

Approach to Incomplete Colonoscopy: New Techniques and Technologies

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Abstract: Colonoscopy is the most widely used screening modality for the detection and removal of colon polyps and for the prevention of colorectal cancer. To identify all colon lesions and reduce the risk of colorectal cancer, it is important to perform a complete colonoscopy. The success of screening colonoscopy depends upon several parameters, including bowel preparation and adenoma detection rate. Incomplete colonoscopy rates vary from 4% to 25% and are associated with higher rates of interval proximal colon cancer. This article reviews the potential causes of and preventive measures for incomplete colonoscopy, as well as techniques and technologies that may improve the rate of complete colonoscopy.

Colonoscopy is the most widely used screening modality for the detection and removal of colon polyps and for the prevention of colorectal cancer (CRC).¹ Since the introduction of colonoscopy in the 1960s, the technology associated with this procedure has progressed considerably. The advantages of colonoscopy include complete visualization of the colon, detection and removal of polyps, and tissue sampling of significant lesions. In addition, colonoscopy with polypectomy reduces the incidence of CRC by up to 90%.²⁻⁴ The overall success of screening colonoscopy depends upon several parameters such as bowel preparation, cecal intubation rate, withdrawal time, and adenoma detection rate. Cecal intubation is defined as the advancement of the colonoscope tip to a point proximal to the ileocecal valve so that the whole cecal caput, including the medial wall of the cecum, is seen.⁵ Performing a complete colonoscopy is vital for minimizing polyp miss rates in all segments of the colon, including right-sided lesions. A large, multicenter trial of patients undergoing screening colonoscopy found that 50% of patients had significant dysplastic lesions in the proximal colon.⁶ Another study found that the risk of proximal cancer increased 2-fold when colonoscopy was not complete.⁷ Therefore, complete colonoscopy can reduce the rates of interval proximal colon cancer.⁸ Current guidelines propose targets for successful cecal intubation rates of at least 90% for all colonoscopies and at least 95% for screening

Keywords

Incomplete colonoscopy, computed tomography colonography, overtube-assisted colonoscopy, colon capsule

Table. Factors Contributing to an Incomplete Colonoscopy

Patient Factors
• Inadequate bowel preparation
• Discomfort and intolerance
• Body habitus (low body mass)
• Female sex
• Young age
Technical Factors
• Diverticulosis
• Tortuosity
• Adhesions due to previous surgeries
• Angulation or fixation of bowel loops
• Ineffective sedation
Operator Factors
• Endoscopist and technician expertise

colonoscopies, with the knowledge that the majority of clinicians will exceed these minimal standards.^{5,9}

In certain situations, an endoscopist will encounter difficulty in advancing the colonoscope through the colon, leading to incomplete colonoscopy. Incomplete colonoscopy rates vary from 4% to 25%.¹⁰⁻¹³ This article reviews the potential factors of an incomplete colonoscopy and the strategies for preventing such a situation. It also highlights the management of incomplete colonoscopy and discusses new techniques and technologies that can be utilized to improve visualization of the entire colon.

Factors Contributing to an Incomplete Colonoscopy

Multiple issues contribute to an incomplete colonoscopy in clinical practice, including patient, technical, and operator factors (Table). Common patient factors include inadequate bowel preparation, discomfort and intolerance, low body mass, female sex, and young age. Technical factors include diverticulosis, tortuosity, adhesions due to previous surgeries, angulation or fixation of bowel loops, and ineffective sedation.¹⁴⁻¹⁸ Operator factors may also play a role according to the expertise of the endoscopist or technician. For example, one study showed that colonoscopies performed later in the day had higher rates of incompleteness, suggesting operator fatigue to be an important factor.¹⁹ The competency of the endoscopist appears to be a significant factor in determining the success of colonoscopy as well; the American Society for

Gastrointestinal Endoscopy (ASGE) guidelines state that for trainees, 500 colonoscopies may be required to consistently achieve cecal intubation in 90% of procedures.²⁰

Strategies for Preventing an Incomplete Colonoscopy

It is important to identify and anticipate the risk factors listed in the Table before scheduling a colonoscopy. After the risk factors have been identified, strategies to prevent an incomplete colonoscopy should be implemented. Strategies include customizing the bowel preparation, choosing the appropriate sedation, changing positions and abdominal pressure, ensuring proper endoscopic technique, and considering the use of water techniques, carbon dioxide, and magnetic endoscope imaging.

