Article published online: 2022-04-14

Efficacy and tolerability of colonoscopies in overweight and obese patients: Results from a national database on gastrointestinal endoscopic outcomes

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Authors
Monica Passi, Farial Rahman, Christopher Koh, Sheila Kumar

Institution
Digestive Diseases Branch, National Institute of Diabetes & Digestive & Kidney Diseases, National Institutes of Health, Bethesda, Maryland, United States

submitted 26.1.2021
accepted after revision 17.9.2021

Bibliography
Endosc Int Open 2022; 10: E311–E320
DOI 10.1055/a-1672-3525
ISSN 2364-3722

Georg Thieme Verlag KG, Rüdigerstraße 14, 70469 Stuttgart, Germany

Corresponding author
Dr. Monica Passi, National Institute of Diabetes and Digestive and Kidney Diseases, National Institute of Diabetes and Digestive and Kidney Diseases, 10 Center Drive, 20892 Bethesda, Maryland, United States
mpassi305@gmail.com

Supplementary material is available under https://doi.org/10.1055/a-1672-3525

ABSTRACT

Background and study aims Gastroenterologists are encountering a rising number of obese patients requiring colonoscopy. Existing literature regarding colonoscopy outcomes in this population is scant and conflicting. We analyzed a nationwide cohort of patients to identify the effects of body mass index (BMI) on colonoscopy success, efficacy, and tolerability.

Patients and methods The Clinical Outcomes Research Initiative (CORI) endoscopic database was queried for all colonoscopies in adults between 2008–2014. Patients were stratified into four cohorts based on BMI classification for comparison. Multivariable analysis was performed to identify the effect of BMI on procedure outcome, efficacy and tolerability.

Results Of 41,401 procedures, 27,696 met study inclusion criteria. Of these, 49.4 % were performed for colorectal cancer screening, most commonly under anesthesia directed sedation. Patient discomfort was the reason for an incomplete colonoscopy in 18.7 % of all cases, and more frequent among the overweight and obese cohorts. An inadequate bowel preparation was most common in the class III obesity cohort. Compared to the normal BMI group, a BMI ≥ 30 and < 40 kg/m^2 was associated with an increased odds of an incomplete colonoscopy ($P = 0.001$ for overweight, $P = 0.0004$ for class I/II obesity), longer procedure ($P < 0.05$ for all) and poorer tolerance ($P < 0.0001$ for class I/II obesity, $P = 0.016$ for class III obesity). Anesthesia-administered sedation was more commonly used than endoscopist directed sedation amongst the obese cohort compared with the normal BMI cohort ($P < 0.0001$).

Conclusions Endoscopists should consider the increased odds of incomplete colonoscopy, longer procedures, and poorer tolerance when performing colonoscopy in obese patients to improve clinical management and procedural outcome.

Introduction

Currently, more than one-third of US adults are obese, and the prevalence of obesity is projected to exceed 40 % by 2030 [1–3]. Obesity is a well-established, independent, modifiable risk factor associated with an increased risk of adenomas, advanced adenoma recurrence and colorectal cancers (CRC) – the third leading cause of cancer and cancer death worldwide [3–6]. In

2012, 17.7 % of all colorectal cancer cases (85,000) were attributable to excess body mass index (BMI) [7]. The rising prevalence of obesity worldwide is regarded as a major contributor to the increasing prevalence of CRC and is estimated to increase the risk of CRC by 60 % and CRC mortality by 90 % [8]. In light of the growing obesity epidemic, gastroenterology providers nationwide have encountered an increasing number of overweight and obese patients requiring colonoscopies.

Screening colonoscopies can reduce the incidence and mortality from CRC by allowing for early detection of pre-malignant precursor lesions. However, studies have shown that CRC screening participation rates in individuals with obesity are inferior to those with a normal BMI [9]. Prior studies have alluded to both patient and provider-associated barriers including concerns related to bowel preparation, modesty, pain and embarrassment. Alarmingly, failure of physicians to recommend screening colonoscopies in obese patients has also been identified, possibly due to perceived procedural risks, less time for preventive counseling due to competing care demands and obesity-related discrimination [1, 9].

Despite advances in gastrointestinal endoscopy over the past decade, colonoscopies in obese patients represents a challenging issue. Certain endoscopic techniques and maneuvers normally required during the exam (i. e. patient repositioning, application of abdominal pressure) are more difficult to perform on obese patients. In addition, several studies have identified obesity as an independent predictor of inadequate bowel preparation, thereby increasing the risk for missed lesions and procedural complications, need for repeat procedures, and increased overall healthcare costs [10]. Furthermore, there is an increased risk for sedation-related cardiopulmonary complications among overweight and obese patients undergoing propofol-based deep sedation [2, 8, 11]. Consequently, for these patients, most practices require endoscopic exams for obese patients to be strictly under monitored anesthesia care (MAC) [12]. Nonetheless, data on the appropriate sedation approach during endoscopy for obese patients remains sparse and to date, no study exists assessing the safety and efficacy of performing endoscopy under moderate sedation in the obese population [12–15].

A limited number of prior studies have compared the effect of BMI on success, safety, tolerance and efficacy of colonoscopy. Existing literature on this topic have been studies performed outside the US, most of which are single-center analyses of relatively small patient cohorts, and a number of which were survey-based, thus lacking generalizability and reliability [9, 16]. Among gastrointestinal endoscopy literature using national data, no study thus far has investigated the effects of BMI and obesity on procedural and sedation-related variables during colonoscopy.

The national endoscopic database (NED) contains procedural data collected by the clinical outcomes research initiative (CORI) from 2000 to 2014. Using this nationwide database (CORI-NED), our goal was to identify the effects of BMI on colonoscopy success, efficacy and tolerability. Additionally, we aimed to identify whether method of sedation (endoscopist versus anesthesia-driven sedation) is predictive of procedural success among overweight and obese patients.

