Effect of propofol anesthesia on force application during colonoscopy

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Background: Sedation is frequently used during colonoscopy to control patient discomfort and pain. Propofol is associated with a deeper level of sedation than is a combination of a narcotic and sedative hypnotic and, therefore, may be associated with an increase in force applied to the colonoscope to advance and withdraw the instrument.

Objective: To compare force application to the colonoscope insertion tube during propofol anesthesia and moderate sedation.

Design: An observational cohort study of 13 expert and 12 trainee endoscopists performing colonoscopy in 114 patients. Forces were measured by using the colonoscopy force monitor, which is a wireless, handheld device that attaches to the insertion tube of the colonoscope.

Setting: Community ambulatory surgery center and academic gastroenterology training programs.

Patients: Patients undergoing routine screening or diagnostic colonoscopy with complete segment force recordings.

Main Outcome Measurements: Axial and radial forces and examination time.

Results: Axial and radial forces increase and examination time decreases significantly when propofol is used as the method of anesthesia.

Limitations: Small study, observational design, nonrandomized distribution of sedation type and experience level, different instrument type and effect of prototype device on insertion tube manipulation.

Conclusions: Propofol sedation is associated with a decrease in examination time and an increase in axial and radial forces used to advance the colonoscope. (Gastrointest Endosc 2014;79:657-62.)

Abbreviation: CFM, colonoscopy force monitor.

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Colonoscopy is one of the most frequently performed medical procedures in the United States and remains the preferred method of colorectal cancer screening.[1] Colonoscopy is generally performed by using either moderate sedation or monitored anesthesia with propofol.[2,3] Endoscopists use propofol to effect a deeper level of sedation and less-painful procedure and produce a shorter recovery time and higher level of patient acceptance.[4,5] The absence of pain perception with deep sedation may obviate the endoscopist's need to modify technique as a result of the patient's pain response.[4,6-8]

Take-home Message

- Peak force applied to the colonoscope insertion tube is increased when patients receive propofol anesthesia.

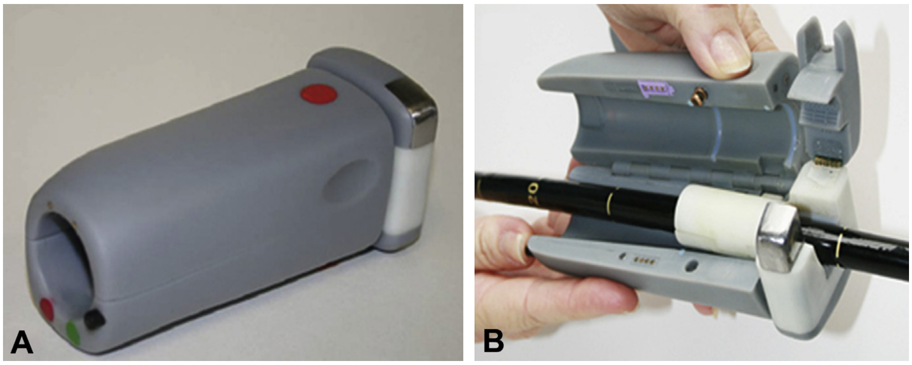

Figure 1. Colonoscopy force monitor in closed position (**A**) and with insertion tube attached (**B**).

TABLE 1. Patient characteristics

Variables	Overall sample, mean (SD) (N = 114)
Age, y	55.6 (11)
Male, no. (%)	62 (54)
Height, in	67 (4)
Weight, lb	176 (40)
Indication, no. (%)	
Screening	76 (67)
Diagnostic	38 (33)
Moderate sedation, no. (%)	81 (71)
Medication	
Meperidine, no. (%)	35 (31)
Dose, mg (range)	43 (12) (25-60)
Fentanyl, no. (%)	52 (46)
Dose, μg (range)	94 (47) (25-250)
Midazolam, no. (%)	81 (71)
Dose, mg (range)	3.9 (1.7) (1-9)
Propofol, no. (%)	33 (29)
Dose, mg (range)	329 (165) (80-750)
Operator expertise level, no. (%)	
Novice/intermediate	16 (14)
Advanced trainee	29 (25)
Expert	69 (61)

Colonoscopy force-monitoring measures all of the forces applied by the endoscopist to the insertion tube to introduce and withdraw the instrument. Previous studies demonstrated significant differences in axial and radial forces among endoscopists and along the length of the colon.[9,10] Because the patient's pain response is likely to modify the endoscopist's behavior, we examined the effect of sedation method on applied force in a study characterizing force-application patterns in endoscopy.

