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The effect of GI endoscopy nurse experience on screening colonoscopy outcomes

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Abstract

Background—The effect of gastrointestinal endoscopy nursing experience on colonoscopy outcomes is unknown.

Objective—To determine whether nurse experience was associated with screening colonoscopy complications, procedure length, and cecal intubation.

Design—Retrospective analysis of screening colonoscopies performed by attending physicians between August 2003 and August 2005. Nurse experience was measured in weeks.

Setting—University of North Carolina Hospitals.

Subjects—Twenty-nine nurses were employed during the study period, 19 of whom were newly hired. A total of 3,631 eligible screening colonoscopies were analyzed.

Interventions—N/A

Main outcome measurements—The primary outcome was any immediate complication; secondary outcomes included time to cecum, total procedure time, and cecal intubation rate.

Results—In procedures staffed by nurses with 2 weeks of experience or less, 3.2% had complications compared with 0.3% for procedures with more experienced nurses (OR 10.4, 95% CI 3.55, 30.2). For nurses with 6 months of experience or less, 18% of procedures had cecal intubation times greater than one standard deviation above the mean compared with 12% for more experienced nurses (OR 1.60, 95% CI 1.30, 1.97). Similar results were seen for total procedure duration (OR 1.61,

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95% CI 1.32, 1.97) and cecal intubation rates (OR 1.81, 95% CI 1.37, 2.39). All relationships held after adjusting for potential confounding factors.

Limitations—Retrospective, single center study.

Conclusions—Gastrointestinal endoscopy nurse inexperience is associated with an increase in immediate complications, prolonged procedure times, and decreased cecal intubation rates for screening colonoscopies. These findings have implications for nurse training, procedure efficiency, colonoscopy quality assessment, and patient safety.

Keywords

Colonoscopy; Nursing; Outcomes

Screening colonoscopy is felt to be a safe, efficacious, and cost-effective strategy for the prevention of colorectal cancer. As such, it is recommended by a number of national organizations for everyone at the age of 50, and for selected populations at a younger age.[1-3] Gastroenterologists, however, are cognizant of the measurable risks of colonoscopy. Potential complications include: pain; infection; bleeding requiring transfusion or hospitalization (2.5% of cases post-polypectomy); perforation (0.4% of all cases and 1% of cases post-polypectomy); respiratory events such as aspiration or respiratory depression (1-5% of cases); cardiovascular events such as arrhythmia or hypotension (1% of cases); and even death (0-0.03% of cases).[4-7]

Because of these risks, a number of investigators have identified predictors of so-called "difficult" colonoscopies, procedures that are either associated with complications or increased procedure times. Physician inexperience is one such factor, which can be ameliorated with rigorous training.[8-12] There are also a number of patient-related factors, including increased age, female sex, poor bowel preparation, lower body mass index (BMI), prior abdominal surgery and prior hysterectomy in particular, complicated diverticular disease, and a history of constipation or laxative use.[7, 11-21] It is unknown, however, whether factors related to GI endoscopy nurse experience impact colonoscopy outcomes.

The Society for Gastroenterology Nurses and Associates (SGNA) has published on-line training guidelines which state that the GI endoscopy nurse "completes an orientation based on individual learning needs…and practice setting…and identifies learning needs based on performance behaviors…."[22] Accordingly, our center individualizes training for each endoscopy nurse based on prior nursing experience, with graduated responsibility and independence as well as supervision by a more experienced nurse during at least the first two to four weeks of procedural experience. In recent years, however, our GI procedures unit has had a high rate of nurse turnover resulting in a cohort of nurses with relatively little initial GI endoscopy nursing experience. Our clinical impression was that this change had a potential impact on colonoscopy outcomes, but the overall effect was not known. The aim of this study, therefore, was to determine whether the experience level of GI endoscopy nurses was associated with screening colonoscopy outcomes including complications, procedure times such as time to cecum and total procedure time, and cecal intubation rate. We hypothesized that nurse inexperience is associated with increased screening colonoscopy complications, increased procedure times, and decreased cecal intubation rates.

METHODS

This was a retrospective study of outpatient screening colonoscopies performed from August 2003 through August 2005 at University of North Carolina (UNC) Hospitals' two GI procedure units, a hospital-based unit and an off-site outpatient-only unit. All procedures with a diagnostic

indication were excluded. Procedures in which GI fellows were involved were excluded from this study to eliminate any potential trainee effect on outcomes. All data were captured from electronic endoscopy databases (ProvationMD and ProvationRN, Provation Medical, Minneapolis, MN) and from the electronic medical record of the UNC Hospitals. These databases are maintained for clinical purposes, and all data are entered by physicians and nurses in the course of routine clinical care.

