outpatient screening and nonscreening colonoscopies. Gastrointest Endosc. 2013;77(3):419–29.
99. Ko CW, Riffle S, Michaels L, et al. Serious complications within 30 days of screening and surveillance colonoscopy are uncommon. Clin Gastroenterol Hepatol. 2010;8(2):166–73.
100. Castro G, Azrak MF, Seeff LC, Royalty J. Outpatient colonoscopy complications in the CDC's Colorectal Cancer Screening Demonstration Program: a prospective analysis. Cancer. 2013;119 Suppl 15:2849–54.
101. Levin TR, Zhao W, Conell C, et al. Complications of colonoscopy in an integrated health care delivery system. Ann Intern Med. 2006;145(12):880–6.
102. Nelson DB, McQuaid KR, Bond JH, et al. Procedural success and complications of large-scale screening colonoscopy. Gastrointest Endosc. 2002;55(3):307–14.
103. Alam M, Schuman BM, Duvernoy WF, et al. Continuous electrocardiographic monitoring during colonoscopy. Gastrointest Endosc. 1976;22:203.
104. Herman LL, Kurtz RC, McKee KJ, et al. Risk factors associated with vasovagal reactions during colonoscopy. Gastrointest Endosc. 1993;39(3):388–91.
105. Da Silva RM. Syncope: epidemiology, etiology, and prognosis. Front Physiol. 2014;5:471.
106. Davison ET, Levine M, Meyerowitz R. Ventricular fibrillation during colonoscopy: case report and review of the literature. Am J Gastroenterol. 1985;80:690–3.
107. Ugajin T, Miyatani H, Momomura S, et al. Ventricular fibrillation during colonoscopy: a case report—colonoscopy in high-risk patients should be performed with ECG monitoring. Intern Med. 2008;47(7):609–12.
108. Gupta SC, Gopalswamy N, Sarkar A, et al. Cardiac arrhythmias and electrocardiographic changes during upper and lower gastrointestinal endoscopy. Mil Med. 1990;155(1):9–11.
109. Eckardt VF, Kanzler G, Schmitt T, Eckardt AJ, Bernhard G. Complications and adverse effects of colonoscopy with selective sedation. Gastrointest Endosc. 1999;49(5):560–5.
110. Ristikankare M, Julkunen R, Mattila M, et al. Conscious sedation and cardiorespiratory safety during colonoscopy. Gastrointest Endosc. 2000;52(1):48–54.
111. Day LW, Kwon A, Inadomi JM, Walter LC, Somsouk M. Adverse events in older patients undergoing colonoscopy: a systematic review and meta-analysis. Gastrointest Endosc. 2011;74(4):885–96.
112. Cena M, Gomez J, Alyousef T, et al. Safety of endoscopic procedures after acute myocardial infarction: a systematic review. Cardiol J. 2012;19(5):447–52.
113. Cappell MS. Safety and efficacy of colonoscopy after myocardial infarction: an analysis of 100 study patients and 100 control patients at two tertiary cardiac referral hospitals. Gastrointest Endosc. 2004;60(6):901–9.
114. Lois F. An unusual cause of regurgitation during colonoscopy. Acta Anaesthesiol Belg. 2009;60(3):195–7.
115. Webb T. Pneumothorax and pneumomediatinum during colonoscopy. Anaesth Intensive Care. 1998;26:302–4.
116. Marwan K, Farmer KC, Varley C, Chapple KS. Pneumothorax, pneumomediastinum, pneumoperitoneum, pneumoretroperitoneum and subcutaneous emphysema following diagnostic colonoscopy. Ann R Coll Surg Engl. 2007;89(5):W20–1.
117. Koltun WA, Coller JA. Incarceration of colonoscope in an inguinal hernia. "Pulley" technique of removal. Dis Colon Rectum. 1991;3:191–3.
118. Leisser A, Delpre G, Kadish U. Colonoscope incarceration: an avoidable event. Gastrointest Endosc. 1990;36(6):637–8.

119. Singla S, Keller D, Thirunavukarasu P, et al. Splenic injury during colonoscopy—a complication that warrants urgent attention. J Gastrointest Surg. 2012;16(6):1225–34.
120. Kamath AS, Iqbal CW, Sarr MG, et al. Colonoscopic splenic injuries: incidence and management. J Gastrointest Surg. 2009;13(12):2136–40.
121. Michetti CP, Smeltzer E, Fakhry SM. Splenic injury due to colonoscopy: analysis of the world literature, a new case report, and recommendations for management. Am Surg. 2010;76(11):1198–204.
