

## Review

# The Dirty Side of Colonoscopy: Predictors of Poor Bowel Preparation and Novel Approaches to Overcome the Shortcomings

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## Abstract

Colonoscopy significantly reduces the incidence and mortality of colorectal cancer. The quality of bowel preparation plays a direct role in the efficacy, safety, and economic burden of colonoscopy. High-quality bowel preparation is essential for meeting colorectal cancer screening goals during colonoscopy, and consideration of risk factors for inadequate cleansing can help optimize the preparation regimen. If preparation is inadequate, there are salvage methods available to improve success. A number of patient-specific factors, comorbidities, and medications can contribute to inadequate bowel preparation. Age, gender, and socioeconomic status are all associated with poor quality preparation. Comorbidities such as chronic constipation, diabetes mellitus, neurological and neuropsychiatric disorders, history of gastrointestinal surgery, and cirrhosis, as well as the use of medications such as opiates and tricyclic antidepressants can also affect preparation quality. Improvement of preparation depends on the specific factor, but can involve variation in lavage regimen, the use of adjunctive agents, and medication management. For preparation deemed inadequate during colonoscopy, there are techniques described to intra-procedurally provide more cleansing. In addition, for patients requiring same-day salvage preparation or are at high risk for poor lavage, there are two technological options that provide increased preparation quality.

Keywords: colonoscopy preparation; predictors of poor bowel preparation; quality colonoscopy, adenoma detection

## Introduction

Colorectal cancer (CRC) is one of the leading causes of cancer-related death both in the United States [1] and worldwide [2]. The most recent epidemiological data estimates the annual CRC-related mortality rate to be 50,830 in the United States [1] and 693,900 globally [2]. Of increasing concern is the rising trend of CRC incidence and mortality amongst adults younger than 50 years of age in the United States [3-5], with data from the United States National Cancer Database (1998-2007) suggesting an overall percentage increase per year of 2.7% and 3.9% for colon and rectal cancer, respectively, amongst adults younger than age 50 [6].

Colonoscopy has been shown to effectively reduce the

incidence and mortality of CRC [7,8]. The efficacy of colonoscopy is directly linked to an adequate bowel preparation. While studies have not demonstrated prep quality to have an impact on cancer detection rates [9], there has been indisputable evidence linking increased adenoma detection rates (ADR) to a 'good' or 'excellent' bowel prep [9-11]. Missed lesions during colonoscopy, largely in part due to suboptimal bowel preparations, are thought to account for a significant portion of interval cancers [12]. Decreased detection rates are associated with poorer outcomes. A 2014 study found that risk of interval cancer decreased by 3% for every 1% increase in adenoma detection rate, and risk of fatal interval colorec-

tal cancer decreased by 5% [13]. Higher adenoma detection rates also were associated with decreased advanced-stage disease.

Additionally, inadequate bowel preparations place patients at an increased risk of procedure-related adverse events. Lastly, there is a significant cost burden associated with the consequences of an inadequate bowel preparation (i.e. repeated procedures, shortened intervals, etc.). Thus, an adequate bowel preparation for colonoscopy is a must. The choice of bowel prep and patient education to ensure adherence is essential and is beyond the scope of this review. This review will focus on patient-specific factors, co-morbid conditions, and concomitant medication use that increases the risk for a suboptimal preparation.

### **The Burden of Inadequate Bowel Preparations Decreased adenoma detection rates**

The link between colonoscopy preparation and the detection of suspected neoplasia been described in the literature for nearly 15 years [14,15]. Both retrospective and prospective data have consistently demonstrated an increased adenoma miss rate of greater than 40% and an increased advanced adenoma miss rate of greater than 35% [16-20]. Furthermore, objective evidence i.e. Boston Bowel Preparation Scores (BBPS) of 2 or 3, which equate to intermediate- and high-quality preparations respectively, in all segments have significantly improved ADR when compared to a BBPS of 0 or 1 in all segments (low-quality preparation) [16,21].