Patients and methods

National Endoscopic Database (NED) of CORI (CORI-NED) and data collection

We utilized the CORI database–a large national multicenter consortium of 108 sites from 87 practices, created for the means of studying outcomes and utilization of endoscopy in a variety of practice settings (74 % community practice, health maintenance organizations (HMOs) and private practices, 15 % government agencies (e. g. military and Veterans Affairs Health Services), and 12 % academic medical centers). Participating sites use a structured, computerized report generator to process all endoscopic reports and comply with quality control requirements. Data are subsequently transmitted electronically to a central data repository, the CORI-NED database, which is in part funded by the National Institutes of Diabetes and Digestive and Kidney Diseases (NIDDK). This study was exempt from IRB approval as it is a retrospective analysis of de-identified data.

Version four of the CORI-NED database (CORI V4), which includes data recorded from 2008 to 2014, was queried to identify all adult patients (≥ 18 years old) undergoing colonoscopy for any indication. BMI was calculated using weight (kg)/height (m^2) and stratified according to the World Health Organization classification. Four cohorts were identified: 1) normal BMI (BMI ≥ 18.5 and ≤ 24.9 kg/m^2); 2) overweight BMI (BMI ≥ 25.0 and ≤ 29.9 kg/m^2); 3) class I and II obesity (BMI ≥ 30 and ≤ 39 kg/m^2) and; 4) class III obesity (BMI ≥ 40 kg/m^2). Patients < 18 years old, procedures done in the inpatient setting, and those with incomplete or missing demographic and procedure related data were excluded.

Anthropometric and procedural data were compared among the cohorts. Specific data collected included: age, gender, ASA class, race, endoscopy facility type, personnel administering sedation (anesthesia provider versus "other" (including endoscopist, non-gastroenterology providers and advanced practice providers)), completion of procedure, procedure duration, bowel preparation type prescribed, Boston Bowel Preparation (BBPS) score, number of aborted procedures, and number of cases terminated due to poor bowel preparation and patient discomfort. Endoscopy facility type include those procedures done in ambulatory surgical centers, defined as independently operated medical facilities outside the hospital setting that specialize in elective same-day or outpatient surgical procedures and those done within the hospital setting (endoscopy suite and surgical operating room). For all colonoscopies, procedure success was defined by procedure "completed" as reported by the endoscopist. Type of sedation administered was also recorded (minimal (anxiolytic) sedation; moderate (conscious) sedation; deep sedation and; general anesthesia). Minimal anxiolytic sedation is defined as use of an anxiolytic medication alone, commonly a benzodiazepine, such that the patient remains responsive to verbal commands. Moderate (conscious) sedation, commonly provided through a combination of benzodiazepine and opioid medications, refers to a slightly deeper level of sedation where a patient maintains ventilatory and cardiovascular function and is able to make purposeful responses to verbal or light tactile stimulation. In contrast a patient undergoing deep sedation may require ventilatory or airway support, but typically maintain cardiovascular function, and cannot be aroused easily but may respond purposefully to repeated of painful stimulation. At the level of general anesthesia, the patient cannot be aroused by painful stimuli, and more often type require airway or ventilatory support and occasionally are unable to maintain their cardiovascular function. The primary objective of this study was to identify the effects of BMI on colonoscopy completion rate, procedure duration, patient tolerance, and choice of personnel administering sedation.

Statistical analysis

Although some of the patients included had more than one procedure performed during the study period, quantities observed in different procedures were assumed to constitute statistically independent observations for the purposes of data analysis. Descriptive statistics were prepared with the use of contingency tables and presented as either frequencies for categorical data or mean and standard deviation (SD) for continuous data unless otherwise specified. The student *t*-test or the chi-squared test, employing Yates' correction for continuity where appropriate, were performed to understand differences in baseline values amongst the BMI subgroups. Of the demographic and procedural factors found to be significantly associated on univariate logistic regression analysis, multivariate logistic regression models were performed to calculate an adjusted odds ratio for factors related to higher BMI. All analysis was done in SAS 9.4 (Cary, North Carolina, United States). Statistical significance was set at $P<0.05$. It is recognized that there was multiple testing of outcome data arising from individual procedures. The uncorrected *P* values are presented along with the effect of correction utilizing the method of Bonferroni whenever that correction would remove statistical significance at the $P<0.05$ level.