Adequate Bowel Preparation

Patient education regarding adequate bowel preparation, such as the importance of colon cleansing and specific instructions on how best to prepare for the colonoscopy, is vital. A prospective study evaluating 10,571 colonoscopies found that the completion rate of colonoscopies in patients with satisfactory bowel preparation was 67.5% compared with 36.0% in patients with poor bowel preparation (odds ratio, 3.76; $P=.0005$).²¹ A 2016 retrospective study of 28,368 colonoscopies showed that better bowel preparation significantly increased the rate of examination completion, with 99.5% completed colonoscopies from adequate bowel preparation vs 88.4% completed colonoscopies from poor bowel preparation.²² A subsequent study confirmed a high yield of lesions in colonoscopies with better bowel preparation.²³

Certain patients are at risk for inadequate bowel preparation, including patients with a history of suboptimal bowel preparation, diabetes, chronic constipation, or abdominal surgery, as well as patients on medications that slow gut motility (eg, tricyclic antidepressants, opiates). In such patients, a 2-day extended preparation, with larger volumes of bowel preparation, can be considered.¹⁸ Split-dose bowel preparation has shown to have better colon cleansing in all segments of the colon, and has recently become the standard of care for colon cleansing.²⁴

Appropriate Sedation

Choosing the appropriate sedation method in advance can facilitate procedure completion and improve patient tolerance. Conscious or moderate sedation for screening colonoscopy is well tolerated and cost-effective for most patients. Monitored anesthesia care with propofol should be considered in young women, patients with chronic abdominal pain, long-term opiate users, and patients with a history of abdominal surgery, as these factors are

predictors of an inadequate response to moderate sedation.²⁵ One study reported a completion rate of 98% in 119 patients upon repeat colonoscopy with anesthesia assistance.²⁶

Endoscopic Techniques

A comprehensive review of tips for achieving a successful colonoscopy outlined specific techniques for loop reduction and problem-solving in an algorithmic fashion.²⁷ Because the left colon is the most difficult segment of the colon to navigate during insertion, the endoscopist should begin a colonoscopy by anticipating altered sigmoid anatomy and reduce the loops before advancing beyond the splenic flexure. Narrowing and angulations of the sigmoid colon may cause difficulty if an adult colonoscope is inserted; therefore, a pediatric colonoscope or gastroscope may be a better choice, as these devices have a compact arc that can overcome tight turns and allow for easier progress through the sigmoid, and are more flexible compared to standard colonoscopes.²⁷

Abdominal Pressure and Position Changes

The development of looping can cause pain and discomfort to the patient and make advancement of the colonoscope difficult. Abdominal pressure and position changes can be helpful when loops develop. The use of nonspecific abdominal pressure, specific pressure near the tip of the colonoscope, and position changes with the patient are encouraged in a stepwise manner. A study evaluating pressure technique found that nonspecific abdominal pressure was initially more successful on the left side of the colon (78%) than on the right side of the colon (47%; $P < .0005$), and as the colonoscopy progressed, specific pressure became more useful on the right side.²⁸ If abdominal pressure was not beneficial, changing the position of the patient from left lateral to supine was effective in 68% of patients with difficult colonoscopy.²⁸

Water Techniques

Water techniques, such as water exchange and water immersion, are 2 colonoscopy methods that utilize infusion of water to distend the lumen of the colon. With water exchange, water is suctioned during insertion, whereas with water immersion, water is primarily suctioned during withdrawal. Infused water during the colonoscope insertion weighs down the left colon, straightening the sigmoid and, thus, facilitating advancement. Suctioning the air minimizes angulations, and the colon shortens.^{29,30} A prospective study of 44 unsedated patients with a history of abdominal surgery compared the use of water immersion to air insufflation.³¹ Patients who underwent water immersion had a higher rate of cecal intubation (86% vs 50%; $P = .0217$).³¹ Water exchange

colonoscopy has certain advantages over conventional air insufflation colonoscopy, including less discomfort,³² less or no sedation,^{33,34} and less need for external abdominal pressure and change in patient position to complete the examinations.³⁵