There is some debate as to whether there is any clinically significance between intermediate and high-quality preparations. A study evaluating 438 male patients who underwent screening or surveillance colonoscopies with a subsequent repeat examination within 60 days by a different blinded endoscopists, totaling 1,161 colon segments found a 10% absolute increase in adenoma miss rate in patients with BBPS of 3 or 2 compared with 1 (5.6, 5.2 vs 15.9, respectively) [16]. Recent studies have additionally demonstrated the rate of detection for sessile serrated polyps (SSPs) to increase with improved preps [21]. It is important to recognize that the higher rate of detection for SSP was not due to the detection of diminutive polyps; rather, the majority of detected SSPs were greater than 5 mm in size.

These studies highlight the importance of high-quality preparation. Despite early evidence demonstrating little difference between intermediate- and high-quality preparation, emerging evidence suggests that a higher quality preparation is required to detect SSPs and right-sided neoplasia.

### **Increased procedure-related risks**

Patients with inadequate bowel preparations are more likely to have longer procedure times when compared to patients with an adequate preparation [22]. This inherently places patients at an increased risk, both from a proce-

dural standpoint as well as from an anesthesia standpoint. Electrocautery and argon plasma coagulation (APC) is commonly used during colonoscopy for polypectomy, tissue ablation hemostasis. A complication due to these thermal interventions is gas explosion, which is exceedingly rare but can be life-threatening. Gas explosion occurs as a result of: (1) presence of combustible gases produced by fermentation non- absorbable carbohydrates by commensal colonic bacteria (e.g. hydrogen and methane), (2) presence of a combustive gas (e.g. oxygen), and (3) application of a heat source (electrocautery or APC) [23,24]. Studies have demonstrated that an adequate bowel preparation significantly reduces the levels of both hydrogen and methane to far below the minimal explosive concentration, thus stressing the importance of an adequate bowel preparation in terms of patient safety [25].

### **Increased economic burden**

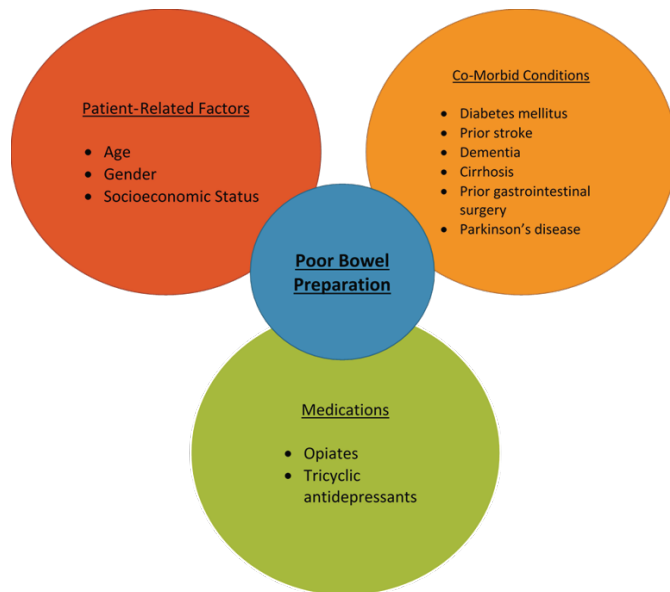
There is significant cost associated with a poor bowel preparation, with both direct and indirect cost assumed by both the patient and the endoscopist. A recent single-center study based in a university setting retrospectively evaluated the outcome of colonoscopies performed over a 3-month period [26]. They subsequently changed patient instructions and the pre-assessment of the bowel preparation used and repeated the same measurements over 3 different cycles on 3 different occasions. By simply altering these pre-procedure factors, the single center saved an average of £150,000, largely owing to the reduction in number of repeat procedures due to poor prep.

Another study evaluated intra-procedural time spent suctioning fluid and washing the colon in order to adequately visualize the mucosa in 200 consecutive patients in both private practice and university hospital locations [27]. Additionally, they prospectively asked colonoscopists to designate exams that they felt should be repeated at a shortened interval because of a suboptimal preparation. Cost analysis found that suboptimal bowel preparations resulted in a 12% and 22% increase in costs at the private and public university hospital, respectively. The effect of adequate preparation on adenoma detection rate has broader economic implications as well. ADR has become a measure for merit-based payment for colonoscopic procedures, first included as a measure within the Physician Quality Reporting System (PQRS) under the Centers for Medicare and Medicaid services in 2015 and was subsequently transitioned into a measure within the Merit-based Incentive Payment System (MIPS) that replaced PQRS [28].