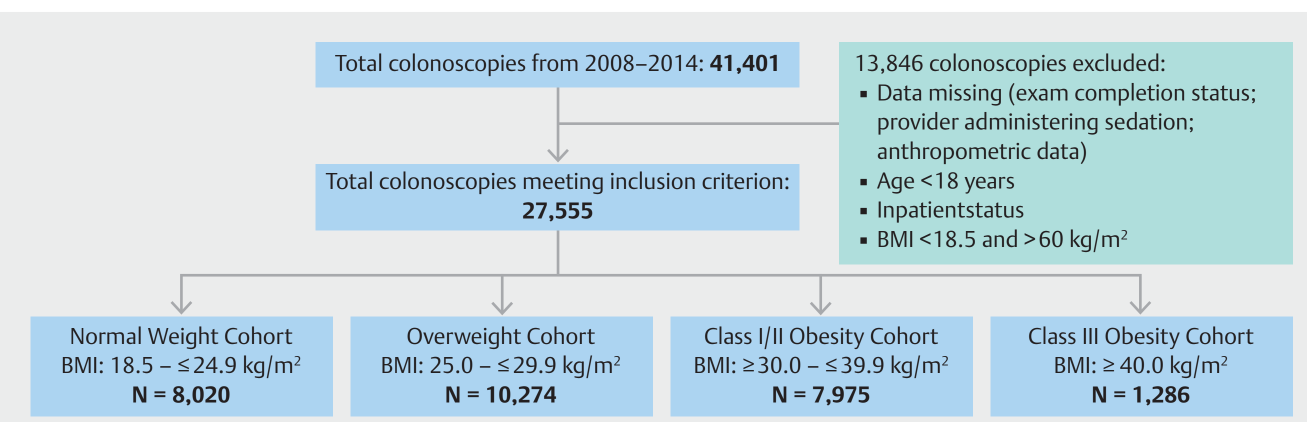
Results

Clinical characteristics

Of 41,401 colonoscopies between 2008 and 2014, 27,555 colonoscopies met inclusion criteria and were stratified by patient BMI into one of four subgroups: normal BMI (8,020 (29.1 %)), overweight BMI (10,274 [37.3 %]), class I/II BMI (7,975 [28.9%]) and class III BMI (1,286 [4.7 %]) (▶ **Fig. 1**). Baseline characteristics are presented in ▶ **Table 1**. Among the entire cohort, the mean BMI was 28.9 ± 5.54 kg/m² and the mean age was 58.9 ± 12.7 years. The majority of patients were non-Hispanic Caucasian females with an ASA classification of I or II, which was consistent on BMI subgroup analysis. While females were more prevalent among the normal BMI and class III obesity subgroups, males were more common in the overweight BMI and class I/II obesity subgroups. Over one-quarter of the class III obesity subgroup had an ASA classification of > III, however, the majority of patients in all BMI subgroups were classified as ASA Class I or II. The subgroups were significantly different with regards to age, gender, race and ASA class ($P<0.0001$) (▶ **Table 1**).

Procedural and sedation dharacteristics

The majority of colonoscopies among the entire group were performed using moderate sedation (69.7 %). This trend remained true upon further stratification by BMI class. The largest proportion of colonoscopies performed under deep sedation was seen in the Class III obesity cohort (25.8 %) as detailed in **Supplemental Table 1**. Sedation was most frequently administered by an anesthesia provider in the whole cohort (61.1 %) as well as upon stratification across BMI subgroups (▶ **Table 2**).



▶ **Fig. 1** Study flow diagram. Allocation of patients into four cohorts based on the classification of weight status by BMI: "Normal Weight" (BMI: 18.5 to ≤ 24.9 kg/m², n = 8,020); "Overweight" (BMI: ≥ 25.0 to ≤ 29.9 kg/m², N = 10,274); "Class I/II Obesity" (BMI ≥ 30.0 to ≤ 39.9 kg/m², N = 7,975) and; "Class III Obesity" (BMI > 40.0 kg/m², N = 1,286). Excluded colonoscopies with significant data missing (i. e. extent of colon reached, provider administering sedation, patient's height and weight for calculation of BMI), procedures performed in patients < 18 years old and procedures performed in patients with a BMI < 18.5 and > 60 kg/m².

▶ **Table 1** Demographic characteristics by BMI subgroup.

	Entire group N = 27,555	Normal weight N = 8,020	Overweight N = 10,274	Class I–II obesity N = 7,975	Class III obesity N = 1,286	*P* value
BMI range	18.5–60.0	18.5–24.9	25.0–29.9	≥ 30– 39.9	40–60.0	< 0.0001
▪ mean BMI (kg/m²)	28.9	22.5	27.3	33.5	44.6	
Age, years (mean, SD)	58.9 ± 12.7	58.0 ± 17.7	60.0 ± 13.7	58.9 ± 13.1	57.1 ± 13	< 0.0001
Females (N, (%))	13,942 (50.6 %)	5046 (62.9 %)	4413 (43.0 %)	3736 (46.8 %)	747 (58.1 %)	< 0.0001
Race (N, (%))						
▪ White	24,747 (89.8 %)	7211(89.9 %)	9276 (90.3 %)	7165 (89.8 %)	1095 (85.1 %)	0.002
▪ Black	1,586 (5.8 %)	377 (4.7 %)	600 (5.8 %)	486 (6.1 %)	123 (9.6 %)	< 0.0001
▪ Asian	520 (1.9 %)	288 (3.6 %)	179 (1.7 %)	52 (0.7 %)	1 (0.1 %)	< 0.0001
▪ Other[1]	702 (2.5 %)	144 (1.8 %)	219 (2.1 %)	272 (3.4 %)	67 (5.2 %)	< 0.0001
Hispanic (N, (%))	2,429 (8.8 %)	559 (7.0 %)	940 (9.1 %)	805 (10.1 %)	125 (9.7 %)	< 0.0001
ASA Class (N, (%))[2]						< 0.0001
Class I & II	25,187 (91.5 %)	7,568 (94.4 %)	9590 (93.3 %)	7086 (88.9 %)	943 (74.1 %)	
Class ≥ III	2,349 (8.5 %)	452 (5.6 %)	684 (6.7 %)	889 (11.1 %)	324 (25.9 %)	

[1] Other race: Native American, Hawaiian, multi-racial.
[2] 27,536 patients in the entire cohort had ASA class recorded in the CORI-NED database.

Among the entire group and upon subgroup analysis, approximately half of all colonoscopies were performed for CRC screening purposes (49.7 %). The majority of colonoscopies were documented as successfully completed for the entire cohort (97.7 %), and on subgroup analysis. Of those procedures not completed (2.3 %), an inadequate or poor bowel preparation was reported in 38.8 % of cases amongst the entire cohort (▶ **Table 2**, ▶ **Fig. 2**). Of data available on adequacy of bowel preparation for colonoscopy using the BBPS score, the majority of patients in the entire cohort were noted to have a BPPS score of 7 to 9 (49.4 %), followed by a score of 4 to 6 (43.2 %), which remained consistent across BMI subgroups. A larger percentage of colonoscopies were reported to have a BBPS score of 0–3 for the class III obesity cohort (16.1 %) as compared to all other BMI categories ($P < 0.0001$) (▶ **Table 2**). Prescription of GoLytely seemed to linearly increase with increasing BMI, whereas the inverse was seen with the prescription of MiraLAX based bowel preparations (**Supplemental Table 1**).