The main exposure, nursing experience, was measured in weeks from the initial calendar time of the start date in a GI procedures unit to the calendar time of the specific procedure date. This time excluded any general orientation time in a procedures unit and marked the first procedure in which each nurse was involved. For nurses starting employment during the study time frame, exact start dates were known; none of the new nurses had prior experience in a GI procedures unit and all training and initial experience was obtained at the UNC inpatient unit. For nurses already working in our procedure units at the start of the study time frame, previous start dates in any endoscopy unit were determined from employment records. Therefore, a level of nurse experience was known for every nurse participating in every colonoscopy during the study period, and during the course of the study, a given nurse might have participated in some cases as an inexperienced nurse and in some cases as an experienced nurse. When two nurses were present during a procedure (with the more experienced nurse training and mentoring the less experienced nurse), the experience level of the less experienced nurse was assigned to the case. At our center, nurses administer sedation under physician orders as individualized to each patient, monitor patients, and assist with technical aspects of the procedure, but do not perform any part of the endoscopy. Nurses staffing a given procedure were identified from the finalized report in our electronic endoscopy database. Because nursing experience was not normally distributed, and because a nurse's experience continually changed throughout the study time period, nurse experience was categorized for analysis based on the data distribution. Since this had not been previously studied, categories could not be determined *a priori*. We attempted, however, to determine a threshold level of experience for each of our outcomes that might translate to a clinically useful end-point; where needed, sensitivity analyses were performed.

The primary outcome for this study was the occurrence of any immediate procedural complication, as recorded in the endoscopy database. Complications were defined as: respiratory depression unresponsive to supplemental oxygen, with or without use of reversal agents; hypotension requiring pharmacologic support or fluid bolus; cardiac arrhythmia (bradycardia with heart rate <60, heart block, non-sinus tachyarrhythmia with heart rate > 100), with or without use of reversal agents; colonic perforation; and death. Of note, our endoscopy unit uses continuous ECG cardiac monitoring. Because this was a retrospective study and because our unit's catchment area is too broad, the occurrence of delayed complications could not be assessed.

Secondary outcomes included time to cecum, total procedure time, and cecal intubation rate, as recorded in minutes in the endoscopy database. Because the procedure times were not normally distributed and because small differences in procedure durations are not clinically significant, they were dichotomized at one standard deviation above the mean for analysis. Cecal intubation rate was defined as the proportion of cases in which the colonoscope was advanced to the cecum, as documented by the endoscopist, given that the bowel preparation was adequate and that an attempt to reach the cecum was made (ie that the recto-sigmoid junction was passed). This eliminated cases which were terminated early for severe colonic inflammation or technical reasons, as well as those that did not adequately view all of the colonic mucosa due to inadequate prep.

Other covariates of interest included procedural factors such as: physician-assessed bowel preparation quality; doses of medications administered; depth of colonoscope insertion;

physician-assessed difficulty of the procedure and patient tolerance; findings (diverticulosis; polyps) and maneuvers (polypectomy); and the number of nurses present during each procedure. Patient factors of interest were also assessed and these included: patient age; sex; American Society of Anesthesiologists (ASA) classification (1 = normal healthy patient; 2 = mild to moderate, well-controlled systemic disease; 3 = severe systemic disease; 4 = incapacitating disease that is a constant risk to life; 5 = moribund patient not expected to survive 24 hours without an operation);[23] body mass index (BMI; calculated as body weight in kilograms divided by height in square meters); comorbidities including coronary artery disease (CAD) or hypertension (HTN), diabetes (DM), obstructive sleep apnea (OSA) or snoring, and chronic obstructive pulmonary disease (COPD) or other respiratory disease; and past surgical history including hysterectomy, bowel resection, hernia surgery, cholecystectomy, appendectomy, or other abdominal surgery. Each of these covariates is routinely recorded in our endoscopy databases during patient intake process prior to the procedure.

