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## Key Points

- Critical knowledge of colorectal anatomy is imperative to performing appropriate endoscopic examinations.
- Appreciation for anatomic variations can help in progress during colonoscopy.
- Mural findings and internal clues are appropriate adjuncts in helping the endoscopist proceed with forward advancement and eventual cecal intubation.
- Looping during colonoscopy is common. Various types of loops can be encountered, and appreciation of these formations is mandatory. Having a standardized protocol for preventing and reducing these loops is fundamental in assurance of forward progression and intubation while minimizing patient discomfort and morbidity.
- Observation and verification of certain anatomic landmarks throughout the colon are helpful for providing a roadmap to continued intubation. Similarly, photography of some of these landmarks is required to document successful complete colonoscopy.

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## Background

Colonoscopy is an effective and efficient tool in the diagnostic and therapeutic management of colon and rectal diseases and allows for complete mural examination and management of the anus, rectum, colon, and terminal ileum. First described by

Drs Wolff and Shinaya in 1971 [1–3], numerous exponential advancements in optics, imaging modalities, mechanics, techniques, and instrumentation have made colonoscopy a gold standard in detection and prevention of deaths from colorectal cancer [4–7]. Indeed colonoscopy has also been found to have particular advantages in colorectal cancer screening, surveillance of inflammatory bowel diseases, and management of volvulus and other benign diseases [8]. Mastery of anatomic landmarks and impressions during the procedure is fundamental to the performance of endoscopy and allows for improved and optimal maneuverability, insertion and withdrawal, and also maximizing enhanced diagnostic and subsequent therapeutic yield. Knowledge of normal anatomy and its variants are critical to the appreciation of pathological changes or abnormalities, including polyps, diverticuli, carcinomas, and fistulae, among other findings (Fig. 2.1).

Recent advancements in CT colonography and fluoroscopy have been helpful in better defining anatomic landmarks and in facilitating colonoscopy by reducing looping and straightening and shortening maneuvers [9]. Furthermore, utilization of good basic technique and an appreciation and implications of standardized approach to difficult intubation (redundancy, difficult sigmoid, poor tolerance to sedation) help to yield improved maneuverability and successful colonoscopy [9–11].

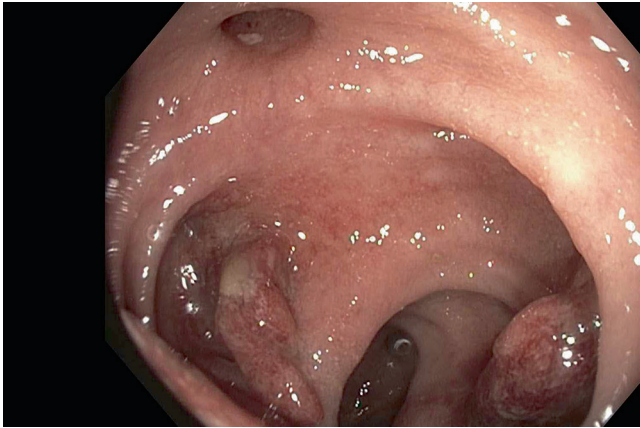
Technique for colonoscopic advancement will be further discussed in other chapters in greater detail, particularly as it relates to interventions such as biopsy, polypectomy, endoscopic mucosal resections and endoscopic submucosal dissections, and also tattooing.

Above all, certain standards in endoscopy should be followed to assure patient safety and successful colonoscopy. These including being gentle, minimal blind pushing, keeping the lumen within view, periodic and frequent withdrawal motions for straightening, and avoidance of mucosal whitening or reddening (“redout”) by scraping or sliding by the wall of the colon. Pain and incomplete colonoscopy are generally due to loop or bowing formation and resultant mesenteric

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**Fig. 2.1** Pseudopolyps and diverticuli. This is a picture taken during evaluation of the sigmoid colon in a patient with long-standing ulcerative colitis. Note the inflammatory appearance of the enlarged polyps, the excavating diverticuli, and the burnt out appearance of the wall of the remaining colon

stretching and, in some occasions, irritable bowel disease. Abdominal pressure to prevent and reduce looping with patient repositioning is a useful sometimes necessary adjunct in successful colonoscopic advancement.

## Anatomic Variations

Difficulty in successful colonoscopy is generally related to anatomic variations as it relates to redundancy in the colon or its retroperitoneal attachments leading to looping of the instrument. This looping can lead to stretching of the mesentery and significant pain, and occasionally incomplete colonoscopy. One study of 100 patients reported looping in 73% of patients with a total of 165 loops noted [9]. A fundamental understanding of the anatomy and variations thereof can aid the operator in achieving a maximal rate of successful cecal intubations.

Using intraoperative assessments, Saunders and his group found that colonic length is significantly greater in women (155 vs. 145,  $p = 0.005$ ), with the most pronounced difference noted in the transverse colon, where the colon may dip into the pelvis more often in women than in men (62% vs. 26%,  $p < 0.001$ ) [12, 13].

Similarly, portions of the colon that are typically presumed to be fixed (ascending and descending colon and the hepatic and splenic flexures) have been noted to have variable degree of mobility and freedom. Roughly 8–9% of the descending and ascending colons were mobile as a result of a redundant and non-fixed mesentery. One-fifth of patients had a mobile splenic flexure. The transverse colon reached the symphysis pubis in 29% of patients. Lastly, in approximately 20% of patients, the sigmoid colon had variable

adhesions as a result of diverticular disease or pelvic surgery or congenital adhesions [13]. The redundancy in the sigmoid and transverse colon can lead to difficulty in successfully advancing and overcoming these portions as a result of looping or bowing. Indeed, this can occur in up to 91% of patients, with N-type bowing of the sigmoid in 79% and deep transverse bowing in up to 34% [14, 15].

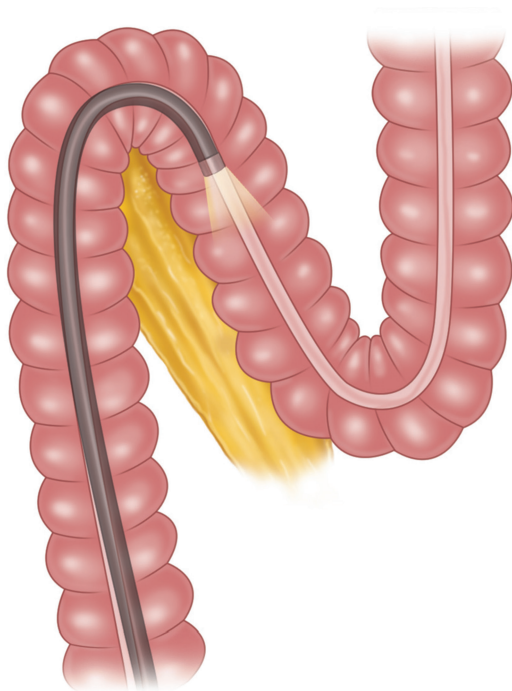
Lastly, based on operative findings, ethnic variations in colonic length have been suggested with patients from Asia and the Far East noted to have longer colons ( $P = NS$ ), but Caucasians/Western populations observed to have more sigmoid adhesions ( $p < 0.05$ ), longer descending mesocolons ( $p = 0.01$ ), more mobile splenic flexures ( $p < 0.016$ ), and longer transverse colons reaching the symphysis pubis or lower ( $p < 0.001$ ) [16].