122. Ahmed A, Eller PM, Schiffman FJ. Splenic rupture: an unusual complication of colonoscopy. Am J Gastroenterol. 1997;92: 2101–4.
123. Petersen CR, Adamsen S, Gocht-Jensen P, et al. Splenic injury after colonoscopy. Endoscopy. 2008;40(1):76–9.
124. Stein DF, Myaing M, Guillaume C. Splenic rupture after colonoscopy treated by splenic artery embolization. Gastrointest Endosc. 2002;55:946–89.
125. Shi X, Shan Y, Yu E, et al. Lower rate of colonoscopic perforation: 110,785 patients of colonoscopy performed by colorectal surgeons in a large teaching hospital in China. Surg Endosc. 2014;28(8):2309–16.
126. Rathgaber SW, Wick TM. Colonoscopy completion and complication rates in a community gastroenterology practice. Gastrointest Endosc. 2006;64(4):556–62.
127. Buisson A, Chevaux JB, Hudziak H, et al. Colonoscopic perforations in inflammatory bowel disease: a retrospective study in a French referral centre. Dig Liver Dis. 2013;45(7):569–72.
128. Araujo SE, Seid VE, Caravatto PP, Dumarco R. Incidence and management of colonoscopic colon perforations: 10 years' experience. Hepatogastroenterology. 2009;56(96):1633–6.
129. Polter DE. Risk of colon perforation during colonoscopy at Baylor University Medical Center. Proc (Bayl Univ Med Cent). 2015;28(1):3–6.
130. Damore LJ, Rantis PC, Vernava AM, Longo WE. Colonoscopic perforations. Etiology, diagnosis, and management. Dis Colon Rectum. 1996;39(11):1308–14.
131. Korman LY, Overholt BF, Box T, Winker CK. Perforation during colonoscopy in endoscopic ambulatory surgical centers. Gastrointest Endosc. 2003;58(4):554–7.
132. Luning TH, Keemers-Gels ME, Barendregt WB, et al. Colonoscopic perforations: a review of 30,366 patients. Surg Endosc. 2007;21(6):994–7.
133. Foliente RL, Chang AC, Youssef AI, et al. Endoscopic cecal perforation: mechanisms of injury. Am J Gastroenterol. 1996;91:705–8.
134. Orsoni P, Berdah S, Verrier C, et al. Colonic perforation due to colonoscopy: a retrospective study of 48 cases. Endoscopy. 1997;29(3):160–4.
135. Avgerinos DV, Llaguna OH, Lo AY, Leitman IM. Evolving management of colonoscopic perforations. J Gastrointest Surg. 2008;12(10):1783–9.
136. Trecca A, Gaj F, Gagliardi G. Our experience with endoscopic repair of large colonoscopic perforations and review of the literature. Tech Coloproctol. 2008;12(4):315–21.
137. Magdeburg R, Collet P, Post S, et al. Endoclipping of iatrogentic colonic perforation to avoid surgery. Surg Endosc. 2008;22: 1500–4.
138. Yang DH, Byeon JS, Lee KH, et al. Is endoscopic closure with clips effective for both diagnostic and therapeutic colonoscopy-associated bowel perforation? Surg Endosc. 2010;24(5): 1177–85.
139. Kim HW. What is different between postpolypectomy fever and postpolypectomy coagulation syndrome? Clin Endosc. 2014;47(3):205–6.
140. Cha JM, Lim KS, Lee SH, et al. Clinical outcomes and risk factors of post-polypectomy coagulation syndrome: a multicenter, retrospective, case-control study. Endoscopy. 2013; 45(3):202–7.
141. Lee SH, Kim KJ, Yang DH, et al. Postpolypectomy fever, a rare adverse event of polypectomy: nested case-control study. Clin Endosc. 2014;47(3):236–41.
142. Rabeneck L, Paszat LF, Hilsden RJ, et al. Bleeding and perforation after outpatient colonoscopy and their risk factors in usual clinical practice. Gastroenterology. 2008;135:1899–906.
143. Waye JD. Management of complications of colonoscopic polypectomy. Gastroenterologist. 1993;1(2):158–64.
144. Rosen L, Bub DS, Reed JF, Nastasee SA. Hemorrhage following colonoscopic polypectomy. Dis Colon Rectum. 1993; 36(12):1126–31.
145. Sawhney MS, Salfiti N, Nelson DB, et al. Risk factors for severe delayed postpolypectomy bleeding. Endoscopy. 2008;40(2):115–9.