Statistical analysis was performed with Stata version 9 (StataCorp, College Station, TX). Routine descriptive summary statistics and bivariate analysis were conducted initially. Chi-square was used for comparisons between categorical variables, and Student's t-test was used for continuous variables. Multivariable analysis was conducted with logistic regression and an analysis of covariance strategy. Specifically, all potential confounders were included in an initial model for each outcome. Then, a backwards elimination approach was used to remove variables that did not change the odds ratio (OR) substantially, defined *a priori* as a total change in estimate of 10% or less. Additionally, to assess for the possibility of overfitting of the model due to limited numbers of outcomes for procedural complications, reduced models containing two covariates of interest and the outcome variable were assessed; adjusted OR's from these reduced models were compared to the OR's of the fully adjusted models. Because physician experience was non-differentially distributed between experienced and inexperienced nurses (in our units, both doctors and nurses rotate between procedure rooms without a set pattern), physician experience was not included in the initial regression model, but modelling was repeated with an added parameter for physician procedural volume during the study time frame to assess any effect on the estimated odds ratio. Because nurses participated in cases at both the hospital-based and the outpatient procedure units, location of the procedure was not included in the regression models. Similarly, because having two nurses present during a procedure was a proxy measure for the main exposure of interest, this covariate was not included in the models. Finally, for each outcome, all interactions between the exposure and potential confounding covariates were assessed at once with a likelihood ratio test. Because there were no significant interactions by this test, interaction terms were not included in the models. Missing data were excluded from bivariate and multivariable statistical analysis.

This study protocol was approved by the UNC School of Nursing Institutional Review Board.

RESULTS

Patient characteristics

A total of 3,614 patients, accounting for 3,631 screening colonoscopies, were identified from the electronic databases and were included in the study (Table 1). There were 17 patients who had repeat procedures due to inadequate bowel preparation. The mean patient age was 58.4 (range: 21-90), and 42% were male. The mean BMI was 27.7 (range: 14-76), with 64% of the study population categorized as either overweight (BMI > 25) or obese (BMI > 30). The presence of any comorbidity was identified in 86% of subjects, and 47% had more than one comorbidity. Physician-assessed ASA classification, however, indicated that the vast majority had only mild to moderate, well controlled, systemic disease (97% with ASA score of 1 or 2). More than half of patients had at least one past abdominal surgery, with 24% having had hysterectomy and 22% having had appendectomy.

Nurse characteristics and nursing experience

A total of 29 GI endoscopy nurses were employed over the study time frame (Table 2). Ten nurses were present at the beginning of the time frame and 15 were present at the end, corresponding to 19 new nurses hired over the study period and 14 nurses leaving over the same time span. The mean nurse experience for the primary nurse involved in the procedure was 157 weeks (range 1-583). The distribution of nursing experience was as follows: 157 procedures (4%) were staffed by a nurse with 0-2 weeks of experience; 912 by a nurse with 3 weeks to 6 months of experience (25%); 418 by those with 7-12 months experience (11%); 542 by those with 13-24 months (15%); 61 with 25-36 months (2%); 383 with 37-48 months (11%); 289 with 49-60 months (8%); and 869 were staffed by a nurse with greater than 60 months of experience (24%). There was no association between nurse experience and patient demographic characteristics or comorbidities (data not shown).

Procedure characteristics

The 3,631 screening colonoscopies included in this study comprised 37% of the total of 9,790 colonoscopies performed during the study time frame (Table 3). The remainder were cases in which GI fellows were involved and/or were colonoscopies performed for reasons other than screening. Overall, 20 different attending physicians (all experienced colonoscopists with greater than 1,000 procedures completed) performed a mean of 181 colonoscopies (range during the study time frame: 11-554). Procedures with fellow involvement, as noted above, were excluded. There was no association between physicians and specific nurses, as both doctors and nurses rotate between procedure rooms without a set pattern.

A mean of 124 mg of fentanyl and 4 mg of midazolam were used for conscious sedation. Physician-reported bowel preparation was excellent or good in 78% of procedures, and was not reported in 7% (n = 267). Physicians rated approximately 11% of cases as difficult, and did not report a difficulty level in 10% (n = 368). Overall, physicians reported a subjective impression that 87% of patients tolerated the procedure either “well” or “fairly well”.