Interestingly, when comparing CT colonography and colonoscopy, considerable variance in overall length were noted, with a shorter distance observed on colonoscopy (167 cm vs. 93.5 cm), though this may be related to experience of the endoscopist and also the accordion-like effect of successful intubation. Furthermore, colonography was able to observe and document a higher number of acute angle flexures and tortuosity. In the same cohort of patients undergoing both modalities, while looping occurred in 73 of 100 patients, fluoroscopic-assisted straightening maneuvers were successful in 95%. Successful cecal intubation was precluded in only 2 of 100 patients due to an obstructing sigmoid carcinoma and a redundant colon [9].

## Mural Findings and Internal Cues Helpful in Advancement

Small clues can be helpful in locating the lumen and directing forward advancement of the colonoscope. The lumen is located at the center of converging/radially oriented folds (not seen around diverticular orifices). The darkest side of a mucosal view or the darkest area of a fluid-filled colon should be nearest to the center of the colon and lumen. Aiming toward these areas with gentle insufflation should help in achieving proximal progression.

Curved arcs on inspection can also provide clues in determining where to progress within the channel of the colon. Arcs may be caused by haustral folds or reflections of the circular muscle fibers under the mucosal surface or highlights reflected off the surface of the microscopic innominate grooves. Enlarged muscle fibers run longitudinal along the colon (tenia coli) and may be used as a direction of orientation (similar to a white line/stripe along a highway). These are prominent and can be most easily seen along the transverse colon, splenic flexure, and particularly in the cecum.



**Fig. 2.2** Formation of sigmoid N-loop during colonoscopy. Note how the long mesentery allows stretching of the sigmoid colon. Minimal angulation of the tip will be helpful in advancement of the scope until the loop can be reduced

While progressing through difficult angulation or tortuous folds, a phenomenon called “redout” may be observed—with complete loss of any anatomic landmarks available to guide forward travel. To overcome this, standard guidelines in procedural endoscopy recommend additional gentle insufflation while pulling back with maintenance of current. This will generally smooth out the bend, shortening the colon that is past the tip, and straightening the forward colon while decreasing disorientation (the latter due to reduction of angulation). One exception to the rule may be encountered during creation of N-loops of the sigmoid, where steep/acute angulation of the tip with forward advancement may lead to exacerbation of the bowing/looping distal to the tip (walking-stick phenomenon). In these cases, a slight reduction in angulation may be helpful during forward pushing (Fig. 2.2).

## Positioning

Traditionally, colonoscopy is generally performed in the left lateral decubitus position with the hips and knees flexed at 60°–90°. Rare exceptions exist—including intubation and endoscopy through ileostomies or colostomies—and in these situations, the patient is usually in the supine position. Occasionally, as noted above and detailed further throughout the manuscript, application of manual pressure and

repositioning into the right lateral or occasionally supine and/or prone positions may help with preventing looping and ultimate cecal intubations [17, 18].

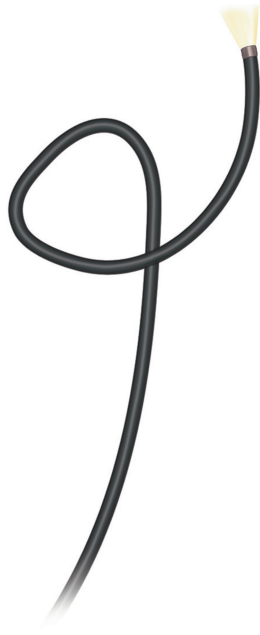
In the left lateral position, the descending colon is typically fluid filled. In the right lateral position, the descending colon is more air filled. With this knowledge, positioning into the supine or right lateral position while navigating the sigmoid and descending colon can lead to forward progress. Once progress has been made, repositioning into the standard left lateral decubitus position may allow continued intubation.

Stool and fluid can also be helpful in determining location of the lumen in the colon. Liquid effluence is generally dependent. Articulation of the tip away from a flat air fluid level will generally guide the operator toward the lumen. Similarly, stool coming through an orifice is generally coming through the main lumen. Care should be taken, however, not to confuse a scybalum-filled diverticulum with the lumen of the colon.

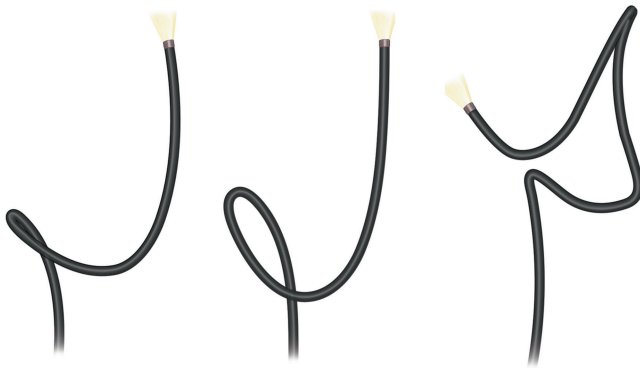
## Looping

Looping is very common during forward progression of colonoscopy. These are generally formed due to redundancies in the colon and/or hypermobile mesenteries, typically seen in the sigmoid and transverse colon [19]. Paradoxical movement and loss of 1:1 relationship of tip/shaft advancement are generally caused by sharp angulation and loop formation and are the first signs of loop formation. Typical findings include slippage with paradoxical motion and loss of sensitivity or resistance changes on advancement. Forward pushing at this stage will only increase the size of the loop, cause distention of the colon, further stretch the mesentery, and subsequently increase pain experienced by the patient.

Appreciation of the formation and direction of these loops with an understanding of the underlying anatomy will allow the operator to subsequently reduce these loops, straighten the bowel, and continue with forward progression. The most typical loop is the N-loop (or spiral loop) formed during advancement through the sigmoid colon (80%). The alpha ( $\alpha$ )-loop is encountered in about 10% of cases with an anterior/ventral-oriented sagittal loop formation (Fig. 2.3). Lastly, deep transverse looping is noted in approximately 30% of cases (Fig. 2.4). More atypical loops caused by mobile colonic attachments include the reverse  $\alpha$ -loop (5%, posterior/dorsal counterclockwise looping of the sigmoid or descending colon requiring strong counterclockwise torque retraction for reduction), reverse splenic flexure loop (3%, ventral left sided angulation and then reorientation to the right), gamma-loop of the transverse colon (1%), and a reverse sigmoid spiral (1%, with the scope oriented initially



**Fig. 2.3** Scope view image of an alpha ( $\alpha$ )-loop. Note the appearance typical of a sigmoid volvulus. Pushing through this loop until the descending colon is reached and then reduction with clockwise torqueing and withdrawal will lead to a straightened path for the colonoscope and future ease in progression and navigation of the splenic flexure



**Fig. 2.4** Common loops formed during colonoscopy include the (a) sigmoid N-loop (sometimes called bowing), (b)  $\alpha$ -loop with medialization of the sigmoid colon by volvulus formation, and (c) deep transverse colon loop

anterior and ventral in the caudal orientation and then followed in a cephalad posterior dorsal position leading to medialization, rather than lateral positioning of the sigmoid and descending colon) (Fig. 2.5).