Patient discomfort was reported as the reason for an incomplete colonoscopy in 18.7 % of all cases. Endoscopist's perception of patient's tolerance during colonoscopy was "good" and "excellent" in most cases among the entire cohort (59.4 % and 38.1 %, respectively) and held true when stratified by BMI subgroup. A larger percentage of patients were reported as having a "poor" tolerance to colonoscopy among the Class III obesity cohort (0.9 %) followed by the Class I/II obesity cohort (0.4 %) (▶ **Table 2**).

Effect of BMI on colonoscopy efficacy

Compared to the normal BMI cohort, the class I/II obesity subgroup had a significantly higher odds of having an incomplete colonoscopy procedure (aOR 0.88, 95 % CI 1.05, 1.22; $P = 0.001$). In contrast, there was no significant difference in the odds of procedure completion amongst the overweight and class III obesity subgroups as compared to the normal BMI subgroup (aOR 0.96, 95 % CI 0.99, 1.14; $P = 0.07$ and aOR 0.98, 95 % CI 0.86, 1.13; $P = 0.99$, respectively) (▶ **Table 3**, ▶ **Fig. 3**).

Procedure duration was less than 15 minutes (min) in the majority of patients (74.8 %). Compared to the normal BMI cohort, the overweight BMI cohort had an increased odds of having a longer procedure (> 15 to < 30 min) as compared with a shorter procedure (< 15 min) (aOR 1., 95 % CI 1.01,1.18; $P = 0.03$). There was no other significant difference in procedure duration among the overweight as compared to normal BMI subgroups. Additionally, as compared to the normal BMI subgroup, the class I/II obesity subgroup and the class III obesity subgroup had a higher odds of procedures lasting > 15 min ($P < 0.05$ for all), although no difference when comparing procedures with a duration greater than 60 min (▶ **Table 3**, ▶ **Fig. 3**). Interestingly, the proportion of procedures lasting between 15 and 30 min, 30 and 45 min, 45 and 60 min, and greater than 60 min seemed to linearly increase with increasing BMI ($P < 0.0001$ for all) (▶ **Table 2**, ▶ **Fig. 4**).

Effect of BMI on personnel administering sedation

There was a significantly higher odds for sedation to be administered by an anesthesia provider as compared to an endoscopist or other personnel among the overweight BMI as com-

▶ **Table 2** Procedure and sedation characteristics by BMI subgroup.

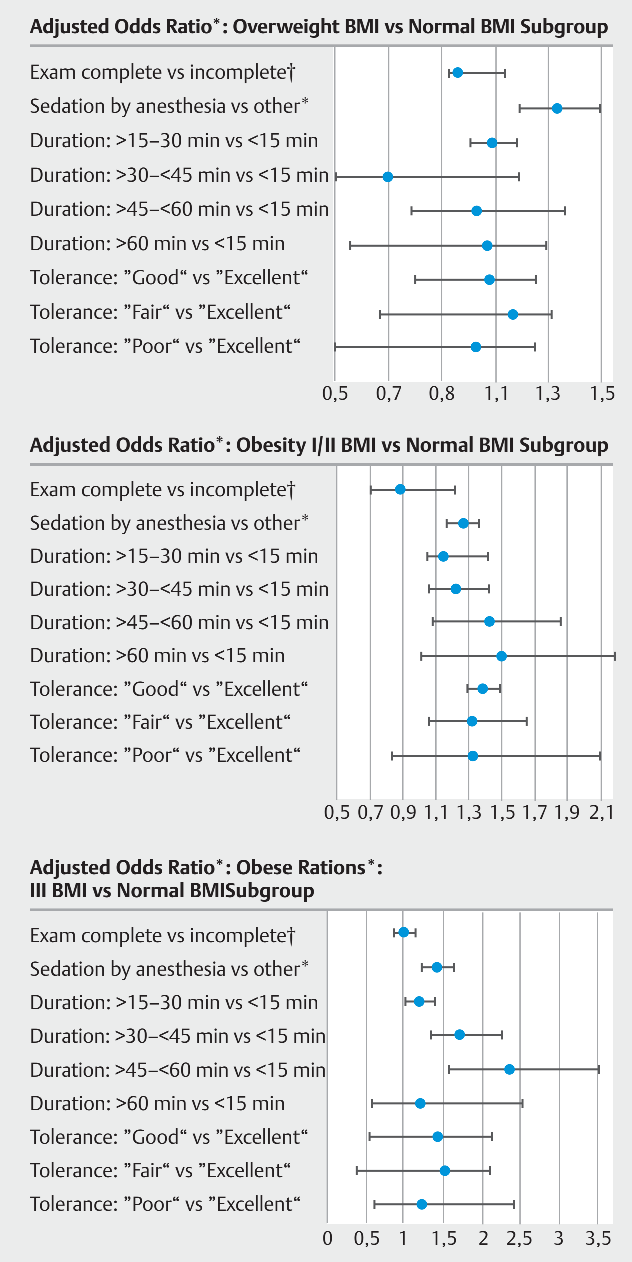
	Entire cohort N = 27,555	Normal weight N = 8,020	Overweight N = 10,274	Class I – II Obesity N = 7,975	Class III Obesity N = 1,286	*P* value
Personnel administering sedation (N, %)						< 0.0001
▪ Anesthesia	16,844 (61.1 %)	5,344 (66.6 %)	6,285 (61.2 %)	4,560 (57.2 %)	655 (50.9 %)	
▪ Other[1]	10,711 (38.9 %)	2,676 (33.4 %)	3,989 (38.8 %)	3,415 (42.8 %)	631 (49.1 %)	
Procedure tolerance (N, %)						< 0.0001
▪ Excellent	10,498 (38.1 %)	2,621 (32.7 %)	3,857(37.5 %)	3,390 (42.5 %)	630 (49.0 %)	
▪ Good	16,370 (59.4 %)	5,211 (65.0 %)	6,165 (60.0 %)	4376 (54.9 %)	618 (48.1 %)	
▪ Fair	560 (2.0 %)	154 (1.9 %)	206 (2.0 %)	174 (2.2 %)	26 (2.0 %)	
▪ Poor	129 (0.5 %)	36 (0.4 %)	46 (0.4 %)	35 (0.4 %)	12 (0.9 %)	
Procedure Duration (N, %)						< 0.0001[1]
▪ < 15 min	20,605 (74.8 %)	6201 (77.3 %)	7713 (75.1 %)	5804 (72.8 %)	887 (68.9 %)	
▪ ≥ 15 min to < 30 min	5,044 (18.3 %)	1340 (16.7 %)	1914 (18.6 %)	1534 (19.2 %)	256 (19.9 %)	
▪ ≥ 30 min to < 45 min	1,356 (4.9 %)	347 (4.3 %)	474 (4.6 %)	436 (5.5 %)	99 (7.7 %)	
▪ ≥ 45 min to < 60 min	384 (1.4 %)	90 (1.1 %)	124 (1.2 %)	135 (1.7 %)	35 (2.7 %)	
▪ ≥ 60 min	166 (0.6 %)	42 (0.5 %)	49 (0.5 %)	66 (0.8 %)	9 (0.7 %)	
Number of Incomplete Procedures, total (N, %)[2]	634 (2.3 %)	142 (1.8 %)	241 (2.3 %)	189 (2.4 %)	62 (4.8 %)	0.61
Inadequate bowel prep[3]	246 (38.8 %)	59 (41.5 %)	82 (34.0 %)	62 (32.8 %)	9 (14.5 %)	< 0.0001
Patient discomfort[4]	119 (18.7 %)	22 (15.5 %)	47 (19.5 %)	33 (17.5 %)	17 (27.4 %)	< 0.0001
BPPS Total Score (N, %)[5]						
▪ Score 0–3	201 (7.4 %)	48 (7.7 %)	63 (6 %)	65 (7.4 %)	25 (16.1 %)	< 0.0001
▪ Scope 4–6	1166 (43.2 %)	240 (38.6 %)	417 (39.7 %)	445 (50.9 %)	64 (41.3 %)	< 0.0001
▪ Score 7–9	1334 (49.4 %)	333 (53.6 %)	570 (54.3 %)	365 (41.7 %)	66 (42.3 %)	< 0.0001
Screening as indication (N, %)	13,682 (49.4 %)	3955 (49 %)	5128 (50 %)	3986 (49.7 %)	613 (47.5 %)	< 0.0001