Immediate complications

The primary outcome of any immediate complication occurred 16 times (0.4%) (Table 3). Seven complications were due to bradycardia, 2 were due to hypotension, and 7 were due to respiratory depression. No immediate colonic perforations or deaths were recorded in our database, and no patients required hospital admission or intubation. Reversal agents, including atropine, naloxone, and flumazenil, were used in 11 patients. Details from each of the 16 cases with a complication are provided in Table 4. For 15 of the patients, the age range was from 47 to 83 years; one 27 year-old undergoing screening for a high risk indication also experienced a complication. Thirteen different nurses participated as the primary nurse in these cases, and 5 of the cases were staffed by two nurses. Seven physicians were involved in the 16 cases, and there was no association between physician and complication ($p = 0.17$) or nurse and complication ($p = 0.17$) On bivariate analysis (Table 5), complications were associated with having multiple past abdominal surgeries (1.2% of patients with multiple past abdominal surgeries had a complication compared to 0.4% of patients without multiple past surgeries; $p = 0.03$) and with lower BMI (patients having complications had a mean BMI of 23.8 compared to patients without complications who had a mean BMI of 27.7; $p = 0.01$).

The occurrence of a complication was associated with nurse inexperience. Thirteen of the 16 total complications (81%) occurred during procedures staffed by nurses hired during the study period. While 8 complications occurred during procedures staffed by a nurse with 6 months of experience or less in a GI endoscopy unit (OR 2.4, 95% CI 0.9-6.4), the highest proportion of complications (as a percentage of the total number of procedures) occurred during procedures staffed by a nurse with 2 weeks of experience or less (Figure 1). Specifically, complications

occurred during 3.2% of these procedures (5 of 157) compared with 0.3% of procedures (11 of 3,474) staffed by nurses with greater than 2 weeks of experience ($p < 0.001$ by chi-square; $OR_{crude} = 10.4$, 95% CI 3.55, 30.2). This association held after the multivariable analysis (Table 6) adjusting for potential confounding factors including patient age, sex, bowel preparation quality, BMI, ASA score, presence of multiple comorbidities, multiple past abdominal surgeries, past hysterectomy, severe diverticulosis, and polypectomy ($OR_{adjusted} = 10.5$, 95% CI 2.26, 49.1). The addition of physician procedure volume to the model also did not change this result.

Cecal intubation time

The mean cecal intubation time was 11.0 minutes (range 1.1 - 60.3) (Table 3). Factors associated with a prolonged time to cecum greater than one standard deviation above the mean (18 minutes) included older age, female sex, having the procedure performed at the hospital based unit, poor quality bowel preparation, having multiple past abdominal surgeries (in particular, having a past hysterectomy), and receiving higher medication doses for conscious sedation (Table 5).

Prolonged cecal intubation times were associated with nurse inexperience. Eighteen percent of procedures with a cecal intubation time greater than one standard deviation above the mean (167 of 923) were staffed by a nurse with 0-6 months of experience compared to 12% of procedures (282 of 2,320) staffed by a nurse with greater than 6 months of experience ($p < 0.001$ by chi-square; $OR_{crude} = 1.60$, 95% CI 1.30, 1.97). This association also held after the multivariable analysis (Table 6) adjusting for potential confounding factors including patient age, sex, bowel preparation quality, BMI, ASA score, presence of multiple comorbidities, multiple past abdominal surgeries, past hysterectomy, severe diverticulosis, and polypectomy ($OR_{adjusted} = 1.34$, 95% CI 1.01, 1.78). The addition of physician procedure volume to the model also did not change this result.

Total procedure time

The mean total procedure time was 23.1 minutes (range 1.8 - 120.1) (Table 3). Factors associated with prolonged total procedure time included older age, having the procedure performed at the hospital-based unit, poor bowel preparation, the presence of multiple comorbidities, having multiple past abdominal surgeries, receiving higher medication doses for conscious sedation, and finding and removing one or more polyps (Table 5).

Prolonged procedure times were associated with nurse inexperience. Eighteen percent of procedures with a total procedure time greater than one standard deviation above the mean (182 of 1,031) were staffed by a nurse with 0-6 months of experience compared to 12% of procedures (296 of 2,524) staffed by a nurse with greater than 6 months of experience ($p < 0.001$ by chi-square; $OR_{crude} = 1.61$, 95% CI 1.32, 1.97). This association also held after the multivariable analysis (Table 6) adjusting for potential confounding factors including patient age, sex, bowel preparation quality, BMI, ASA score, presence of multiple comorbidities, multiple past abdominal surgeries, past hysterectomy, severe diverticulosis, and polypectomy ($OR_{adjusted} = 1.54$, 95% CI 1.18, 2.01). The addition of physician procedure volume to the model also did not change this result.

Cecal intubation rate

The overall cecal intubation rate was 95%, with the terminal ileum examined in 28% of cases (Table 3). For analysis, however, the cecal intubation rate given that the bowel preparation was adequate and an attempt was made to reach the cecum was 93%. This value is lower because 74 cases in which the cecum was reached were excluded because the bowel preparation was

deemed poor or inadequate and the colonic mucosa was insufficiently examined. Factors that were associated with a reduced rate of cecal intubation are presented in Table 5.