## Reduction of Loops

An appreciation loop formation and protocolized regimen to reduce these loops are imperative in allowing continued progression and reduction of pain and other morbidities



Reverse alpha 5%



Reverse splenic flexure 3%



Gamma 1%



Reverse sigmoid spiral 1%

**Fig. 2.5** Less common and difficult loops encountered during colonoscopy. These include (in counterclockwise order from top left) (a) reverse  $\alpha$ -loop, (b) deep gamma ( $\gamma$ )-loop of the transverse colon, (c) reverse splenic flexure loop, and (d) reverse sigmoid spiral loops. Approach to reduction is discussed in the text

associated with colonoscopy. These loops are generally overcome by gently withdrawing of the colonoscope and while maintaining the angulation (up-down/left-right), de-torqueing the scope in clockwise direction with the wrist. This maneuver prevents slippage. On subsequent advancement, the operator should then try clockwise torqueing. Occasionally, anticlockwise torqueing and retraction followed by anticlockwise torqueing and advancement may be necessary if the above maneuvers are repeatedly unsuccessful. Lastly, changing positioning or abdominal pressure application may be useful with incorporation of the above steps [17]. Successful manipulation of these loops will be met by forward 1:1 or great advancement of the tip and the shaft of the colonoscope. Real-time magnetic image-guided endoscopy can sometimes be used as an adjunct to help visualize and subsequently reduce looping during scope



advancement [14, 15]. This tool may be particularly helpful in the early learning phases of colonoscopy.

Additional steps pertinent to progression of the colonoscopy procedure as they relate to the particular segment of anatomy will be discussed below.

## Anatomy

The following will describe various key anatomic landmarks that should be appreciated during advancement and progression of the procedure leading to a successful colonoscopy.

### Anus

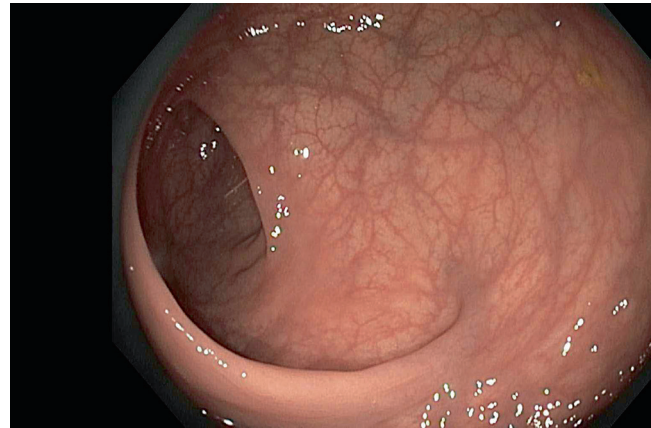
The first landmark to be visualized and assessed is the perianal area and anal canal. This area of the intestinal canal is frequently overlooked and, in the case of colonoscopy, poorly visualized. Care should be made to grossly evaluate for any external diseases perianally and exclude noteworthy entities such as anal carcinoma (squamous cell, melanoma, etc.), fissures, fistulae, and abscesses. Hemorrhoids are typical findings and should be documented accordingly. In the setting of suspected inflammatory bowel disease, careful visual inspection for waxy elephant ear Crohn's tags should be performed and documented. These are commonly mistaken for benign hemorrhoids. A digital rectal examination of the anorectal canal is then performed to assure no significant mass or excavating lesion exists, as well as provides an assessment for any stricture or stenosis. These can be related to intrinsic inflammatory bowel disease such as Crohn's disease, or may be related to postoperative healing, or carcinoma. If any of these are found, cautious biopsies may be indicated. Care should be utilized however to prevent fistula formation in this vicinity. In some cases, a bimanual examination may be warranted if a mass or penetrating lesion or fistula is suspected. Once visual and digital rectal examination is performed, the colonoscopy can then be initiated.

Once the tip of the colonoscope is inserted within the anorectal canal, using variations of either air, carbon dioxide (CO<sub>2</sub>), or water insufflation/instillation, the rectum is then visualized. Typically, there may be residual stool or fluid in the rectal vault from the preparation. This should be sufficiently suctioned out for appropriate evaluation of the anorectal and rectal mucosa.

### Rectum

#### Key Landmarks

- Dentate line
- Rectal valves/folds



**Fig. 2.6** Rectal fold/valves—in this colonoscopic image, the mid and distal folds can be appreciated on the left and right side, respectively. The upper/proximal rectum is in the background, while the mid and then upper portions of the distal rectum are seen in the foreground

The rectum is approximately 15 cm long and, for clinical descriptive purposes, can be divided into approximately 5 cm thirds (proximal, mid, and distal). These portions of the rectum will be demarcated by incomplete haustral valves or folds of Houston (upper/proximal/first, middle/second, lower/distal/third) that can be used as landmarks when describing any atypical lesions (carcinomas, polyps). The proximal/upper fold is considered the uppermost/cephalad extent of the rectum and denotes the rectosigmoid junction (Fig. 2.6). The authors recommend not utilizing only numerical designation but rather descriptive terms (distal or lower instead of first) as this avoids confusion in terms of location and orientation. When commenting on findings, it is helpful to both note the location of these lesions based on distance from the anal verge (or preferably dentate) and also the location related to these rectal folds or valves (i.e., “6 cm above the anal verge, on and distal to the lower/distal rectal fold”). This is significantly important when surgical approaches are to be considered or when imaging is later performed and needs to be correlated to endoscopic findings.

Occasionally, lesions may not be able to be endoscopically managed at the time of index colonoscopy. Advanced endoscopic therapeutic interventions such as endoscopic mucosal resection or endoscopic submucosal dissection may benefit the patient with benign polypoid disease. Surgical (or combined endolaparoscopic) management may also be warranted for malignancy or medically refractory disease. Anticipating the need for these above modalities, photodocumentation with location and anatomic landmarks is critical for the referred physician or surgeon. Furthermore, it may be appropriate to inject a submucosal tattoo on the distal/anal side of the lesion. This should be done using three areas of injection circumferentially around the wall of the colon. The only area that would not definitively need tattooing is a

lesion in the cecum. Rectal lesions are helpful to tattoo in case regression is noted after neoadjuvant chemoradiation therapy.