MATERIALS AND METHODS

Study design and protocol

Observational data were obtained from protocols designed to examine the performance characteristics of a new device developed to characterize the force patterns used by experienced and trainee endoscopists in academic and community practice. Each experienced endoscopist was board certified in gastroenterology and had performed more than 2000 colonoscopies. Trainees were enrolled in an accredited gastroenterology fellowship program and performed colonoscopies under the supervision of one of the co-investigators. The clinical protocol was reviewed and approved by the Western Institutional Review Board (Tacoma, Wash) or the respective institutional review board. In brief, 13 experienced endoscopists and 12 trainee endoscopists practicing in an ambulatory endoscopy center (Chevy Chase Endoscopy, Chevy Chase, Md)

TABLE 2. Force and time parameters sedation type

		Sedation		
	Overall (N = 114)	Moderate (N = 81)	With propofol (n = 33)	*P* value
Max push, N	24.14 (12.76)	21.3 (11.8)	31.1 (12.6)	.0001
Max pull, N	−18.35 (9.00)	−16.6 (8.6)	−22.6 (8.6)	.001
Max torque clockwise, N·m	0.57 (0.21)	0.51 (0.18)	0.70 (0.22)	<.0001
Max torque counterclockwise, N·m	−0.56 (0.22)	−0.49 (0.19)	−0.74 (0.19)	<.0001
Average push, N	4.16 (1.31)	3.8 (1.1)	5.0 (1.4)	<.0001
Average pull, N	−2.90 (0.81)	−2.8 (0.8)	−3.1 (0.7)	.04
Average torque, N·m	0.10 (0.03)	0.10 (0.03)	0.12 (0.02)	<.0001
Average push/pull force rate, N/s	0.47 (0.13)	0.48 (0.15)	0.45 (0.08)	.33
Average torque rate, N/s	0.02 (0.01)	0.02 (0.01)	0.02 (0.002)	.21
Average push force plus torque vectors	6.58 (1.72)	6.1 (1.6)	7.8 (1.5)	<.0001
Time to cecum, min	11.40 (6.19)	12.1 (6.6)	9.7 (4.9)	.06
Exam time, min	21.32 (10.03)	23.1 (10.4)	16.9 (7.5)	.002

Values shown are mean (standard deviation). *P* values are based on 2-sample *t* tests. Nonparametric tests based on the distribution of the variables provided similar results. *Max,* maximum.

or one of the participating academic centers (Georgetown University, Washington, DC; University of Pennsylvania, Philadelphia, Pa; Montefiore Medical Center, Bronx, NY; and VA Medical Center, Washington, DC) were recruited to participate in the study. Adult male and female patients between 30 and 75 years of age who were American Society of Anesthesiologists class 2 or lower presenting to the endoscopy unit for screening or diagnostic colonoscopy were considered for inclusion. Each colonoscopy was performed by using either an Olympus PCF 11.3-mm series (Chevy Chase Endoscopy, University of Pennsylvania), CF 12.8-mm series (Olympus Imaging America Inc, Center Valley, Pa) (VA Medical Center), or Pentax EC 12.9-mm series (Pentax Medical, Montvale, NJ) (Georgetown and Montefiore) colonoscopes. Patients received either moderate sedation with a combination of a narcotic (meperidine or fentanyl) and sedative hypnotic (midazolam) or monitored anesthesia with propofol administered by an anesthesiologist. Choice of sedation was based on endoscopy unit and physician preference. To obtain trainee force data in those cases in which the trainee encountered difficulty and the supervising endoscopist took charge, this was noted and the attending derived values were excluded from force calculations.