Carbon Dioxide

Carbon dioxide can be used for colonic insufflation to prevent prolonged colonic distention and discomfort.³⁶ Carbon dioxide is rapidly absorbed through the intestinal mucosa, transported by blood to the lungs, and exhaled. A meta-analysis has shown a significant reduction in abdominal pain during and following the procedure, but no difference was noted in the cecal or ileal intubation rate and time or in the total examination time compared with air insufflation.³⁷ Water methods combined with carbon dioxide have shown significant increase in cecal intubation rate; however, this may be attributed to the water method itself.

Magnetic Endoscope Imaging

The magnetic endoscope imaging (MEI) system Scope-Guide (Olympus Optical) is a technology that offers real-time visualization of the colonoscope shaft in 3-dimensional views. The system helps to identify difficult anatomy, recognize and overcome loops, and apply specific abdominal pressure in the appropriate location. This technology also allows for training on loop reduction skills. A randomized, controlled, prospective study involving 296 patients compared standard colonoscopy to colonoscopy with MEI performed by either trainees or experienced endoscopists.³⁸ Cecal intubation rates were higher (100% vs 89%) and intubation times were shorter (11.8 vs 15.3 min) in the MEI trainee group compared to the standard colonoscopy trainee group. Additionally, shorter intubation times (8.0 vs 9.3 min) were noted with MEI performed by experienced endoscopists.³⁸ A meta-analysis reviewed approximately 2900 patients who underwent MEI or standard colonoscopy.³⁹ Cecal intubation rates were higher with MEI, but no difference was noted in overall cecal intubation times. These benefits were mostly noted among inexperienced endoscopists.³⁹ Currently, the MEI system is recommended primarily for training; however, the system appears promising for improving colonoscopy completion and loop reduction. There is a learning curve in the use of this technology, even for experienced endoscopists, as it involves additional imaging during the procedure.

Management of Incomplete Colonoscopy

The ASGE and the American College of Gastroenterology recommend a cecal intubation rate of at least 90%



Figure 1. A second-generation colon capsule (PillCam, Medtronic) is an alternative endoscopic approach to a failed standard colonoscopy.

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for all colonoscopies and at least 95% in screening colonoscopies.^{5,9} These high rates of colonoscopy completion for effective patient care are quality metrics tied to reimbursement. Management options relate to patient factors, institutional expertise, and available technologies. If a standard colonoscopy is not successful despite the described methods, alternative endoscopic approaches or imaging can be considered. Current options include repeat colonoscopy with or without anesthesia, double-contrast barium enema, computed tomography colonography (CTC), or overtube-assisted colonoscopy. Newer technologies include the colon capsule (PillCam, Medtronic; Figure 1) and the C-Scan Cap imaging system (Check-Cap Ltd; Figure 2).

Repeat Colonoscopy

Repeat colonoscopy can be attempted depending on the reasons for incomplete colonoscopy, and can be performed with different sedation methods, anesthesia assistance, alternate instruments, and different physicians. It is important to customize the bowel preparation and to educate the patient. Of note, deeper sedation means less assistance by the patient. MEI can be considered for repeat colonoscopy.

Imaging

Double-Contrast Barium Enema With the introduction of other imaging technologies, the role of double-contrast barium enema is restricted due to its low sensitivity for adenoma detection; therefore, its use is discouraged. One study suggests adequate visualization with this method in 77% to 94% of patients after incomplete colonoscopy.⁴⁰ In a study directly comparing double-contrast barium enema with repeat colonoscopy for completion of colonoscopy, the polyp detection rate was significantly superior with repeat colonoscopy (34.3% vs 3.6%; $P < .001$).⁴¹

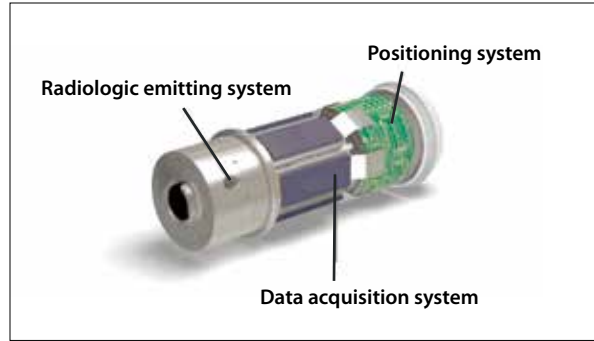


Figure 2. The C-Scan Cap imaging system (Check-Cap Ltd) is a newer technology that provides a different approach to colon imaging.