146. Heldwein W, Dollhopf M, Rösch T, et al. The Munich Polypectomy Study (MUPS): prospective analysis of complications and risk factors in 4000 colonic snare polypectomies. Endoscopy. 2005;37:1116–22.
147. Kim HS, Kim TI, Kim WH, et al. Risk factors for immediate postpolypectomy bleeding of the colon: a multicenter study. Am J Gastroenterol. 2006;101(6):1333–41.
148. Wu XR, Church JM, Jarrar A, et al. Risk factors for delayed postpolypectomy bleeding: how to minimize your patients' risk. Int J Colorectal Dis. 2013;28(8):1127–34.
149. Watabe H, Yamaji Y, Okamoto M, et al. Risk assessment for delayed hemorrhagic complication of colonic polypectomy: polyp-related factors and patient related factors. Gastrointest Endosc. 2006;64:73–8.
150. Hui AJ, Wong RM, Ching JY, et al. Risk of colonoscopic polypectomy bleeding with anticoagulants and antiplatelet agents: analysis of 1657 cases. Gastrointest Endosc. 2004;59:44–8.
151. Moon HS, Park SW, Kim DH, et al. Only the size of resected polyps is an independent risk factor for delayed postpolypectomy hemorrhage: a 10-year single-center case-control study. Ann Coloproctol. 2014;30(4):182–5.
152. Buddingh KT, Herngreen T, Haringsma J, et al. Location in the right hemi-colon is an independent risk factor for delayed post-polypectomy hemorrhage: a multi-center case-control study. Am J Gastroenterol. 2011;106(6):1119–24.
153. Choung BS, Kim SH, Ahn DS, et al. Incidence and risk factors of delayed postpolypectomy bleeding: a retrospective cohort study. J Clin Gastroenterol. 2014;48(9):784–9.
154. Dobrowolski S, Dobosz M, Babicki A, et al. Blood supply of colorectal polyps correlates with risk of bleeding after colonoscopic polypectomy. Gastrointest Endosc. 2006;63(7):1004–9.
155. Sorbi D, Norton I, Conio M, et al. Postpolypectomy lower GI bleeding: descriptive analysis. Gastrointest Endosc. 2000;51: 690–6.
156. Rossetti A, Buchs NC, Breguet R, et al. Transarterial embolization in acute colonic bleeding: review of 11 years of experience and long-term results. Int J Colorectal Dis. 2012;28:777–82.

157. Liaquat H, Rohn E, Rex DK. Prophylactic clip closure reduced the risk of delayed postpolypectomy hemorrhage: experience in 277 clipped large sessile or flat colorectal lesions and 247 control lesions. Gastrointest Endosc. 2013;77(3):401–7.
158. Katsinelos P, Fasoulas K, Chatzimavroudis G, et al. Prophylactic clip application before endoscopic resection of large pedunculated colorectal polyps in patients receiving anticoagulation or antiplatelet medications. Surg Laparosc Endosc Percutan Tech. 2012;22(5):e254–8.
159. Cheung RJ, Ortiz D, DiMarino AJ. GI endoscopic reprocessing practices in the United States. Gastrointest Endosc. 1999; 50(3):362–8.
160. Muscarella LF. Inconsistencies in endoscope-reprocessing and infection-control guidelines: the importance of endoscope drying. Am J Gastroenterol. 2006;101(9):2147–54.
161. Spach DH, Silverstein FE, Stamm WE. Transmission of infection by gastrointestinal endoscopy and bronchoscopy. Ann Intern Med. 1993;118(2):117–28.
162. Kovaleva J, Peters FT, van der Mei HC, Degener JE. Transmission of infection by flexible gastrointestinal endoscopy and bronchoscopy. Clin Microbiol Rev. 2013;26(2):231–54.
163. Kola A, Piening B, Pape UF, et al. An outbreak of carbapenem-resistant OXA-48—producing Klebsiella pneumonia associated to duodenoscopy. Antimicrob Resist Infect Control. 2015;4:8.
164. Lee SH, Chung IK, Kim SJ, et al. An adequate level of training for technical competence in screening and diagnostic colonoscopy: a prospective multicenter evaluation of the learning curve. Gastrointest Endosc. 2008;67(4):683–9.
165. Spier BJ, Benson M, Pfau PR, et al. Colonoscopy training in gastroenterology fellowships: determining competence. Gastrointest Endosc. 2010;71(2):319–24.
166. Peters SL, Hasan AG, Jacobson NB, Austin GL. Level of fellowship training increases adenoma detection rates. Clin Gastroenterol Hepatol. 2010;8(5):439–42.