Colonoscopy force monitor system

The colonoscopy force monitor (CFM) system was described previously.[10] In brief, it comprises a handheld wireless colonoscope attachment with force-measuring ability (Fig. 1), a docking station to recharge the batteries, and a laptop computer with Bluetooth wireless communication. The handheld colonoscope attachment is designed so that the endoscopist can maintain a conventional hand position over the insertion tube of the colonoscope. The physician manipulates the colonoscope by using the CFM, and the measured push/pull force and torque values are wirelessly transmitted to the computer. The CFM is considered a nonsignificant-risk device and underwent standard high-level disinfection between procedures. The CFM system software provides calibration of the device, collects and records the data, and displays the measurements.

Parameter calculations and statistical analysis

Continuous force recordings were processed by using MATLAB 6.1 (MathWorks, Natick, Mass) to produce 11 parameters that represent push/pull and rotational forces, time derivatives of force, and examination time.[10] Patient and procedure characteristics, force parameters, anesthesia, and operator expertise levels were summarized for the overall sample (N = 114) by using mean and standard deviation for continuous variables and frequency and percentage for categorical variables. Values are expressed in newtons, newton meters, and newtons per second. A newton is a measure of force applied in an axial direction. For example, a 10-N push force represents approximately 1 kg of push force applied to the insertion tube. A newton meter (N·m) is a measure of force applied as rotational or torque force. This value takes into account the relationship between the distance from the axis and the magnitude of