### **Patient-Specific Factors**

Adverse outcomes due to inadequate bowel preparation include poorer patient outcomes, lower ADR, and increased economic burden. Factors that may predispose patients to increased risk of inadequate bowel preparation include sociodemographic factors, surgical history,

specific comorbid medical conditions, and concomitant medications (Figure 1).



**Figure 1.** Factors impacting bowel preparation.

### Age

Age is a frequently cited factor in predicting inadequacy of bowel preparation [29-31]. A study reporting on 300 colonoscopy patients found the mean age of those with inadequate preparation to be 66.2 versus 62.5 in patients with adequate preparation [29]. This was statistically significant both univariate analysis and remained significant in multivariate analysis along with factors such as polypharmacy and interpreter requirement.

Other studies suggest that age has confounding elements in predicting preparation efficacy. An analysis of factors affecting different age groups in colonoscopy preparation observed three age groups: nonagenarians, septuagenarians, and quinquagenarians [30]. Nonagenarians failed colonoscopy at statistically significantly greater rates than the other two groups, primarily because of poor preparation or tortuous colons. In overall multivariate analysis, decline in mental and functional status were the only significant predictors of inadequate bowel preparation. Decreased functional state is likely a key contributor to poor adherence to the preparation regimen, due to decreased patient capacity to adhere to the regimen or difficulty in caregiver adherence to the regimen.

### Gender

Many studies have reported male sex to be an independent predictor of poor bowel preparation [29, 32-34]. It is unknown if there is a physiological mechanism that contributes to this association, and this effect is currently attributed to gender differences in perceptions of medical care and decreased utilization of and adherence to medical care by male patients that have been demonstrated in numerous prior studies [35]. This is further supported by literature that excludes non-adherent patients from analysis. When these non-adherent patients are excluded, there

is no significant difference in efficacy of preparation between male and female patients [31].

### Socioeconomic status

Several socioeconomic factors affect the quality of bowel preparation. Lower education status is generally identified as being associated with poor preparation, with some variation between studies [36]. Other literature has demonstrated an association with low health literacy and poor preparation [29]. Having Medicaid as primary insurer and requiring an interpreter, both factors affecting health literacy, have been shown to be significant predictors of poor preparation quality [29].

### Co-morbidities Impacting Bowel Preparation

#### Chronic constipation

Chronic constipation (CC) is a condition marked by symptoms of constipation for a period of greater than three months and can be secondary to disease processes or medications, or a primary problem [37]. CC has been associated as an independent risk factor for poor bowel preparation [32,36]. But there are multiple factors that may contribute to inadequate preparation in patients with CC, including etiology.

Primary causes of chronic constipation can be divided into functional constipation, slow-transit constipation, and defecation disorders [38]. Functional constipation disorders, which include chronic idiopathic constipation (CIC) and constipation predominant irritable bowel syndrome (IBS-C) are marked by a typically normal transit time and lack of other constipation inducing etiology [38,39]. Typically, constipation is defined at three months of bowel movements with over 25% involving over two or more symptoms including straining, Bristol 1-2 stools, tenesmus, sensation of obstruction, requirement of manual manipulation for defecation, and fewer than three bowel movements per week [40]. CIC is distinguished by the presence of these symptoms with a normal transit time without meeting the criteria for IBS-C. IBS-C is similarly distinguished by symptoms of constipation, including Bristol 1 or 2 stool, as well as abdominal pain associated with defecation [40]. While there appears to be an overlap in symptoms of both disorders, MRI comparison with laxative use comparing CIC versus IBS-C patients found larger colonic volume in CIC patients both at baseline and after laxative ingestion [41]. Additionally, IBS-C patients experience a temporary relative increase in motility within subsequently returned to a similar rate as CIC patients, which extended time to first bowel movement for the CIC patients [41]. This change in motility likely impacts the success of preparation.