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Computed Tomography Colonography CTC produces 2- and 3-dimensional images that allow reconstruction of endoluminal images of the colon. Smaller volumes of bowel preparation, as compared to standard colonoscopies, are needed the day prior to the test. Contrast agents are used for stool and fluid tagging, and iodinated or barium contrast is incorporated into the residual fecal matter to differentiate it from polyps. The colon is then insufflated with air or carbon dioxide. CTC is often performed after incomplete colonoscopy. In 546 patients with incomplete colonoscopy due to redundancy and tortuosity who underwent CTC, 13.2% had additional polyps of at least 6 mm in size.⁴² Of these patients, 63% underwent repeat colonoscopy, and it is estimated that the positive predictive value per patient undergoing CTC for masses, large polyps, and medium-sized polyps was 91%, 92%, and 65%, respectively.⁴² The main advantages of CTC are that no sedation is required, a smaller amount of bowel preparation is needed, and it is less invasive than a colonoscopy. CTC also has the benefit of being performed on the same day as the colonoscopy and may be used safely in anticoagulated patients. Disadvantages include lower sensitivity for polyp detection compared to colonoscopy, lack of therapeutic capability, and occasional underdistention of the sigmoid, especially if the endoscopist encounters a difficult sigmoid colon. In experienced hands, and in the appropriate clinical setting, CTC may be a good alternative to conventional colonoscopy and can also provide information on extracolonic findings; however, if the reason for colonoscopy was a positive fecal immunochemical test, then CTC may be inadequate.

Overtube-Assisted Colonoscopy

The concept of overtube-assisted colonoscopy was introduced in the 1980s.⁴³ The overtube helps to straighten the endoscope and the colon upon loop formation and

colonic angulations. Several variations have been developed to decrease mucosal injury and perforations. The currently available overtube endoscopes are the single-balloon enteroscopy (SBE) overtube (ST-SB1, Olympus America) and the double-balloon enteroscopy (DBE) overtube (TS-13140, Fujinon). Spiral overtubes are available for pediatric colonoscopes or enteroscopes (eg, Endo-Ease Discovery SB and Endo-Ease Vista, both from Spirus Medical).⁴⁴

Balloon-assisted enteroscopes initially were created to allow deep insertion of the endoscope into the small bowel. SBE and DBE are used for incomplete colonoscopies and can be used in patients who have risk factors for a difficult colonoscopy. Dedicated colonoscopes using the double-balloon technologies are also available, although their use is limited to availability of these technologies.

Double-Balloon Enteroscopy and Colonoscopy DBE has been available for clinical use since 2003.⁴⁵ It comprises a 200-cm endoscope and an overtube, each with an inflatable latex balloon near its tip. The overtube and endoscope are advanced in sequence with the help of the balloons to pleat the bowel; thus, looping is minimized and the endoscope can advance deep into the small intestine.

The double-balloon colonoscopy, another modality that can be utilized for patients with incomplete colonoscopy, is shorter than the double-balloon enteroscopy, at 152 cm. A Japanese multicenter, prospective trial that included 110 patients with incomplete colonoscopies reported a 100% cecal intubation rate and a median intubation time of 12 minutes.⁴⁶ Subsequently, the same group demonstrated the safety of the double-balloon colonoscopy with no reported complications.⁴⁷ The reasons for incomplete colonoscopies were loop formation, colon angulation, and pain.⁴⁷ Approximately 50% of the patients had abdominal surgery, and 20% had a history of diverticulosis.⁴⁷ The yield of double-balloon colonoscopy for clinically significant lesions was 50% in this patient population.⁴⁷ A smaller study in which 20 patients underwent colonoscopy with the double-balloon enteroscopy for prior incomplete colonoscopy reported successful cecal intubation in 95% of the patients, with a mean cecal intubation time of 28 minutes. No complications were reported.⁴⁸