As with the other outcomes, a reduced cecal intubation rate was associated with nurse inexperience. Nine percent of procedures during which the cecum was not reached (91 of 979) were staffed by a nurse with 0-6 months of experience compared to 5% of procedures (128 of 2,385) staffed by a nurse with greater than 6 months of experience ($p < 0.001$ by chi-square; $OR_{crude} = 1.81$, 95% CI 1.37, 2.39). This association also held after the multivariable analysis (Table 6) adjusting for potential confounding factors including patient age, sex, bowel preparation quality, BMI, ASA score, presence of multiple comorbidities, multiple past abdominal surgeries, past hysterectomy, severe diverticulosis, and polypectomy ($OR_{adjusted} = 1.90$, 95% CI 1.15, 3.15). The addition of physician procedure volume to the model also did not change this result.

DISCUSSION

This study examined the effect of the level of GI endoscopy nursing experience on selected outcomes of screening colonoscopies performed by experienced attending physicians. We found that even after adjusting for factors known to be associated with difficult colonoscopies or colonoscopic complications, patients undergoing screening colonoscopy staffed by a nurse with 2 weeks or less of GI endoscopy nursing experience had approximately 10 times the odds of having an immediate procedural complication compared with procedures staffed by a nurse with greater than 2 weeks of GI endoscopy nursing experience. Additionally, screening colonoscopies staffed by nurses with 6 months or less of GI endoscopy nursing experience had approximately: 1.6 times the odds of a cecal intubation time greater than 1 standard deviation above the mean; 1.6 times the odds of a total procedure time greater than 1 standard deviation above the mean; and 1.8 times the odds of not reaching the cecum.

In contrast to the growing literature examining the learning curve for nurse endoscopists performing flexible sigmoidoscopy and colonoscopy,[24, 25] to our knowledge the effect of GI endoscopy nurse experience on colonoscopy outcomes has not been previously reported. Moreover, it is not known whether similar effects would be observed for other GI procedures such as upper endoscopy, endoscopic ultrasound (EUS), or endoscopic retrograde cholangiopancreatography (ERCP). It is therefore somewhat difficult to contextualize our results, and our findings will need to be confirmed in other settings. Limited data within the field of gastroenterology is only peripherally helpful. In 1989, Matthews and colleagues performed an ex-vivo experiment utilizing a training protocol for ERCP nurses injecting contrast dye.[26] They confirmed their hypothesis that inexperienced nurses injected contrast at higher pressures than did nurses experienced in ERCP techniques, and that after training sessions for the novice nurses, the injection pressures between the two groups were equivalent. This was not a clinical study, however, and there do not appear to be any published accounts of whether this improvement seen after training resulted in a decreased frequency of post-ERCP pancreatitis. In one other unrelated study, investigators found that nurses could better assess pain during colonoscopies than could the endoscopists, but quality of pain assessment was not correlated with nursing experience.[27] Expanding the literature search to other procedural fields such as cardiac catheterization, interventional radiology, and bronchoscopy yields no other pertinent studies.

When interpreting the findings of our study, there are a number of limitations that must be considered. Because this was a retrospective analysis, there may be concerns about validity and bias. First, misclassification of the exposure of nursing experience is possible, but unlikely. For new nurses, the exact start dates were known and none of the nurses had prior experience in a GI procedures unit. For established nurses, start dates were also known, and even if there

was some error in recording these, most nurses had far greater than 6 months of experience already, so the reported results would not be affected. It is also a strength of this study that both the experience level of every individual nurse was known for each colonoscopy in which they participated, and that the exact number of colonoscopies staffed by each nurse at every stage of the study was known. Moreover, every colonoscopy performed by an attending physician alone over the study time frame was included, thus limiting the bias that could result from selecting only the cases with known complications. Although there were a relatively small number of complications, we analyzed a large number of cases not only to identify them but to provide a high level of detail concerning other covariates in addition to nurse experience levels. We are also reassured that our regression model was stable because the crude odds ratio was essentially unchanged from the fully adjusted odds ratio.