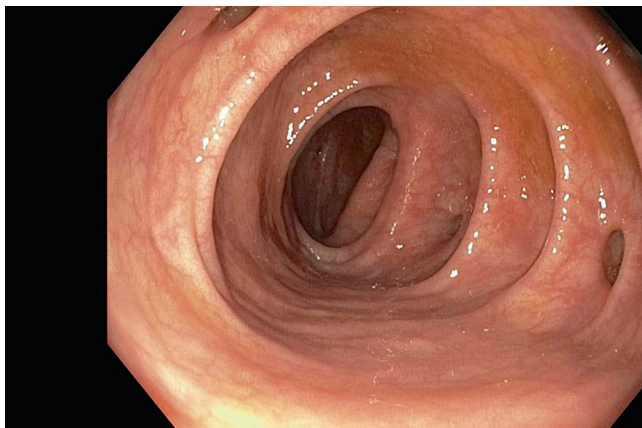
Progression through the retroperitoneal rectum is generally straightforward with mostly forward pushing, insufflation, and gentle clockwise torqueing required at times. Once the proximal rectum has been traversed, it may be helpful to gently pull back and unloop and reduce any redundancy and excess scope previously inserted.

## Rectosigmoid and Sigmoid Colon

### Key Landmarks

- Upper rectal valve/fold
- Diverticuli
- Tortuosity in women and patients with long-standing constipation
- Stenoses/strictures due to diverticular disease

At approximately 15–20 cm above the anal verge, the endoscopist will encounter the rectosigmoid and then distal sigmoid colon. This is also the area where the colon is now located within the peritoneal cavity above the peritoneal reflection. Care should be taken in this vicinity as there are commonly located and experienced tortuosities and angulations, strictures/stenoses, and significant diverticular disease in this vicinity (Fig. 2.7). Furthermore, redundancy of the colon in this area may lead to excessive looping of the endoscope. Overly aggressive forward movement and/or twisting may lead to mechanical trauma along the wall of the colon. Barotrauma related to over distention with air is also a significant risk in this area. Both of these are common causes of perforation, particularly in this area. The cecum is also a very



**Fig. 2.7** Sigmoid colon with diverticuli. Note the excavating lesions noted on the sides of the wall of the sigmoid colon. Also, the endoscopist should appreciate the larger and darker center lumen that should be used as a guide to advance the scope. In this image, fluid is noted on the upper right, signifying the dependent portion of the colon

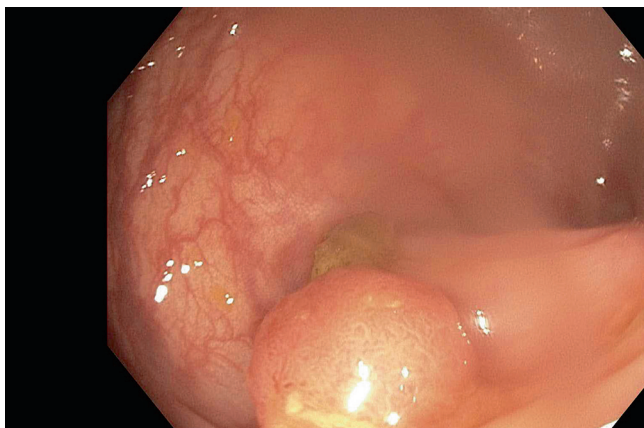
common area for perforation due to barotrauma as it relates to LaPlace's law with this proximal-most portion of the colon having a larger radius and thinner wall/tension. Perforations rates are typically less than 0.1%, but may reach 18% based on indication for therapeutic procedure being performed in these areas [20–30].

During advancement in this area, care should be made to use judicious insufflation and at the same time also aspiration techniques utilized to draw in the more proximal lumen while telescoping and advancing the colonoscope further into the colon. Excessive inflation of the colon can lengthen and distend the colon and, in some cases, enhance twisting or angulation and kinking of the colon and prevent advancement. In general, during advancement, right and left knobs should be used sparingly, and instead, mechanical twisting or torqueing of the shaft of the scope with the operator's wrist is preferred when trying to negotiate turns. Up-down knob manipulation is very helpful however in centering the scope in the lumen and advancing proximally.

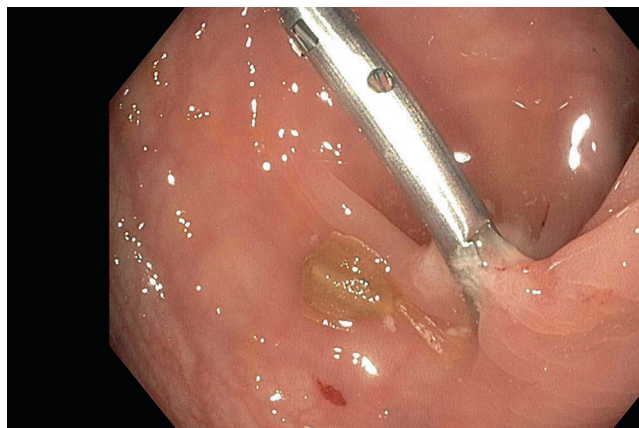
First described in 1986 and 2002, the use of carbon dioxide insufflation [31] and/or water instillation [32] has been found to reduce distention and patient discomfort while facilitating advancement of the colonoscope [33–42]. Most recently, the use of warm water irrigation for colonic distention has been shown to aid in navigating through the left colon with extensive diverticulosis by help differentiating the lumen from the mouths of the diverticuli. Warm water colonic distension has also been shown to decrease sedation requirements and patient pain/discomfort [43, 44]. The potential disadvantages associate with water-aided colonoscopy technique is lower adenoma detection rate in the water-filled portions of the colon and longer procedure time [45–49].

In certain cases due to narrowed, angulated, or fixed sigmoid colons, a pediatric colonoscope or a thin upper endoscope can be used in combination of position changes (supine) and abdominal pressure (one or two hands pushing down and to the left and utilizing up to four hands to cover the entire abdomen). In some cases, guidewire exchanges may be utilized. For redundant sigmoid colons, the use of various enteroscopes and/or endoscopic straighteners can also be utilized [11, 50]. Variable stiffness endoscopes have recently been utilized to help in navigating and advancing the scope.