[1] Other personnel: ICU physician, resident physician, surgeon, advanced practice providers.
[2] Other reasons for incomplete procedures not portrayed: colonic stricture, clinical deterioration/hemodynamic instability, bowel obstruction.
[3] Cecum reached for all colonoscopies performed for screening purposes.
[4] Represents the number of procedures incomplete due to an inadequate bowel preparation and due to patient discomfort.
[5] 2,701 patients in the entire cohort have a BPPS score recorded; 621 patients in the "normal BMI" cohort, 1050 in the "overweight BMI" cohort, 875 in the "class I/II BMI" cohort, and 155 in the "class III BMI" cohort.

pared to the normal BMI subgroup (aOR 1.33, 95 % CI 1.19, 1.49; *P* < 0.0001). Similarly, there were higher odds for sedation to be administered by an anesthesia provider as compared to an endoscopist or other personnel among the class I/II obesity and the class III obesity subgroups as compared to the normal BMI subgroup (aOR 1.26, 95 % CI 1.17, 1.36 and aOR 1.42, 95 % CI 1.23,1.64, respectively *P* < 0.0001 for both) (▶ **Table 3**, ▶ **Fig. 2**). In addition, among the overweight BMI and class I/II and III obese subgroups who had completed colonoscopies, there was a higher odds for sedation to be managed by an anesthesia provider versus an endoscopist (aOR 3.06, 95 % CI 2.80, 3.35; *P* < 0.0001).

Effect of BMI on patient tolerance for colonoscopy

Endoscopist perception of patient tolerance during colonoscopy was "good" and "excellent" in most cases in the entire group (59.4 % and 38 %, respectively) and held true when stratified by BMI subgroup (▶ **Table 2**). In the overweight BMI subgroup, there were higher odds for procedure tolerance to be reported as "good" as compared to "excellent" when compared to the normal BMI subgroup (aOR 1.08, 95 % CI 1.01, 1.18; *P* = 0.03). Similarly, as compared to the normal BMI subgroup, in the class I/II obesity and class III obesity subgroups, there were higher odds of the endoscopist reporting "good" (aOR 1.38, 95 % CI 1.29,1.49 and aOR 1.43, 95 % CI 0.55, 0.72, respectively; *P* < 0.0001 for both) and "fair" (aOR 1.32, 95 % CI 1.06, 1.65 and



▶ **Fig. 2** Adjusted odds ratios comparing overweight BMI, Class I/II obesity and Class III obesity subgroups to normal BMI subgroup. Odds ratios are based on adjusted analysis comparing the effects of BMI (overweight and obese BMI versus normal BMI subgroup) on certain procedure and sedation related variables during colonoscopy exams. Adjusted odds ratios are presented for all colonoscopies among the overweight BMI and obese class I/II and class III BMI subgroups as compared to the normal BMI subgroup. † As reported by the endoscopist. ¥ Other personnel: endoscopists, non-gastrointestinal physicians, advance practice providers. * All values portrayed are adjusted for each of the variables included in this model.

aOR 1.51, 95 % CI 0.38, 0.91, respectively; $P = 0.02$ for both) tolerance as compared to "excellent" tolerance during colonoscopy procedures. There was no significant difference in the odds for a "poorly" tolerated procedure among those in the overweight BMI, class I/II obesity and class III obesity BMI subgroups as compared to those in the normal BMI subgroups (▶ **Table 3**, ▶ **Fig. 2**).