Second, because only immediate complications were routinely recorded in our electronic endoscopy databases, it is almost certain that late complications were missed. While it is possible that the occurrence of a late complication may be related to nurse experience during the procedure, whether or not the complication itself was missed would not vary by nursing experience level and therefore should not affect the results. Because complications are reported by the endoscopist, this reporting should not vary by level of nurse experience either. Additionally, attempting to capture late complications in an open healthcare system with a large rural catchment area is difficult, and the data would likely be unreliable. We would also note that the complications we detected did not include those most dreaded by endoscopists, for example perforation or death, but were instead reversible events. However, each of the complications was potentially life-threatening, and in procedure units without expertise in handling such events, these might have resulted in death or long-term sequelae.

Third, because we used data sources for which information is entered by physicians and nurses during the course of clinical care, data was missing for some variables. However, we saw no differential pattern to missing data between experienced and inexperienced nurses, and all covariates had less than 10% missing data with the exception of data on past abdominal surgeries (approximately 25% missing). Moreover, that our study found the same predictors of difficult colonoscopies as previous investigations lends support to the validity of the data source. A related point is that while cases with two nurses present were almost exclusively training cases, we could not determine from our database if some fraction of these cases represented a handoff of care between two nurses.

An additional limitation is that because this is a single center study, the results may not be generalizable. Specifically, nurse training protocols may be different at other institutions; there may be differences between academic and private practice settings; nurse turnover rates in other settings may vary substantially from ours; and patient populations can vary in illness severity and other characteristics between centers. This is highlighted by the fact that there is no association between nurses and endoscopists at our center, hence the rationale for not including a proxy for physician experience as a potential confounding factor in our initial regression models. However, even after including a parameter for physician colonoscopy volume during the study time period, the results were unchanged. Another potential difference at our center is the mean time to cecum of 11 minutes, even after restricting the procedures to those performed by attending physicians. This is prolonged compared with some reports in the literature from expert technical colonoscopists,[28] but in line with studies of routine clinical practice which report times from 7-11 minutes.[7, 11, 18, 21, 29, 30] The immediate complication rate of 0.4% that we detected, however, is consistent with other estimates in the literature,[4, 5, 7] with the caveat that retrospective series often underestimate the total number of procedural complications.[6] Our overall cecal intubation rate, too, was similar to those rates previously reported in the literature (most of which range between 91 and 99%, depending on the study

setting and colonoscopy indication),[5, 7, 12, 13, 15-19, 30] and met the goal set forth by the U.S. Multi-Society Task Force on Colorectal Cancer.[31]

The findings in this study make intuitive sense. Just as there is a learning curve for GI trainees learning colonoscopies,[8-10] a learning curve for GI endoscopy nurses likely exists as well. The SGNA guidelines tacitly imply this, but rely on individualized training given that nurses can enter the field of gastroenterology with a wide range of previous experience.[22] Nurses must not only master monitoring and recording vital signs, administering conscious sedation, and assessing sedation level, but must become intimately familiar with the colonoscopy procedure protocol, indications, findings, equipment, and therapeutic interventions. We would hypothesize, though cannot confirm from the data currently available to us, that nurse inexperience could predispose to complications, longer procedure times, and lower cecal intubation rates because each of the facets of the colonoscopy procedure is not familiar. For example, sedation may become too deep requiring reversal medications; an inexperienced nurse may not yet know the most effective way to apply abdominal pressure, or may not be able to anticipate when it is needed; and if polypectomy and cautery equipment are not familiar, several minutes may be spent readying these prior to using them. Interestingly, our data suggest that the solution may not be as simple as adding a second, supervising, nurse to the procedure room. Having a second nurse present was associated with increased complications, increased procedure times, and decreased cecal intubation rates, but these results were unchanged when the analysis was limited to cases with only one nurse present. During training cases with two nurses, both may devote more attention to teaching and explaining components of the procedure, and potentially less attention to the patient and colonoscopist. It is possible that complications could be prevented with educational interventions targeting physicians and nurses, such as longer nurse training intervals, physician-driven sedation protocols for new nurses, or ongoing tutorials by anesthesiologists, which highlight the at-risk period of a nurse's first two weeks in a procedures unit, or perhaps by increasing staffing for those procedures. We would stress, however, that all of these potential explanations are hypotheses and that further investigation is needed to determine which factors are most important and what types of interventions would be effective. Moreover, additional prospective research would be needed to determine whether nurse experience correlates with serious complications such as post-polypectomy bleeding, need for hospitalization, bowel perforation, or death.