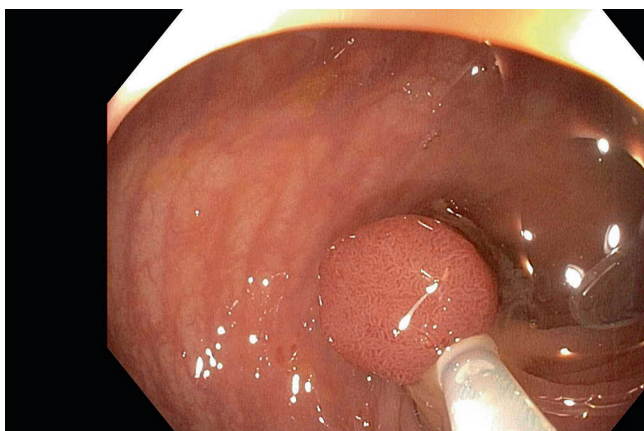
During insertion and navigation through the tortuous rectosigmoid and sigmoid colons and into the otherwise straight descending colon, combinations of right-oriented clockwise wrist twisting/torqueing and de-twisting and pullback/straightening maneuvers may be particularly useful as well. Sometimes, multiple to-and-fro motions may be required to successfully navigate through the sigmoid with minimal looping. It is helpful to gain a masterful handling of the colonoscope. Being able to reposition the scope so that pathological



**Fig. 2.8** A sessile polyp positioned at 6 o'clock. Note the villous architecture on the mucosal surface and benign appearance of the colon wall



**Fig. 2.10** A clip applied to the base of the resection specimen after snare excision of the sigmoid polyp



**Fig. 2.9** The same polyp being resected with the technique of snare polypectomy

findings and working ports are localized at the 4–8 o'clock position will allow for improved ability for diagnostic and therapeutic interventions, such as biopsy, snare and clip applications (Figs. 2.8, 2.9, and 2.10).

Looping in the sigmoid colon is very common and can lead to difficult if not incomplete colonoscopy. Redundancy of the sigmoid colon leading to looping is correlated with female gender, increasing age, low body mass index, prior hysterectomy, and history of constipation [9, 51–53]. Looping can generally be overcome by following good standard endoscopic procedures without special techniques, using combinations of withdrawal-suctioning torquing (clockwise vs. counterclockwise rotations of the endoscopy shaft) to straighten out the affected colon [9].

N- or spiral loops are commonly formed with straight pushing advancement motions through a long and mobile sigmoid mesentery. Interestingly there is minimal pain since the long colon is otherwise not particularly stretched. An alpha ( $\alpha$ )-loop is endoscopically quite advantageous.

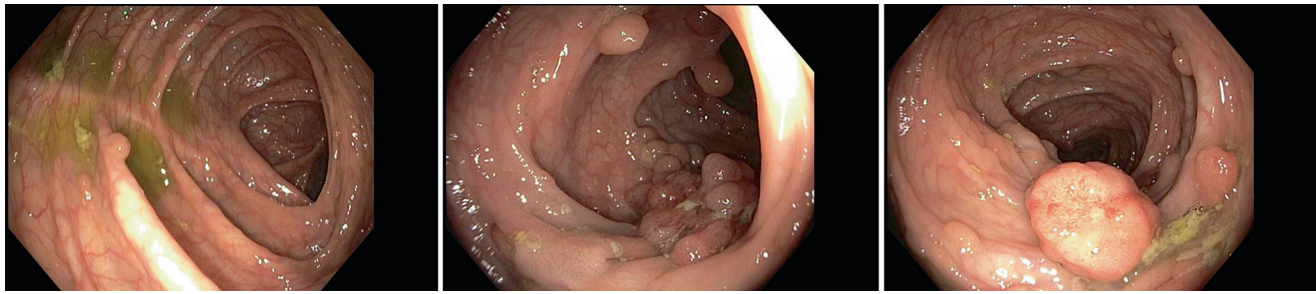
This  $\alpha$ -loop is equivalent to a sigmoid volvulus formation caused during endoscopy due to a very long and mobile sigmoid and a fixed retroperitoneal descending colon. If advancement of the scope is easy without acute bends or discomfort, initially the operator should continue and push through the volvulus or  $\alpha$ -loop. Once the proximal to mid-descending colon has been intubated, reduction of an  $\alpha$ -loop by withdrawal with simultaneous clockwise rotation will yield a straightened colon that is pressed along the posterior abdominal wall/retroperitoneum allowing for further advancement and forward progress without looping or pain [54, 55]. In rare instances, a longitudinal “split” external straightener or overtube device can be utilized to overcome looping [10, 11]. In general, a median of 2.1 (range 1–6) straightening maneuvers may be necessary to reach the cecum [9].

Care must also be taken to avoid intubation of a diverticulum during insertion. Whenever advancing the endoscope, occasional pullback technique to visualize the central larger lumen may be useful to avoid inadvertent mechanical injury or barotrauma and subsequent perforation in this area.

## Descending Colon

Entry into the descending colon is generally accomplished with a back-and-forth motion with clockwise torquing of the colonoscope [55]. Alpha ( $\alpha$ )-loops of the sigmoid colon are suspected when there is more pain than anticipated (secondary to mesenteric twisting and torsion) or paradoxical motion of the tip of the scope. This  $\alpha$ -loop needs to be reduced prior to proceeding with scope advancement past the splenic flexure to minimize pain and increase successful cecal intubation rates. This can generally be performed by withdrawing the scope and slowly and gradually rotating the scope clockwise. This should then straighten out the sigmoid and descending colon and aide in further scope advancement





**Fig. 2.11** Transverse colon with multiple adenomatous polyps of various sizes. Notice the triangular shape of the colon lumen formed by the thickened muscular teniae coli. This patient has familial adenomatous

polyposis and found to have at least 544 adenomatous polyps throughout his colon and rectum

(noted by successful entry into the transverse colon without paradoxical movements).

Typically, once the scope has been manipulated through the sigmoid colon, the descending colon is seen as a straight path lumen with few diverticuli, if any, and generally without angulation. The circular appearance is related to the thick circular muscles lining the wall of the descending colon. This is principally related to the attachments to the retroperitoneal white line of Toldt laterally along the left abdominal wall and the mesentery to the retroperitoneum overlying Gerota's fascia.

## Splenic Flexure

### Key Landmarks

Sharp turn/angulation

Bluish hue of adjacent spleen

Proximal transverse colon/triangular haustra

Pressure applications are most used and helpful in overcoming the angulations and redundancies in the flexures (splenic and hepatic). The splenic flexure is generally more redundant than the hepatic flexure. In some instances, a bluish-gray hue may be noted through the thin wall of this flexure, and this corresponds to the spleen that may be intimately attached to the colon. Rough forward advancement without appropriate finesse may lead to traumatic splenic rupture and hemorrhage [56–59]. Changing position to the partial right lateral decubitus may help traverse the distal descending colon and splenic flexure.

The best clue signifying successful passage of the splenic flexure is progression from a fluid-filled descending colon to an air-filled, triangular-shaped transverse colon.

Once past the splenic flexure, at the distal transverse colon, attempts should be made to withdraw and reduce any looping or extraneous endoscope within the colon. This is generally helped by the fixation by the phrenocolic ligaments.

The splenic flexure acts as a fulcrum allowing forward progression through the transverse colon while withdrawing,

through upward/cephalad lifting of the colon due to a cantilever effect. Similarly, using gravity as an assistant, the right lateral decubitus position helps in forward progression past the splenic flexure and through the transverse colon.