Slow-transit constipation, referred to as colonic inertia in severe state, is marked by a decrease in number of bowel movements as well as rate of colonic motility [42]. It is presumed to be caused by a decreased number of interstitial cells of Cajal, and subsequent, dysmotility due to decreased gut automaticity [42]. If motility is affected,

specifically colon transit time, patients are significantly more likely to present with poor preparation. One study found that patients with slow colonic transit time had a 26% inadequate bowel preparation rate compared to 9.4% with normal transit time, among chronically constipated patients [43]. Assessing frequency of bowel movements prior to preparation have also been found to affect risk of poor bowel preparation, and patients with fewer than three bowel movements per week were five times more likely to have inadequate preparation than those with more frequent bowel movements [44].

Defecation disorders, including dyssynergic defecation, involve an anatomical or behavioral cause leading to inadequate evacuation, and retention [40]. Patients with dyssynergic defecation typically have a physiological or psychological trigger that causes spasm of the anal sphincter during defecation [38]. Dyssynergic defecation can also lead to increased transit time, worsening symptoms, and increasing risk for inadequate bowel preparation [45].

Secondary causes of chronic constipation include medication effect and constipation secondary to neurological disorders, metabolic disorders, myogenic disorders, and obstructive causes including stricture and colorectal cancer [38].

Neurological causes that may contribute to constipation are decreased pacemaker activity of interstitial cells of Cajal, decreased central autonomic output, and pelvic nerve dysfunction leading to loss of inhibitory reflex [46].

Metabolic disorders that may cause constipation include diabetes mellitus, in which complications can decrease peripheral nerve activity [46], and hypercalcemia, in which increased activation of calcium-sensing receptors decrease gastrointestinal smooth muscle activity [47].

Hypothyroidism is also associated with decreased global gastrointestinal activity, including increased transit time [48].

Myogenic disorders are also associated with constipation. 47% of patients with Duchenne muscular dystrophy have been reported to have chronic constipation [49]. Decreased muscle tone and activity can both contribute to decreased motility or ability to defecate and can worsen symptoms [50].

Despite the high risk for poor preparation among patients with CC, some studies have evaluated possible alternatives and improvements to increase quality of preparation. One study compared PEG (polyethylene glycol) versus sodium phosphate (NaP) lavage and found no difference in tolerance, but a statistically significant improvement in preparation quality [51]. Transient hyperphosphatemia in some patients within the study reinforced the need for avoidance in patients with renal disease. Another study evaluated the use of bisacodyl as an addition to either PEG or NaP lavage and found 95% bowel cleansing rates with NaP and bisacodyl [52].

The use of probiotic agents containing *Bacillus subti-*

*lis* and *Streptococcus faecium* for two weeks prior to NaP lavage in constipated patients and found a statistically significant improvement in preparation rate with addition of the probiotic [53].

### Diabetes Mellitus

Diabetes mellitus (DM) is frequently associated as a risk factor for poor bowel preparation, with some citing up to 38% having inadequate preparation [31,36,54-55]. The mechanism for poor bowel cleansing is believed to result from poor motility, as 60% of diabetic patients complain of constipation [56], though there have been multiple explanations posited.

Some studies argue that the decreased motility is due to enteric autonomic neuropathy [56,57]. A study comparing colon myoelectrical and motor activity in diabetic patients found worsening to absent post-prandial gastrocolic response corresponding with severity of constipation [57]. It has also been demonstrated that decreased motility may be a direct result of hyperglycemia [58].

However, other studies have found a lack of association between insulin dependence, blood sugar control, or presence of peripheral neuropathy and quality of preparation among diabetic patients, despite being at higher risk for inadequate bowel preparation [59].