In conclusion, nurse inexperience is associated with increased odds of screening colonoscopy immediate complications, prolonged procedure times, and decreased cecal intubation rates. These findings have potential implications for GI endoscopy nurse training, colonoscopy quality measures, patient safety, and procedure efficiency. Finally, targeting the procedures staffed by nurses new to the GI procedure unit may be a way to decrease a substantial proportion of immediate screening colonoscopy complications, but future research in this area is needed to evaluate this hypothesis.

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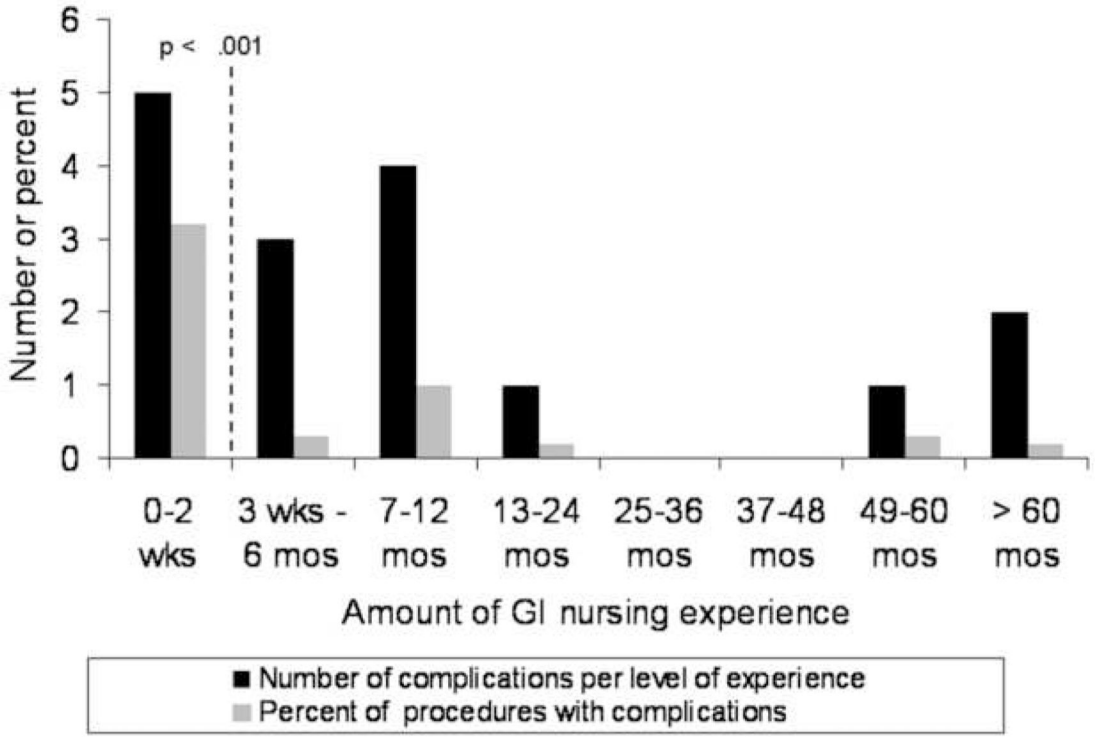

Figure 1.

Association between amount of GI endoscopy nursing experience and immediate complications from screening colonoscopy. Note that both absolute numbers and proportions are presented on this figure, as specified on the y-axis. The black bars represent the total number of complications occurring at each level of nursing experience. The grey bars represent the proportion of cases in which complications occurred for each level of nursing experience. The dotted line shows that for the primary outcome of complications, nurse experience was dichotomized at two weeks of experience or less. By chi-square, $p < 0.001$ for the overall association comparing greater and less than two weeks of experience.

Table 1

Patient characteristics* (n = 3614 patients; n = 3631 screening colonoscopies) †

Characteristic	Mean or percent
Mean age (range, ± SD)	58.4 (21-90) ± 9.5
% male	42.2
BMI (mean, range, ± SD)	27.7 (14-76) ± 6.1
underweight (% BMI < 18.5)	1.2
normal (% BMI 18.5 - 24.9)	35.2
overweight (% BMI 25 - 29.9)	36.0
obese (% BMI 30 - 39.9)	23.2
morbidly obese (% BMI > 40)	4.4
Other medical conditions (%)	
any comorbidity	86.2
multiple comorbidities	46.5
HTN/CAD	51.6
DM	15.0
OSA/snoring	55.2
COPD/other respiratory condition	14.5
Past surgeries (%)	
any past abdominal surgery	56.0
past multiple abdominal surgeries	15.8
s/p hysterectomy	24.3
s/p bowel resection	2.2
s/p hernia surgery	13.0
s/p cholecystectomy	13.2
s/p appendectomy	21.6
s/p other abdominal surgery	0.5
Pre-procedure ASA score (%)	
I — normal healthy patient	45.5
II — mild or moderate systemic disease	51.7
III — severe systemic disease	2.8