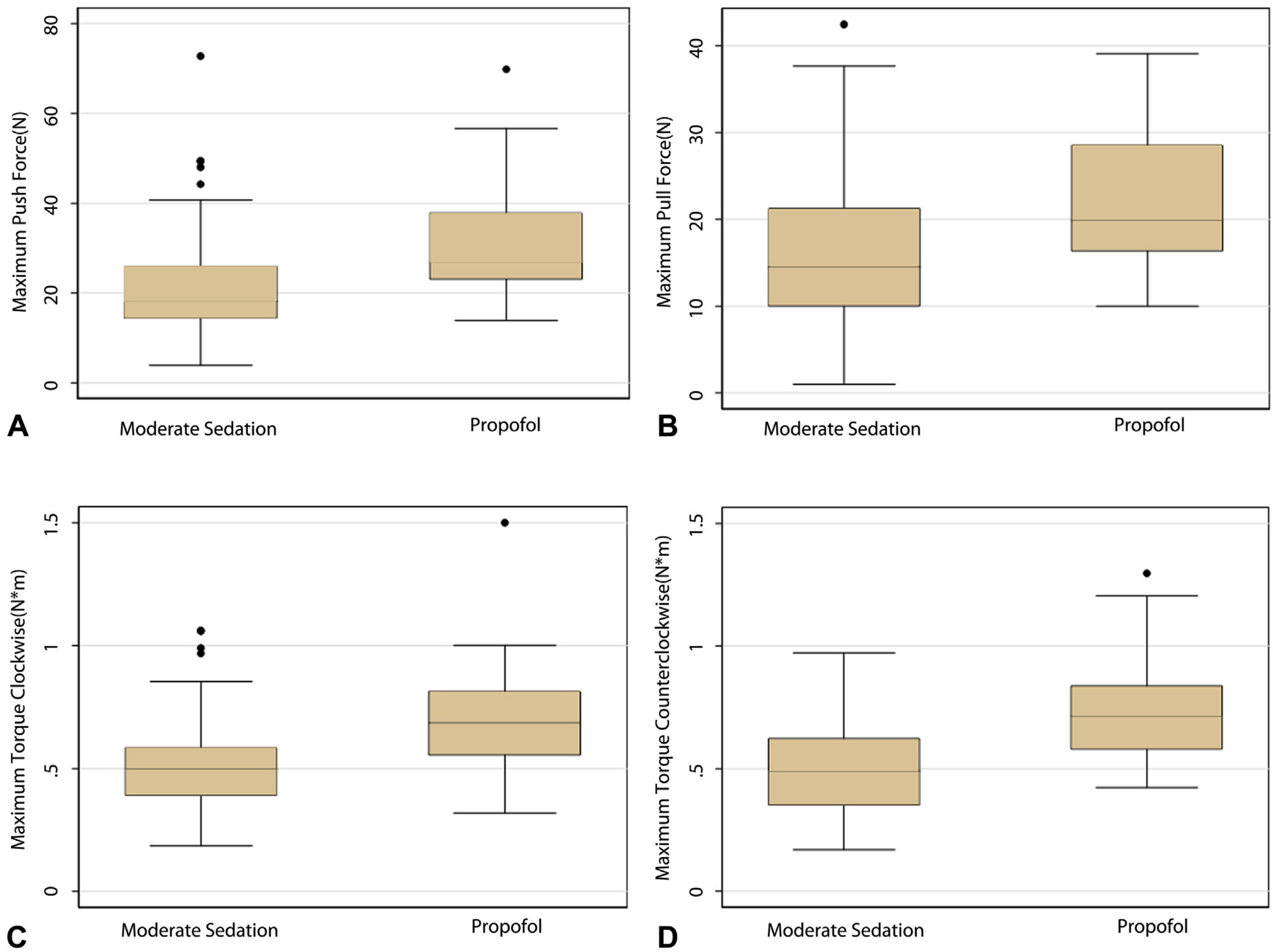

Figure 2. Boxplots for force application based on sedation type. Maximum push force (**A**), maximum pull force (**B**), maximum torque clockwise (**C**), maximum torque counterclockwise (**D**). Axial and radial forces were significantly higher with propofol anesthesia.

force that is applied. For example, 1 N·m represents 1 N of force applied 1 m from the axis of the insertion tube. N/s and N·m/s are measures of the rate at which force is applied to the insertion tube. The range of force necessary to perforate or produce a seromuscular tear in human operative or cadaveric specimens has been estimated to be 26.7 to 90 N for a perforation and 22.2 to 71.6 N for a tear.[11]

To determine whether there were differences by sedation type and patient sex, mean force parameters and examination times were compared by using 2-sample *t* tests. *P* values were also computed by using nonparametric rank tests. Boxplots were obtained to offer a visual presentation of the differences. All statistical analyses were conducted by using Intercooled Stata 11 (StataCorp, College Station, Tex). A *P* value $<$.05 was considered statistically significant.

RESULTS

Table 1 describes the patient population studied. The majority of patients received moderate sedation with fentanyl as the preferred analgesic. Monitored anesthesia was performed primarily at 2 of the 5 centers. In 1 center, all procedures were performed with propofol, and this accounted for 27 of the 33 propofol cases. Overall, trainees accounted for 40.4% of cases but represented 66.7% of the propofol cases and 29.6% of the moderate-sedation cases. However, this difference in trainee case distribution did not appear to account for the difference in effect of anesthesia. Sixty-one percent of the procedures were performed by attending endoscopists. Of the remaining procedures, 14% were performed by novice and intermediate trainees (first and second year), and 25% were performed by advanced trainees (third year).

Table 2 presents an analysis of the calculated force parameters. Peak push, pull, clockwise, and counterclockwise torque forces were significantly higher with propofol anesthesia. For example, the maximum push force with propofol was 46% higher than with moderate sedation (31.1 N vs 21.3 N, respectively). In contrast, the average push/pull and torque rates did not differ. Although the difference in the time to reach the cecum did not achieve statistical