As a result of such high risk of inadequate preparation being attributed to the diagnosis of DM, multiple studies have evaluated options and alternatives for improvement of lavage. One study evaluated the addition of patient education, low-fiber diet, and adjustment of anti-hyperglycemic medication to conventional split-dose lavage, resulting in reduction from 20% to 7% inadequate preparation [60]. Another study evaluated for addition of lubiprostone, a chloride channel activator that increases luminal water content and secondarily increases motility, to single dose PEG and found a trend toward improved preparation with lubiprostone that was not statistically significant [61]. A third study that evaluated conventional PEG preparation, split-dose PEG, and split-dose PEG preceded by bisacodyl found a trend towards split-dose PEG and split-dose PEG with bisacodyl to improved preparation compared to conventional PEG that was not statistically significant [62].

### Neurological and Neuropsychiatric Disorders

Decline of mental status has been observed to be a contributor to decreased patient adherence, regardless of etiology [30]. Stroke and dementia were both demonstrated to be independent predictors of poor bowel preparation in a study on 649 patients undergoing colonoscopy [32]. Although literature specifically identifying the role of neurocognitive disease in affecting preparation is sparse, a meta-analysis evaluating 12 studies that included history of stroke or dementia with relation to bowel preparation observed a weighted odds-ratio of 2.09 towards such a history as a predictor of poor quality of preparation. [36].



Impairment of gastrointestinal motility leading to constipation has been observed in both the acute post-stroke stage [63,64] as well as chronically [65,66]. This can manifest through direct injury to the pontine defecation reflex center, resulting in impaired autonomic coordination and decreased motility as well as muscle relaxation that can lead to constipation and fecal impaction [67]. Alternatively, this motility impairment can occur as a result of the conditions and environment of stroke patients. Dietary changes, immobility, and medication use can all alter gut motility [65], and may play a role in altering success of bowel preparation.

Neurodegenerative diseases, including Parkinson's disease have also been observed to be associated with inadequate bowel preparation. Parkinson's disease manifests in many areas of the gastrointestinal tract, including through decreased colon motility [68]. In fact, the initial description of the condition by James Parkinson describes "torpid" bowels requiring "stimulating agents [69]." Disease progression leads to the appearance of alpha-synuclein containing bodies within both the central and enteric nervous systems [70,71]. Presence of alpha-synuclein bodies within the myenteric plexus has been found to be correlated with worsening constipation [72], though there appears to be no myenteric neuronal loss [73]. This dysmotility could provide a basis for explanation for the decreased likelihood for adequate preparation seen in one study [74]. While options for improving bowel preparation Parkinson's disease have not been studied, adequate treatment of the disease and gastrointestinal symptoms are likely important to success.

Many psychiatric illnesses are associated with impaired gut motility [75], and psychiatric triggers, such as anxiety about the preparation process and procedure, have been shown to decrease tolerance of bowel lavage regimens [76]. In combination, both factors can contribute to inadequate adherence and quality of bowel preparation. Treatment of gastrointestinal symptoms, avoidance of medications that induce constipation when possible, and patient education and reassurance are important ways to improve tolerance of and quality of preparation.

### **Prior Gastrointestinal Surgeries**

Surgical intervention on the gastrointestinal tract can affect the nature and speed of gastrointestinal motility. One study observed decreased quality of preparation with both history of appendectomy as well as colorectal resection [31]. Inadequate preparation in both procedures were found to be statistically significant in univariate and multivariate analysis, with odds ratios of 4.6 and 7.5, respectively.

Other surgical procedures were not found to affect preparation quality except for hysterectomy, which was associated with poorer preparation in both univariate and multivariate analysis. A meta-analysis of bowel preparation studies found an adjusted odds ratio of 1.15 towards inadequate preparation with any prior abdominal surgical

history, though this was a pooled analysis that did not separate between procedure type [36].

Other factors can impact the quality of bowel preparation. Bariatric surgery, including Roux-en-Y gastric bypass, results in a retained pouch that serves as a new stomach that is smaller than the patient's initial stomach, in order to limit the patient's oral intake and lead to weight loss [77]. This can subsequently lead to problems when large volume intake is otherwise recommended or necessary, including the intake of bowel lavage for colonoscopy preparation. Current guidelines recommend "low-volume preparation or extended time delivery for high-volume preparations [14]." Patients that have undergone gastric bypass are also at risk for developing dumping syndrome, and sugar intake should be limited during preparation [78].