Discussion

This is the largest, multicenter study evaluating the effect of BMI on the efficacy, tolerability and sedation practices for colonoscopy. This study reflects on nationwide trends pertaining to sedation and procedure characteristics of colonoscopies among overweight and obese individuals. We found that there are significant differences in rate of procedure completion, procedure duration, patient tolerance and choice of provider administering procedural sedation among overweight and obese patients as compared to patients with normal weights.

There is limited, single-center data evaluating the effects of BMI on colonoscopy completion rates [17–19]. Existing data are conflicting, with some studies demonstrate a higher likelihood of an incomplete exam in thin or average weight females and others reporting on an over 2.5 times increased odds for colonoscopy failure in obese individuals [18, 20, 21]. In our study, we found an increased odds for an incomplete colonoscopy exam among patients with a BMI ≥ 25 and < 39.9 kg/m^2 versus those with a normal BMI. Interestingly, however, our findings also showed that there was no significant difference in procedure completion among patients with a BMI > 40 kg/m^2 and those with a normal BMI; it is possible that because a higher proportion of patients within the class III obesity cohort received deep sedation during their procedures, this resulted in better patient tolerance, optimizing the endoscopists chance at successfully completing a procedure [18]. Of note, our study incorporates multicenter data from over 100 endoscopy practices nationwide and thus, is likely a more accurate reflection than previously published studies.

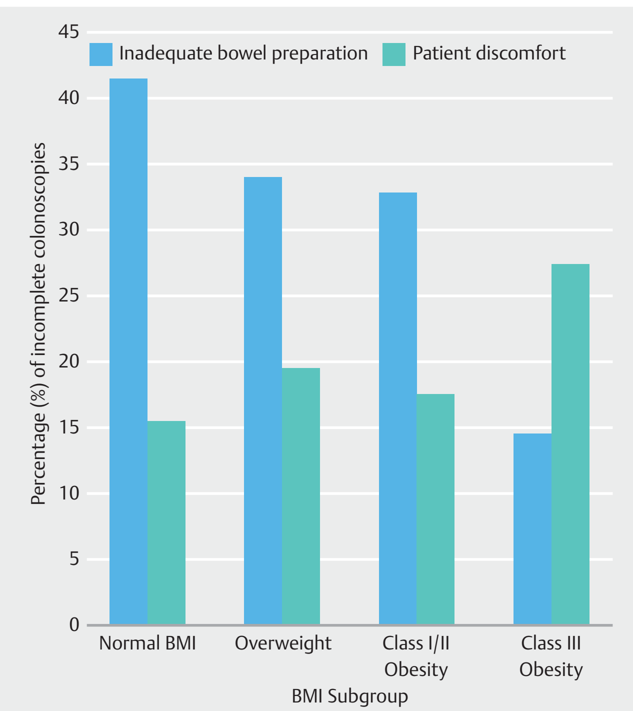
Looping occurs in 90 % of all colonoscopies and is the primary cause for patient discomfort and increased procedure time [22–24]. For varying reasons, both thin and obese patients are known to have colonic anatomy that promotes looping [25]. Ancillary maneuvers such as abdominal pressure and patient repositioning are often employed to correct looping; however, these maneuvers can be difficult to apply to the sedated, obese patient. We believe that this likely plays a role in the lower exam completion rate that was observed in the obese cohort. Prior studies have found that performing colonoscopies in the prone position for obese patients significantly shortens cecal intubation times and decreases pain [26, 27]. Nonetheless, this technique has not been widely adopted by most practices. Our data suggest that implementation of these alternate practices for the obese population may be worthwhile.

As compared to patients with a normal BMI, those with a higher BMI had more poorly tolerated colonoscopy; the reason cited for an incomplete exam was more commonly "patient discomfort" in the overweight and obese subgroups compared to

▶ **Table 3** Multivariable analysis: procedure characteristics in overweight and obese cohorts vs normal BMI cohort.

	Overweight BMI cohort		**Class I/II obesity**		**Class III obesity**	
	Adjusted OR [95 % CI]	***P* value**	**Adjusted OR [95 % CI]**	***P* value**	**Adjusted OR [95 % CI]**	***P* value**
Exam complete vs incomplete	0.96 [0.99–1.14]	0.07[1]	0.88 [1.05–1.22]	**0.001**	0.98 [0.86–1.13]	0.99[1]
Personnel administering sedation						
Anesthesia vs other[2]	1.33 [1.19 – 1.49]	**< 0.0001**	1.26 [1.17–1.36]	**< 0.0001**	1.42 [1.23–1.64]	**< 0.0001**
Procedure duration (vs < 15 mins)						
▪ ≥ 15 to < 30 min	1.09 [1.01–1.18]	**0.03**[1]	1.14 [1.05–1.42]	**0.002**	1.19 [1.02–1.39]	**0.04**[1]
▪ ≥ 30 to < 45 min	1.03 [0.89–1.19]	0.70[1]	1.22 [1.06–1.42]	**0.01**	1.71 [1.34–2.27]	**< 0.0001**
▪ ≥ 45 to < 60 min	1.03 [0.79–1.36]	0.83[1]	1.42 [1.08–1.86]	**0.01**	2.36 [1.57–3.53]	**< 0.0001**
▪ ≥ 60 min	1.07 [0.56–1.29]	0.45 *[1]	1.49 [1.01–2.20]	0.05[1]	1.21 [0.58–2.52]	0.81[1]
Patient tolerance[3] (vs excellent)						
▪ Good	1.08 [0.80–0.91]	**< 0.0001**	1,38 [1.29–1.49]	**< 0.0001**	1.43 [0.55–0.72]	**< 0.0001**
▪ Fair	1.17 [0.67–1.03]	0.08[1]	1.32 [1.06–1.65]	**0.02**[1]	1.51 [0.38–0.91]	**0.02**[1]
▪ Poor	1.03 [0.51–1.25]	0.33[1]	1.32 [0.83– 2.10]	0.14[1]	1.22 [0.61– 2.42]	0.57[1]