Single-Balloon Enteroscopy SBE has been commercially available since 2007.⁴⁹ SBE uses an endoscope and an overtube with a silicon balloon at the tip, which, when inflated, anchors it into the small bowel. When the balloon is anchored, the endoscopist pulls the endoscope and the overtube together, allowing the bowel to pleat over the endoscope, thereby reducing the loops that have formed. Once reduced, the endoscope is advanced deeply into the

bowel until resistance is met, at which point the balloon is deflated and the overtube is advanced over the endoscope until it reaches the tip of the endoscope. The balloon is reinflated, and the cycle is repeated.

The single-balloon system has been shown to be useful in difficult colonoscopies. Reports show a 93% to 100% success rate of reaching the cecum, allowing for endoscopic interventions.⁵⁰⁻⁵² Both single- and double-balloon enteroscopes with overtubes can be considered reasonable alternatives after incomplete conventional colonoscopy, with high success rates. Two studies compared the utility of SBE vs DBE in patients with a history of incomplete colonoscopies, and demonstrated high intubation rates.^{52,53} This suggests that DBE and SBE have similar effectiveness in reaching the cecum in patients with prior incomplete colonoscopy.

Both techniques are good options in patients with redundant colons, sharp angulations, or severe diverticular disease because redundant colons and loop formations are easily overcome and fixed angulations can be adequately managed.

Integrated Inflated Balloon

G-EYE (SMART Medical Systems) is a new colonoscopy with an integrated inflatable balloon at the level of the endoscope bending section, which is reusable and reprocessable. The NaviAid inflation system (SMART Medical Systems) is a balloon device that can be inserted through the colonoscopy channel. These balloon systems can be inflated by the endoscopist upon colonoscopy withdrawal to carry out balloon-assisted colonoscopy. The inflated balloon applies a mechanical effect over the mucosal folds, flattening and straightening them, which allows the endoscopist to reach challenging segments. A prospective, single-center study of the use of this device in 47 patients reported a 100% cecal intubation rate, with a mean cecal intubation time of 4.3 minutes.⁵⁴ No major adverse events were reported.⁵⁴ In a multicenter, randomized, tandem colonoscopy study comparing standard colonoscopy with G-EYE balloon colonoscopy, Shpak and colleagues reported that cecal intubation rates were comparable in 106 subjects who completed back-to-back colonoscopy examinations; however, this study was not intended to evaluate patients with incomplete colonoscopies.⁵⁵

Spiral Overtubes

The spiral overtube is a 90-cm, disposable, flexible, plastic tube with a 5-mm soft spiral thread at the insertion tip that is placed over a pediatric colonoscopy or enteroscopy. The insertion phase of spiral endoscopy consists of rotating the device in a clockwise fashion to reach the farthest extent, or until no more pleating of the small bowel over the colonoscopy is possible. The device is withdrawn using

counterclockwise rotation. One study demonstrated that an overtube (Endo-Ease Vista Retrograde, Spirus Medical), together with a pediatric colonoscope or enteroscope, led to a cecal intubation rate of 92% in patients with a redundant colon.⁵⁶ No adverse events were reported.⁵⁶

Colon Capsule Endoscopy

Colon capsule endoscopy (CCE) first generation (CCE-1) was introduced in 2006.⁵⁷ Second-generation CCE (CCE-2) was instituted later.⁵⁸ CCE-2 has two 172-degree angle cameras in each end of the capsule, allowing for 344-degree coverage. The frame rate alternates between 4 to 35 images per second. At present, the main indication for CCE is colon imaging following an incomplete colonoscopy due to technical difficulties beyond poor bowel preparation. A prospective study of 34 patients undergoing CCE due to incomplete colonoscopy demonstrated that CCE passed the most proximal point reached by conventional colonoscopy in 85.3% of patients; this led to a change in clinical decision-making in 58.8% of the patients.⁵⁹ Of relevance, 40% of the procedures were unsatisfactory due to poor bowel preparation.⁵⁹ In another prospective study, Rex and colleagues measured the accuracy of CCE for detecting polyps at least 6 mm in size in an average-risk population.⁶⁰ A total of 884 patients underwent CCE followed by conventional colonoscopy. After adjusting for poor bowel preparation, CCE identified polyps at least 6 mm in size with 81% sensitivity and 93% specificity, and identified conventional adenomas at least 6 mm in size with 88% sensitivity and 82% specificity.⁶⁰ The false-negative findings from capsule analysis were attributed to sessile serrated polyps and hyperplastic polyps in 26% and 37% of patients, respectively.⁶⁰