### **Cirrhosis**

Presence of cirrhosis as a risk factor for inadequate preparation is frequently measured in studies evaluating colonic lavage because of the many factors associated with cirrhosis that could lead to inadequate preparation. Patients with cirrhosis frequently have decreased gastrointestinal motility [79], and the cause of inadequate bowel preparation appears to be multifactorial.

Autonomic neuropathy has been described in several studies to increase transit time in cirrhotic patients [80,81]. This can further lead to or worsen metabolic derangements and hepatic encephalopathy [82]. Additionally, small intestinal bacterial overgrowth, while traditionally seen as a consequence of decreased motility [83], may also play a role in decreasing motility. This can be seen in the treatment of cirrhotic patients with antibiotics leading to a subsequent improvement in gut motility [84]. Finally, isolated portal-hypertension in rat models has been demonstrated to increase gastrointestinal transit time and may play a role in worsening colon preparation quality [85].

The true relationship of cirrhosis and inadequate bowel preparation remains unclear [36]. Some studies strongly argue that cirrhotic patients have significantly higher rates of inadequate preparation [86,87]. Unfortunately, data are generally limited by the low number of patients with cirrhosis within bowel preparation studies. A prospective study found an odds-ratio of 5 towards poorer preparation in patients with cirrhosis (n=61), while a retrospective study that included 71 patients with cirrhosis found no significant difference in adequacy of preparation [74,88]. Meta-analysis of 12 studies yielded a statistically significant pooled odds ratio of 1.71 towards inadequate preparation in patients with cirrhosis [36].

### **Concomitant Medications Impacting Bowel Preparation**

#### **Opiates**

Many medications are believed to impact the quality of bowel preparation. Opioids have traditionally been

considered to negatively affect preparation quality due to their effect on mu-, delta-, and kappa- receptors within the myenteric plexus that directly lead to decreased motility [89]. Additionally, morphine acts centrally to increase sympathetic activation of alpha-2 receptors within the enteric nervous system that lead to subsequent inhibition of motility [89].

There are several studies demonstrating the negative effects of opioid usage on the quality of preparation. A retrospective analysis including 223 patients using opioids found that opioid usage increased risk of inadequate preparation and that this effect was dose-dependent, with high-dose opioid users having higher risk than those using lower doses [90]. This effect also seems to be age-dependent. Opioid use is often associated with older age in colonoscopy patients [36]. When age is removed as a confounding factor, the effect size of the impact of opioids on preparation quality decreases [36].

### *Tricyclic Antidepressants*

While tricyclic antidepressants function primarily through blockade of serotonin and norepinephrine transporters, they have significant other inhibitory actions that lead to a broad array of side-effects, including gastrointestinal effects [91]. The use of tricyclic antidepressants can affect the quality of bowel preparation through anti-cholinergic effects blocking enteric muscarinic receptors, causing reduction in gastrointestinal motility [32, 90]. Other analyses have found a gender-based heterogeneity with use of this class of medication. Meta-analysis has demonstrated that the negative effect of tricyclic antidepressants on bowel preparation is stronger in female than male patients, with odds-ratios of 2.61 versus 1.41, respectively [36]. It is also possible that the nature of the underlying disease may contribute to nonadherence to the preparation regimen, and this should be considered in optimizing preparation.

### **Novel Approaches to Overcome Poor Preparations**

Pre-procedurally, if there is brown liquid or stool reported following completion of the preparation regimen, there is a 54% probability of inadequate preparation when colonoscopy is performed [92]. When patients have a failed colonoscopy due to inadequate preparation, 23% are likely to have a failed subsequent colonoscopy for inadequate preparation at a later date [93]. In contrast, next-day colonoscopy following further oral purgative had a decreased likelihood of failed preparation with an odds-ratio of 0.31 [93]. In this scenario, it is possible to improve workflow and decrease need for a repeat procedure by preparing the bowel with large-volume enemas or oral purgatives prior to next-day colonoscopy, as is consistent with United States Multi-Society Task Force recommendations [14].