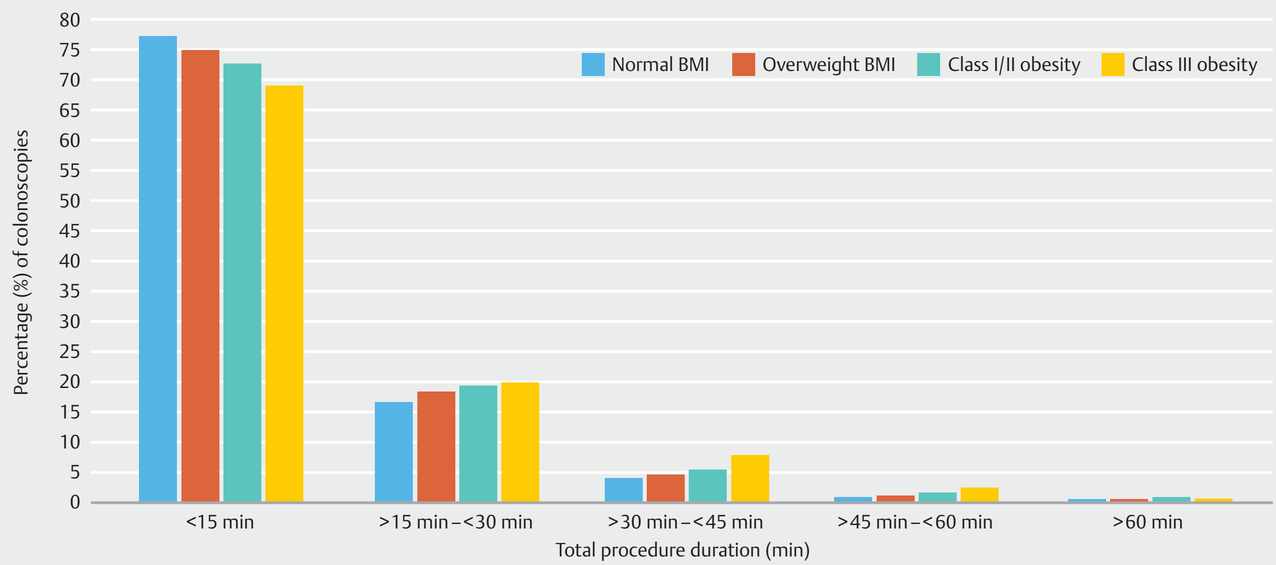
[1] Nominally significant in a single test of hypothesis; however, correction for multiple testing of data removes this significance.
[2] Other personnel includes: endoscopists, non-gastrointestinal physicians, advance practice providers.
[3] Patient tolerance as perceived by the endoscopist.



▶ **Fig. 3** Rate of incomplete colonoscopies due to patient discomfort and inadequate bowel preparation by BMI subgroup. Among the entire study cohort, 18.7 % (n = 119) of colonoscopies were incomplete or aborted due to "patient discomfort" (as reported by the endoscopist) and 38.8 % (n = 246) of colonoscopies were incomplete or aborted due to a poor or inadequate bowel preparation (as defined by a BPPS score of 0–3). A higher rate of colonoscopies incomplete due to an inadequate bowel preparation is observed in the normal BMI subgroup (41.5 %) whereas a higher rate of colonoscopies incomplete due to patient discomfort is observed in the Class III obesity subgroup (27.4 %).

the normal BMI subgroup. Increased looping and requirement for abdominal pressure and repositioning during the exam among the overweight and obese cohorts are possible explanations. This carries important clinical considerations. An uncomfortable exam could have detrimental effects on patient compliance with CRC screening. Prior studies have shown that obesity is associated with lower rates of CRC screening, particularly in obese white women [28]. In our study, among BMI subgroups, the class III obesity group had the fewest proportion of colonoscopies performed for screening purposes (47.5 %) (▶ **Table 2**). Patient satisfaction is becoming exceedingly relevant; discomfort during colonoscopy is likely a primary reason for lower CRC screening rates in the obese population, supported by findings of a recent study that identified inadequate pain control as a primary concern among patients undergoing colonoscopy [29].

Cecal insertion time (CIT) is a well-established surrogate measure for procedure difficulty with a CIT > 10 min considered "difficult" [23, 30, 31]. Prior studies assessing the effects of certain obesity parameters (i. e. BMI, waist circumference, visceral/subcutaneous adipose tissue) on CIT are conflicting [2, 16, 32–34]. While the results of our study did not comment directly on cecal intubation time due to limitations of the CORI-NED database, our study did demonstrate that patients with a BMI of ≥ 30 and ≥ 40 kg/m² had an overall longer procedure duration as compared to those with a BMI < 24.9 kg/m² [35–37]. Considering the results of our nationwide cohort, a higher BMI may be predictive of longer procedures and thus prolonged anesthesia sessions, and perhaps may require better expertise in colonoscopy technique [16].



▶ **Fig. 4** Colonoscopy Exam Duration by BMI subgroup. Colonoscopy procedure duration (minutes) are categorized into 15-minute intervals (< 15 min, > 15 to < 30 min, > 30 to < 45 min, > 45 to < 60 min and > 60 min) for the purposes of analysis. Percentage of colonoscopies that fall within each duration category, by BMI subgroup, is portrayed. While the majority of procedures were less than 15 minutes among the entire cohort (74.8 %), a higher proportion of patients in the Class I/II and III obesity subgroups had procedures lasting > 30 minutes as compared to normal and overweight BMI subgroups.