A prospective, multicenter study utilizing CCE-2 included 96 patients with incomplete colonoscopy.⁶¹ Complete visualization was reached in 69 patients (71.9%). In the 20 patients out of the 27 in whom CCE-2 did not reach the rectum, the capsule passed the colonic segment that was explored in the previous colonoscopy, leading to complete visualization of the colonic mucosa in 92.7% of the patients.⁶¹ A recent meta-analysis of 14 studies evaluated the accuracy of CCE-1 vs CCE-2, with 7 studies in each arm.⁶² The analysis showed a sensitivity of 58% and 54% for polyps larger than 6 mm and 10 mm, respectively, for CCE-1, and a sensitivity of 86% and 87% for polyps larger than 6 mm and 10 mm, respectively, for CCE-2.⁶² These results translate into a clinically relevant improvement of the capsule.

Advantages of CCE include lack of exposure to radiation and discomfort of bowel distension from air insufflation. However, for successful CCE, adequate bowel preparation is an important factor and remains intensive. In one study, patients needed 4 liters of polyethylene glycol

prior to the ingestion of the capsule as well as the use of additional laxatives and prokinetics at various times.⁶⁰ In addition, the optimal training and learning curve associated with CCE have yet to be defined. Another significant limitation is missed polyps.

C-Scan Cap Imaging System

The C-Scan Cap imaging system consists of an ingestible capsule that emits and detects ultra low-dose radiation. The patient ingests the capsule along with a small amount of a radio-opaque contrast agent without needing a bowel preparation while continuing with his or her daily activities. The capsule generates a 3-dimensional reconstruction of the colonic lumen for detection of polyps. Preclinical and clinical testing in healthy volunteers has demonstrated safety and feasibility with a mean radiation dose estimated at 0.04 mSv.⁶³ Projected sensitivity is 80% for cancer and 50% for large polyps.⁶⁴ However, the diagnostic performance of this system is still uncertain. Additionally, several imaging reconstruction-related features, such as measurement of polyp size and colon diameter, still need refinement and validation.

Robotic Colonoscopes

Endotics (Era Endoscopy s.r.l.) is a self-propelled robotic colonoscope consisting of a disposable probe and a console maneuvered from a workstation. The disposable probe has a head with light, water, and air systems, as well as a flexible body with clamps that allow advancement similar to a worm. The endoscopist manages the workstation and can steer 180 degrees in any direction. A study by Tumino and colleagues assessed cecal intubation in 102 patients with previous incomplete colonoscopy and found that cecal intubation was successful in 93.1% of cases.⁶⁵ No adverse events were noted. No other clinical studies have been performed, as this is a fairly new technology that requires clinical validation.

Summary

Complete colonoscopy is essential to ensure a high-quality examination of the colon. Cecal intubation rates greater than or equal to 90% are recommended as a quality benchmark for colonoscopy.^{5,9} In approaching this issue, it is important to first anticipate when a colonoscopy may be difficult. Focusing on bowel preparation techniques prior to the procedure and using appropriate sedation and adjunct techniques such as water immersion, abdominal pressure, and patient positioning during the procedure can overcome many challenges of colonoscopy. If standard colonoscopy is unsuccessful, leading to incomplete colonoscopy, then endoscopic alternatives such as DBE and other overtube technologies have reported good

success for colonoscopy completion. Imaging modalities are also available and can be performed on the same day as colonoscopy. Newer technologies in the form of capsules and robotics may be alternative options in the future; further clinical studies are needed to assess their efficacy and success rates.

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