Keys to traversing the splenic flexure involve a few fundamental steps: (1) pull back the shaft to 50 cm with clockwise torque until there's a catapult-like resistance or slippage of the tip; (2) de-angulate the tip; (3) deflate the colon to keep colon short and supple and adaptable; (4) apply hand pressure over the lower abdomen to prevent looping; (5) torque the shaft clockwise to put torsional straightening force on the sigmoid loop while adjusting angulation to keep lumen in view; and (6) gently push in motion. Occasionally positioning the patient on the back and/or right-side down can also be utilized.

Reverse splenic flexure looping occurs when the descending colon is completely mobile and the colonoscope goes the wrong way around the splenic flexure and through the transverse colon. The scope pushes through a deep transverse loop with an acute angulation at the hepatic flexure. By counterclockwise de-torqueing and withdrawal using the splenophrenic ligament as a fulcrum, the descending colon is then twisted back in its typical anatomic lateral position, and the scope is then passed through the flexure in a conventional manner.

## Transverse Colon

### Key Landmarks

Triangular haustra

Prominent teniae coli

Tortuosity and redundancy noted in women and patients with long-standing constipation.

The transverse colon, proximal to the splenic flexure, is commonly identified by the triangular appearance of the lumen due to the prominent longitudinal muscles of the tenia coli and relatively thin circular muscle fibers (Fig. 2.11). The teniae function as a useful guide for the colonic axis and



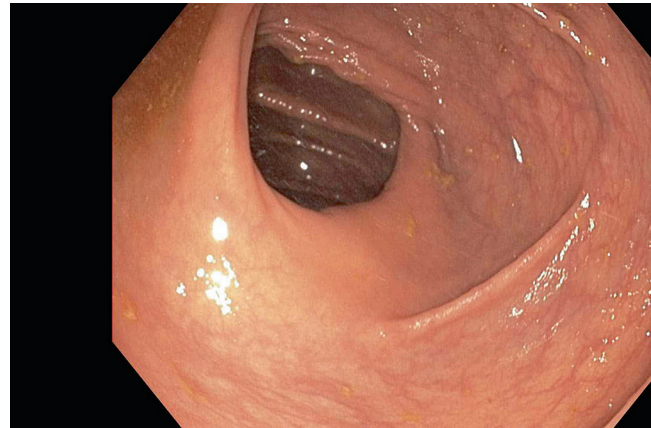
direction of progression. The transverse colon is attached and dependent via its retroperitoneal mesentery just caudal to the pancreas. The transverse colon can reach down to the symphysis pubis, particularly in women or those patients with long-standing constipation [55]. Advancement through the mid- and distal-transverse colon is generally aided using various combinations of tip flexion and also abdominal wall compression. Traditionally, once the mid-transverse colon is reached, pulling back with clockwise rotation will lead to advancement through the proximal transverse colon through paradoxical movement as a result of a cantilever-type effect with the splenic flexure functioning as a fulcrum resulting in the shortening, straightening, and elevation of the colon. Repeated in-and-out push-pull movements may be helpful during this phase. In certain cases, a particularly long transverse colon and mesocolon may lead to the formation of a gamma ( $\gamma$ )-loop with a clockwise volvulus. This is particularly difficult to navigate and generally will require careful withdrawal back to the splenic flexure and reinsertion. In some cases, repositioning the patient in supine or prone position may help straighten the colon for advancement.

## Hepatic Flexure and Ascending Colon

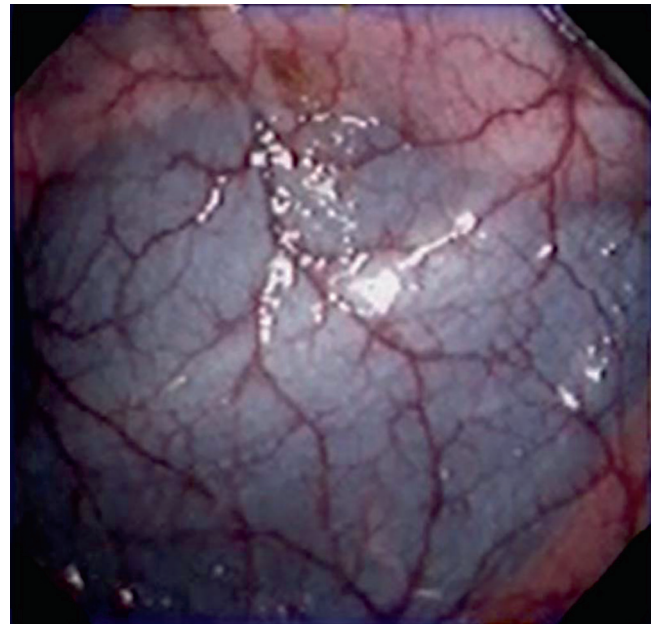
### Key Landmarks

#### Bluish hue of liver

Once reaching the proximal transverse colon, while the patient is in the left lateral decubitus position, suctioning allows the colon to collapse onto the scope and advancement ensues. The hepatic flexure has an acute hairpin turn and requires masterful steering and manipulation to traverse and steer around. Overcoming the angulation of the hepatic flexure can be typically performed through a combination of torquing (counter-) clockwise to gain a few additional centimeters of length, suctioning of the distended colon to collapse and shorten the flexure/bend, and pulling/withdrawing back on the endoscope. This generally leads to an accordion-like bowel slipping onto the shaft with prompt scope advancement (in a paradoxical fashion by withdrawal) into the cecum (Fig. 2.12). The application of abdominal pressure at various points (left upper abdomen, centrally, or right sided) may also be helpful. If the patient is lightly sedated, deep inspiration may help lower the diaphragm and flexure. In some cases, even with right lateral decubitus positioning, it may be difficult to overcome the presumed hepatic flexure. With this scenario, one must suspect that indeed, the scope is positioned at the splenic flexure in this case. One common way to determine this is based on fluid contents. In the left lateral decubitus position, the splenic flexure will have dependent fluid, whereas the hepatic flexure should be dry. (see picture “ascending colon from distal hepatic flexure”). Occasionally, the bluish hue from the liver may be seen through the thin-walled hepatic flexure (Fig. 2.13).