Optimal visualization during colonoscopy is contingent on an adequate bowel preparation, yet only 67.5 % to 78.3 % of patients have an adequate preparation [38]. The finding in our study of increasing GoLytely prescriptions with rising BMI adheres to recommendations borne out of prior studies demonstrating that GoLytely is more efficacious than MiraLAX in the obese population [39]. Yet, in our study, a higher percentage of inadequate bowel preparation scores (BPPS score 0–3) were still observed among obese patients versus the normal BMI subgroup. Several studies have found that an increased BMI is an independent predictor of an inadequate bowel preparation [10, 16, 38, 40]. An inadequate bowel preparation is associated with higher rate of missed lesions, decreased CIR, prolonged procedures, increased patient discomfort, need for repeat procedure, and increased risk for sedation-related adverse events, all of which can contribute to higher healthcare costs [2, 22, 41]. Current estimates suggest that suboptimal bowel preparations increase colonoscopy costs by as much as 12 % to 22 % [22]. These findings suggest the need for an individualized bowel preparation regimen for the obese population to not only improve patient satisfaction, but also to maximize procedural efficiency and success. Furthermore, since obesity is a well-established risk factor for colonic neoplasia, the consequences of missed lesions and failure to follow-up could be particularly deleterious [42–47].

Aside from the technical challenges, obese patients carry a higher risk for sedation-related complications, due to an increased risk of perioperative cardiopulmonary adverse events [48]. The American Society of Anesthesiologists (ASA) Task Force recommend anesthesia assistance for procedures with an elevated risk for sedation-related complications and difficult intubation (e. g., morbid obesity and obstructive sleep apnea) [14, 49]. In accord with this, we found that anesthesia-directed sedation was more commonly utilized among overweight and obese patients versus normal BMI individuals. In addition, among overweight and obese patients who had a completed exam, sedation was more likely to be administered by an anesthesia provider as compared to an endoscopist. Contrary to current practice, there is growing evidence that non-anesthesiologist-administered propofol sedation is safe and effective for endoscopy, even in obese patients undergoing advanced endoscopic procedures [50]. This topic is becoming exceedingly relevant as a larger proportion of obese patients are presenting for routine endoscopy. Current estimates suggest that anesthesia-administered sedation accounts for 40 % of the total overhead cost of an endoscopic exam and that if all colonoscopies were performed in this manner, this could exceed $7 billion US dollars annually [51]. Thus, further data confirming the safety and efficacy of endoscopist-administered sedation in overweight and obese patients is needed to reduce potentially discretionary utilization of anesthesia resources.

This study has several limitations worth noting. The CORI database is a clinical rather than analytical data set, and thus is subject to human error and misclassification bias. Missing data and varying cohort sizes may have introduced an inadvertent selection bias, thereby potentially confounding the results. In addition, due to limitations with the CORI-NED database, we did not stratify procedure by indication for multivariate analysis; had we done so, procedures performed for diagnostic or therapeutic purposes logically would potentially take longer than those performed for colorectal cancer screening. In addition, while we recognize that cecal intubation time is an important quality metric, unfortunately, this is not a variable recorded in the CORI-NED database. Therefore, the total procedure duration reported in our study includes time spent on therapeutic maneuvers that may have been indicated during the procedure. In addition, the BPPS scoring system was first implemented in 2009, whereas data from the CORI V4 database began in 2008; therefore, BPPS scores did not exist for those individuals included in our study who underwent a colonoscopy between 2008–2009. Furthermore, we recognize that a significant percentage of BPPS scores are missing data across all BMI subgroups, which may have introduced an inadvertent selection bias. BPPS score was included in this study's analysis since it serves as a relevant and important colonoscopy outcomes measure and is the only validated bowel cleanliness score that we have to date. Nonetheless, we advise readers to interpret these findings with caution, and future prospective studies should further investigate the potential association between patient BMI and BPPS score. Furthermore, some patients may have undergone upper endoscopy under the same operative session as their colonoscopy; however, since each procedure was identified by a unique procedure identifier (ID) rather than a unique patient ID, we were unable to locate nor account for these instances. Moreover, due to limited data in CORI-NED, we did not account for the experience of the endoscopist (i. e. fellow involvement) in our study which may affect procedure completion and efficiency. Finally, we recognize the subjective nature of "patient tolerance" during endoscopy as perceived by the endoscopist; since this study includes multi-center data input from different endoscopists, without a means for standardizing this data point, the patient "tolerance" parameter is subject to heterogeneity.

Conclusions

In conclusion, in this large nationwide study, obese and overweight individuals were more likely to have a decreased exam completion rate, a prolonged procedure time, an inadequate bowel preparation and poorer procedure tolerance during colonoscopy as compared to individuals with a normal BMI. These findings point to procedure considerations that ought to be considered by the endoscopist and possibly, part of the informed consent process. As the obesity epidemic progresses, screening colonoscopies will become increasingly important to reduce preventable colorectal cancer mortality. We hope that by identifying factors that make colonoscopy challenging in this patient cohort, it will allow for improved clinical decision-making and individualization of the procedure for the overweight and obese patient.

Acknowledgements

Data in this manuscript were obtained from the Clinical Outcomes Research Initiative National Endoscopic Database (CORI-NED), with support from the National Institutes of Health (NIDDK) U01DK5713201 and R33-DK61778-01. In addition, CORI has received support from the following entities to support the infrastructure of the practice-based network: AstraZeneca, Novartis, Bard International, Pentax USA, ProVation, Endosoft, GIVEN Imaging, and Ethicon. The commercial entities had no involvement in this research.

Competing interests

The authors declare that they have no conflict of interest.

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