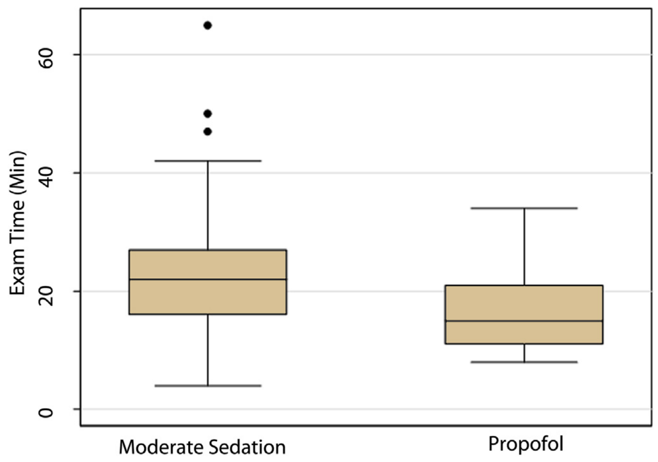

Figure 3. Boxplots of examination time based on sedation type. Examination time represents the total time of force recording and was significantly shorter with propofol anesthesia.

significance (9.7 min vs 12.1 min), examination time was significantly shorter with propofol (16.9 min vs 23.1 min) than for moderate sedation.

To illustrate the effect of sedation on force parameters and examination time, boxplots were obtained with median and range of values shown for each sedation type. Boxplots illustrate the interquartile ranges of values with outliers falling approximately 3 standard deviations outside the mean. Figure 2 demonstrates that for all peak axial and radial force measures, propofol was associated with a higher median force. Significant differences were seen with forces in push and pull force as well as clockwise and counterclockwise torque. In addition, there were more outlier values associated with moderate sedation. Figure 3 illustrates the shorter examination time with propofol compared with moderate sedation.

DISCUSSION

The current observational study demonstrated significant increases in peak and average force when sedation with propofol was used. These findings quantify the clinical impression that endoscopists are more likely to push through loops and angulated segments when propofol is used as the anesthetic. Endoscopy with propofol has several advantages including less pain, higher completion rates, shorter examination and recovery times, and improved cecal intubation rates for less-experienced endoscopists.[7,12,13] However, deeper sedation alters the technique used by the endoscopist to insert and withdraw the instrument.[14] For example, repositioning patients is more difficult with deeper sedation. Rather than using position to change the insertion technique, the endoscopist is more likely to apply more force to the insertion tube. Another disadvantage of deeper sedation with propofol is the concept that skill development may be hampered when trainee experience is limited to patients sedated only with propofol.[15] The absence of patient feedback and the limitation of patient position affect the method of insertion and withdrawal. The current study demonstrates a higher peak force with propofol, suggesting that trainees and experienced endoscopists alike may use push-through techniques to reach the cecum.

Although this study did not link force to an adverse clinical outcome, the magnitude of forces observed were significant and, in some cases, exceeded tear and perforation forces identified on surgical and cadaveric specimens.[11] Compared with moderate sedation, propofol is not associated with an increase in postprocedure morbidity. However, studies that track postprocedure adverse event rates are limited.[5,16-19]

The current study also demonstrates a significant variation in force application that is independent of anesthesia as evidenced by the large range of values and the presence of more outliers with moderate sedation. The variability in force application can be accounted for by both operator and patient characteristics. The variation suggests that certain operators use less force to accomplish the same outcome even when the patients are under deeper anesthesia. The outliers may represent the dynamic between patient characteristics, ie, pain tolerance and anatomic variation, and the willingness of endoscopists to use more force in the course of the examination.

The current study is clearly limited by the fact that these are observational data derived from a relatively small retrospective study without the benefit of random allocation of cases, anesthesia, or endoscopists. Therefore, variability by site, endoscopist experience and training level, sex, anesthesia administration pattern, and instrument type could influence the results. However, the magnitude and significance of the observed difference support the anecdotal impression that forces applied to the instrument are higher when propofol is used. Despite the limitations, these observations support the concept that force monitoring can be used to analyze the role of anesthesia, instrument type, experience, sex, and other variables of the technique used by the endoscopist.

In conclusion, this study suggests that more force is applied when propofol is the method of anesthesia. A randomized, controlled trial of force application to compare moderate sedation and propofol is necessary to confirm these observations. Correlation of force with clinical outcomes such as postprocedure pain and adverse events, medication dose, and operator experience and technique could identify optimal ranges and methods of force application. This study does suggest, however, that even with propofol, procedures can be performed with less force while still achieving an acceptable time to reach the cecum and total examination time.

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