167. Klare P, Ascher S, Wagenpfeil S, et al. Trainee colonoscopists fulfil quality standards for the detection of adenomatous polyps. BMC Med Educ. 2015;15(1):312.
168. Leyden JE, Doherty GA, Hanley A, et al. Quality of colonoscopy performance among gastroenterology and surgical trainees: a need for common training standards for all trainees? Endoscopy. 2011;43(11):935–40.
169. Williams MR, Crossett JR, Cleveland EM, et al. Equivalence in colonoscopy results between gastroenterologists and general surgery residents following an endoscopy simulation curriculum. J Surg Educ. 2015;72(4):654–7.
170. Cohen J, Cohen SA, Vora KC, et al. Multicenter, randomized, controlled trial of virtual-reality simulator training in acquisition of competency in colonoscopy. Gastrointest Endosc. 2006;64:361–8.
171. Sedlack RE, Kolars JC. Computer simulator training enhances the competency of gastroenterology fellows at colonoscopy: results of a pilot study. Am J Gastroenterol. 2004;99:33–7.
172. Jirapinyo P, Imaeda AB, Thompson CC. Endoscopic training in gastroenterology fellowship: adherence to core curriculum guidelines. Surg Endosc. 2015;24:4110–4.
173. Jirapinyo P, Thompson CC. Current status of endoscopic simulation in gastroenterology fellowship training programs. Surg Endosc. 2015;29(7):1913–9.
174. Lieberman D, Nadel M, Smith RA, et al. Standardized colonoscopy reporting and data system: report of the Quality Assurance Task Group of the National Colorectal Cancer Roundtable. Gastrointest Endosc. 2007;65(6):757–66.
175. Singh H, Kaita L, Taylor G, et al. Practice and documentation of performance of colonoscopy in a central Canadian health region. Can J Gastroenterol Hepatol. 2014;28(4):185–90.
176. Beaulieu D, Barkun A, Martel M. Quality audit of colonoscopy reports amongst patients screened or surveilled for colorectal neoplasia. World J Gastroenterol. 2012;18(27):3551–7.
177. Robertson DJ, Lawrence LB, Shaheen NJ, et al. Quality of colonoscopy reporting: a process of care study. Am J Gastroenterol. 2002;97(10):2651–6.
178. De Jonge V, Sint Nicolaas J, Cahen DL, et al. Quality evaluation of colonoscopy reporting and colonoscopy performance in daily clinical practice. Gastrointest Endosc. 2012;75(1):98–106.
179. Bourikas LA, Tsiamoulos ZP, Haycock A, et al. How we can measure quality in colonoscopy? World J Gastrointest Endosc. 2013;5(10):468–75.
180. Ketwaroo GA, Sawhney MS. Quality measures and quality improvements in colonoscopy. Curr Opin Gastroenterol. 2015; 31(1):56–61.
181. Hale MF, Sidhu R, McAlindon ME. Capsule endoscopy: current practice and future directions. World J Gastroenterol. 2014;20(24):7752–9.
182. Hoedemaker RA, Westerhof J, Weersma RK, et al. Non-small-bowel abnormalities identified during small bowel capsule endoscopy. World J Gastroenterol. 2014;20(14):4025–9.
183. Goenka MK, Majumder S, Goenka U. Capsule endoscopy: present status and future expectation. World J Gastroenterol. 2014;20(29):10024–37.
184. O'Donnell S, Qasim A, Ryan BM, et al. The role of capsule endoscopy in small bowel Crohn's disease. J Crohns Colitis. 2009;3(4):282–6.
185. Long MD, Barnes E, Isaacs K, et al. Impact of capsule endoscopy on management of inflammatory bowel disease: a single tertiary care center experience. Inflamm Bowel Dis. 2011; 17(9):1855–62.
186. Dionisio PM, Gurudu SR, Leighton JA, et al. Capsule endoscopy has a significantly higher diagnostic yield in patients with suspected and established small-bowel Crohn's disease: a meta-analysis. Am J Gastroenterol. 2010;105(6):1240–8.
187. Triester SL, Leighton JA, Leontiadis GI, et al. A meta-analysis of the yield of capsule endoscopy compared to other diagnostic modalities in patients with obscure gastrointestinal bleeding. Am J Gastroenterol. 2005;100(11):2407–18.
188. Zagorowicz ES, Pietrzak AM, Wronska E, et al. Small bowel tumors detected and missed during capsule endoscopy: single center experience. World J Gastroenterol. 2013;19(47): 9043–8.
189. Van Gossum A. Wireless capsule endoscopy of the large intestine: a review with future projections. Curr Opin Gastroenterol. 2014;30(5):472–6.