**Fig. 2.12** This is a view as the ascending colon is being paradoxically intubated immediately after navigating through the hepatic flexure while withdrawing the scope



**Fig. 2.13** The bluish hue discoloration visible through the thin-walled colon represents blood within the liver as the hepatic flexure is being traversed. A similar appearance can also be noted while traversing the splenic flexure—and this represents the spleen. Particular care should be utilized in these areas to avoid injury to the capsule of these vascular organs and ensuing hemorrhage

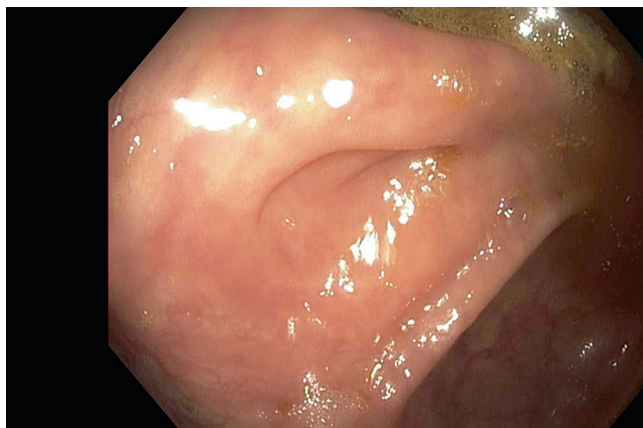
## Cecum/Ileocecal Valve/Appendiceal Orifice

### Key Landmarks

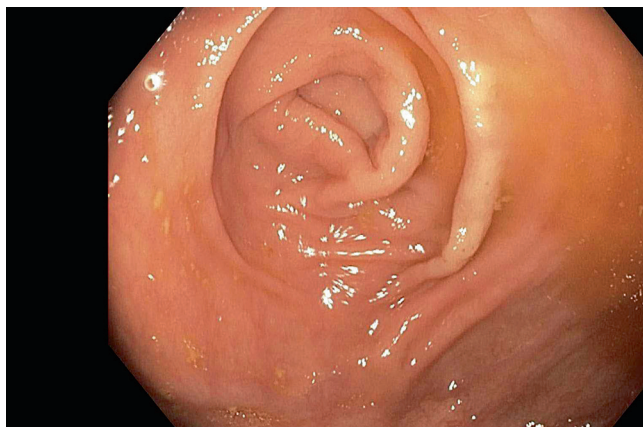
#### Ileocecal valve (ICV)

#### Appendiceal orifice (AO)

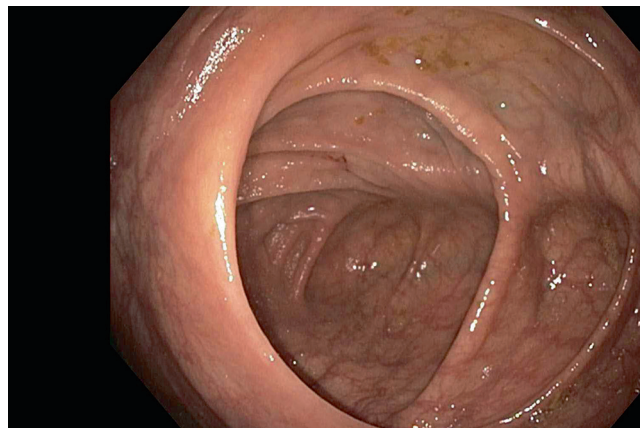
Once the hepatic flexure has been traversed, suctioning action and simultaneous clockwise rotation during withdrawal will lead to an accordion-like slippage of the ascending colon onto the scope with eventual intubation of the cecum. There may be additional maneuvering required at the



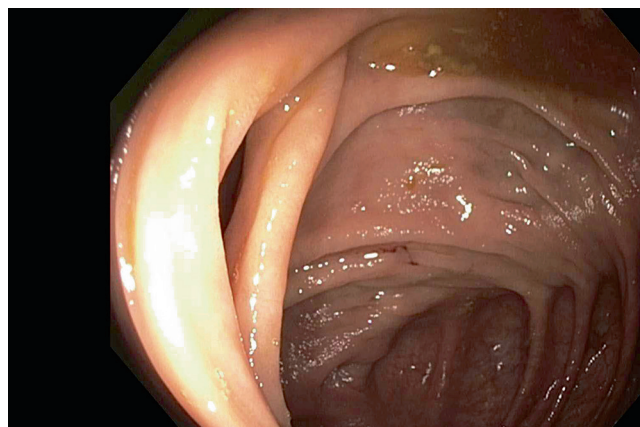
**Fig. 2.14** Typical slit-like appearance of the appendiceal orifice. When attempting ileal intubation, the endoscopist should aim the tip toward the mouth of the slit (in this case, up and to the left)



**Fig. 2.15** Head on view of the open appendiceal orifice. Dependent fluid on the lateral aspect of the cecum. This fluid should be suctioned clear to evaluate for any small or diminutive polyps



**Fig. 2.16** Ileocecal valve and cecum. Note the thickened fold on the left of the picture, corresponding to the ileocecal valve. Hypertrophied and thickened tenia are also noted running longitudinally along the length of the cecum and ascending colon (right of picture). At the apex of the cecum, convergence of tenia is noted in the caput or cecal strap



**Fig. 2.17** The ileum is seen through the two folds of the ileocecal valve on the left with the cecum and cecal strap noted in the background

end to successfully overcome the last of the haustral folds and get the ICV and AO in view. Occasionally a tight turn may be confused with the cecum. The absence of the AO and/or ICV is a precaution again making this error.

The AO is typically a very small curved slit or a hole in a circular whirl of folds. There may be ring-like lymphoid aggregate follicles surrounding the AO on close inspection. Some fluid may be noted coming from the orifice (Figs. 2.14 and 2.15).

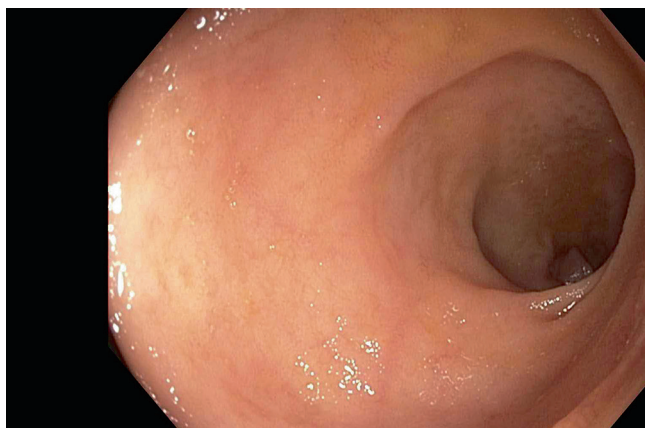
The ICV is best seen as a bulge on the last and most prominent proximal haustral fold, approximately 5 cm proximal to the cecal caput/strap. Occasionally both lips of the valve may be seen (Figs. 2.16 and 2.17).

Photo documentation of key landmarks including the ileocecal valve (ICV) and the appendiceal orifice (AO) at the terminal end of the cecum is now mandated to be included with all endoscopy reports.