While there have been reports of intensive preparation regimens for repeat colonoscopy in patients with inadequate preparation at index colonoscopy, salvage

preparation can be advantageous in that it may eliminate the need to reschedule a procedure to a later date and may improve ADR and other clinically relevant parameters in patients who do not achieve adequate bowel preparation [94].

For sedated patients in which preparation has been deemed inadequate after start of the procedure, three techniques have been described for salvage. The first involves insertion of the colonoscope as far proximal as possible with either a phosphate enema followed by a bisacodyl enema or two phosphate enemas [95]. The second technique involves usage of PEG at the hepatic flexure [96]. A third technique involves application of a sodium phosphate solution to the proximal part of an unclean colon segment [97]. All three techniques conclude with recovery from sedation and usage of the bathroom for further evacuation prior to repeat colonoscopy and have reported adequate success rate. However, a comparison study of PEG enema versus additional oral PEG and same-day repeat procedure following inadequate preparation found improved success with additional oral preparation compared to enema [98].

Recently, high technology options have entered the market recently for same-day or salvage preparation, promising increased patient satisfaction and comfort in addition to improved ADR and other clinical benchmarks while reducing the financial and temporal cost to the patient and healthcare providers.

HyGIeaCare (HyGIeaCare, Inc., Austin, TX) is a Class II FDA approved device for standard colon prep that is available at several centers. The system utilizes a rectally inserted nozzle with a slow infusion of water over that is gravity drained, and the process is typically completed within an hour. Patients are placed on a seat located above a sanitized basin during this process and irrigation continues until effluent is deemed adequate (Figure 2). More than 10,000 patients have been prepped to date with zero severe adverse events, and physicians have reported 97% patient prep adequacy in patient reports [99]. The system has also received positive patient feedback, with 94% of patients stating that they would choose irrigation for their next preparation [100]. Same-day salvage preparation in 24 patients with 8-16 gallons of water, with HyGIeaCare yielded 88% percent of patients achieving adequate preparation [101].

The Pure-Vu system (MOTUS GI, Tirat Carmel, Israel) is a sleeve for standard scopes that is marketed for salvage preparation. It provides local enema and evacuation cleansing and can be advanced along with the colonoscope. The system contains two large evacuation ports and multiple irrigation jets and allows for polypectomy without obscuring visibility (Figure 3).

The accessory is convenient but expands the shape of the head of the colonoscope, reducing its flexibility and changing the tactile sense of resistance— which may represent an encumbrance that could extend total procedure time. The water pressure of Pure-Vu is up to 23 psi which



**Figure 2.** The HyGleaCare system features a reclined seat located above a sanitized basin. A nozzle is inserted rectally to provide continuous low-pressure irrigation, which is evacuated until lavage is complete.

adds to risk of adverse event in brittle or unhealthy colon. A swine study with Pure-Vu reported 100% adequate preparation (n=35), followed by a human study in 2016 (n=50), with 98% adequate preparation from a baseline of 31% [102,103].

### Conclusion

Inadequate bowel preparation for colonoscopy is associated with poor health outcomes and increased cost to both the patient and the healthcare system. The likelihood of adequate preparation can be identified by specific risk factors, including patient specific factors, comorbidities, and medications. However, there are options for improving the likelihood of successful in patients with risk factors that may affect their preparation quality, as well as options for salvage if preparation is deemed inadequate on the day of the procedure.

### Abbreviations

CRC: Colorectal Cancer; ADR: Adenoma Detection Rate; BBPS: Boston Bowel Preparation Score; SSP: Sessile Serrated Polyp; APC: Argon Plasma Coagulation; PQRS: Physician Quality Reporting System; MIPS: Merit-based Incentive Payment System; CC: Chronic Constipation; CIC: Chronic Idiopathic Constipation; IBS-C: Constipation Predominant Irritable Bowel Syndrome; PEG: Polyethylene Glycol; NaP: Sodium Phosphate; DM: Diabetes Mellitus.

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### Conflicts of Interest

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**Figure 3.** The Pure-Vu system sleeve fits onto standard colonoscopes for intraprocedural lavage. The hydrophobic sleeve features two large evacuation ports that are centrally located, and multiple small irrigation jets that are located peripherally.

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