## Terminal Ileum

The most straightforward method of intubation of the terminal ileum is by positioning the end of the scope adjacent to the appendiceal orifice; tipping the colonoscope toward the lip of the AO (presuming the ileum would follow a medial course in the peritoneal cavity and the enlarged aspect of the lip also points medially) and then with slow, gentle withdrawal toward the direction of the ileocecal valve, the scope will naturally then “hook” or fall into the valve and the ileum. The operator will quickly notice the marked variation in the appearance (both luminal surface and diameter) of the ileum. Otherwise, direct visualization of the ileocecal valve at the 6 o’clock position and forward and downward motion through this (slit-like opening on the cecal side of the) ICV can be similarly attempted. Occasionally, the scope may need to be positioned just proximal to the ICV and then with downward tipping,





**Fig. 2.18** The ileum is intubated. Note the change in appearance of the lining of the intestinal wall. Lymphoid aggregates are appreciated as circular dots in the upper aspect of this image

slowly withdrawn. A “redout” view with subsequent gentle insufflation or water instillation will yield an appropriate view of the terminal ileum villi and occasional hypertrophic lymphoid follicular aggregates (Fig. 2.18). In some cases, this may not be able to be performed due to sharp angulation, stricture or stenosis due to postoperative changes or Crohn’s disease, or extraluminal adhesions.

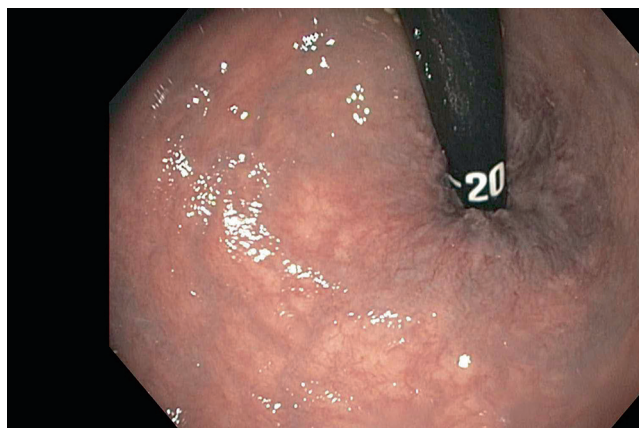
At this point, once successful intubation of the cecum and/or ileum has been performed, a careful withdrawal should be performed. This portion of the procedure should generally take as long as insertion. Insufflation should be judiciously utilized to distend the colon enough so as to be able to attain a good 360° evaluation of the colon for any pathology. In certain cases, back-and-forth motions may be required to look around folds and exclude pathology on the proximal aspects. While going around flexures or bends, it may be similarly necessary to use these to-and-fro motions and also preemptively turn the tip to keep the colon distended and the lumen and walls well visualized. Pathological changes and management of these findings will be discussed later in the text.

## Anorectal Canal

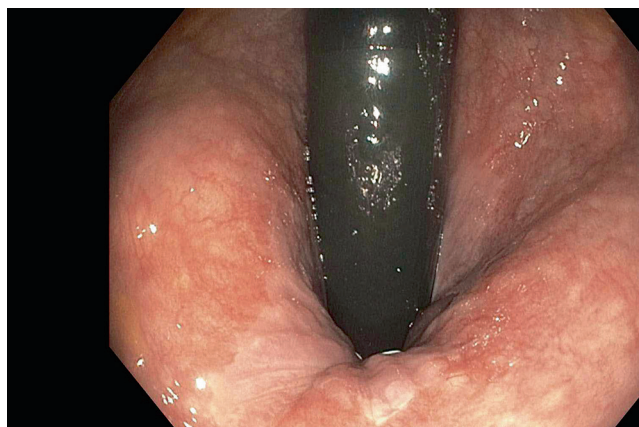
### Key Landmarks

Retroflexed view of distal rectum, dentate, and proximal anal canal

At the termination of withdrawal during the colonoscopy, a retroflexed view should then be performed and photodocumented. This is typically performed by having the scope inserted about 15–20 cm from the verge, then turning the dial maximally in the “up” position (toward the operator), and then manually torqueing the endoscope to the right (Fig. 2.19). This should allow an appropriate, and with twisting, circumferential 360° view of the very distal anorectal canal. The squamocolumnar junction, known as the dentate



**Fig. 2.19** Retroflexed view of the distal rectum and proximal anal canal. The 20-cm marking on the colonoscope is visible. The interface between the pink rectal mucosal line and the white-purplish squamous wall of the anal canal is demarcated by an irregular white dentate line



**Fig. 2.20** A close-up view of the dentate line. The bulge noted to the left may be a result of the rectum being insufflated and distended from the abdominal side over the puborectalis and sphincter complex. The irregular white dentate line is also visible circumferentially

line, should be well visualized (Fig. 2.20). Occasionally, it may be helpful to localize the presence of an abnormality (including tumor) with reference to distance proximal or distal to the dentate line. Typical findings may include internal hemorrhoids and in rare occasions very distal rectal carcinomas, condylomatous lesions of the proximal anal canal, squamous cell carcinomas, and fistulous openings. The dentate line will be visualized, separating the typical pink appearance of the epithelial mucosa of the rectum from the purplish hue of the squamous cell anal canal and vascularized hemorrhoid tissue.

### Pearls and Pitfalls

Appreciation of anatomy and its variations is integral in achieving maximal benefit while performing diagnostic and therapeutic colonoscopy. Careful technique with a structured protocol



to intubate the colon and rectum and also prevent and reduce looping is critical to being able to perform successful and iterative diagnostic procedures and therapeutic interventions. A mastery of instrumentation and insertion and withdrawal techniques, with emphasis on torqueing, allows for enhanced progression with minimal discomfort of the patient. Pain experienced by the patient, paradoxical movement, or loss of 1:1 progression during scope advancement are clues that significant looping has occurred, and reduction of the colonoscope is required. Most loops can be reduced with simultaneous gentle withdrawal and clockwise torqueing action. Maintenance of tip angulation is helpful to prevent disorientation.

Appreciating the key anatomic landmarks with photodocumentation is helpful in both achieving complete colonoscopy and performing therapeutic interventions. Keeping the lumen centered during intubation is critical in avoiding injury and/or perforation of the colon. Water instillation rather than carbon dioxide may be helpful in navigating through the sigmoid and left colon by its gravitational actions. Using internal luminal findings and mural appearance of folds will help keep the operator targeted on the center of the colon. Classic findings to help the endoscopist include the three rectal folds, occasional tortuosity of the sigmoid colon with frequent N- or alpha-looping, the circular/tubular appearance of the descending colon, the triangular appearance of the lumen of the transverse colon caused by the thickened muscular teniae coli, the bulbous and the cavernous cecum with the appendiceal orifice, and ileocecal valve (both of the latter requiring photodocumentation). Occasionally, the hepatic flexure or mid-ascending colon may be confused for the cecum. Without appropriate verification of the above two landmarks, it should be presumed that further advancement is required to successfully intubate the cecum.

Documenting atypical findings with combinations of distance from the anal verge and also anatomic landmarks is helpful for future endoscopic and surgical planning. Tattooing lesions on the distal/anal side in a circumferential pattern may be helpful for the surgeon during future interventions.

## Conclusion

Colonoscopy is a very practical tool in the management and welfare of patients. A fundamental appreciation of the anatomic landmarks, variations encountered during advancement, and reduction of looping can yield a successful, pain-free colonoscopy for the surgeon and patient alike.

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