*Abbreviations: BMI = body mass index; HTN = hypertension; CAD = coronary artery disease; DM = diabetes; OSA = obstructive sleep apnea; COPD = chronic obstructive pulmonary disease; ASA = American Society of Anesthesiologists

†17 colonoscopies were repeated due to poor or inadequate bowel preparation

Table 2

Nurse characteristics

Total number of nurses during study period	29
Nurses at the beginning (#)	10
Nurses at the end (#)	15
New nurses during the study period	19
Nurse turnover (# leaving during study period)	14
Nursing experience of the primary nurse*	
Mean weeks experience (range, ± SD)	157 (1-583) ± 165
Mean number of procedures for new nurses (range, ± SD)	281 (1-799) ± 204
Number of procedures with two nurses present (#, %)	347 (9.6)
For the second nurse present:	
Mean weeks experience (range, ± SD)	213 (8-563) ± 161
Mean number of procedures for new nurses (range, ± SD)	433 (108-728) ± 148

*Primary nurse defined as the nurse primarily responsible for monitoring, administering sedation, and assisting with technical aspects of the procedure.

Table 3

Screening colonoscopy characteristics

Total number of screening colonoscopies during study period (attending only performing)	3631
Total number of all colonoscopies during study period (all indications; fellows and attendings)	9790
Indication for colonoscopy (%)	
Routine screening	86.9
High risk screening	13.1
Location of procedure (%)	
Hospital-based unit	65.6
Off-site unit	34.4
Number of physicians performing procedures	20
Mean number of procedures per MD (range)	181 (11-554)
Sedation medications	
Mean fentanyl dose (range, ± SD; micrograms)	124 (0-500) ± 57.4
Mean midazolam dose (range, ± SD;milligrams)	4.0 (0-16) ± 1.8
Patients receiving adjunct promethazine (%)	1.2
Bowel preparation quality (physician-assessed) (%)	
Excellent	39.9
Good	37.8
Fair	11.8
Poor	2.3
Unsatisfactory	0.9
Not reported	7.4
Physician-rated procedure difficulty (%)	
Not difficult or accomplished with ease	79.4
Difficult	10.5
Not reported	10.1
Overall colonoscopy completion rates (%)	
Reaching cecum or ileum	95.3
Examining ileum[†]	28.3
Incomplete	4.7
Completion rate for cases with adequate bowel preparation in which an attempt for completion was made (%)[*]	93.5
Findings and maneuvers on colonoscopy (%)	
Any diverticulosis	59.5
Severe diverticulosis	7.3
Any polyp	44.3
Polypectomy performed	44.1
Multiple polyps or polypectomies	23.3
Physician-reported patient tolerance (%)	
Tolerated well	79.3
Tolerated fairly well	7.4
Tolerated	1.5
Tolerated poorly	0.5

Not reported	11.3
Procedure times	
Time to cecum (mean minutes; range; SD)	11 (1.1-60.3) ± 7.4
Total time (mean minutes; range; SD)	23.1 (1.8 – 120.1) ± 11.2
Immediate complications	
No immediate complications (%)	99.6
Any immediate complication (#, %)	16 (0.4)
Bradycardia (#)	7
Hypotension (#)	2
Respiratory depression (#)	7
Colonic perforation (#)	0
Death (#)	0
Patients receiving reversal agents (#, %)	11 (0.3)

*The cecum was reached in 74 cases with poor or unsatisfactory preparation, but it was deemed that these examinations did not adequately evaluate the colonic mucosa.

†Ileal intubation performed at the discretion of the endoscopist for screening colonoscopies.

Table 4

Characteristics of patients with screening colonoscopy complications*

Patient	Complication	Reversal	Nurse ID code	Weeks nurse experience (procedure number)	Second nurse experience (proc. number)	Location	Patient details	Procedure details†
1: 79 yo M	bradycardia	none	12	49 (493)	n/a	OU	ASA II; BMI 19.9; past abd surgery	F = 100; M = 3
2: 80 yo M	bradycardia	atropine	13	1 (3)	514 wks (n/a)	UNC	ASA II; BMI 25.8; multiple comorbidities; past abd surgery	F = 25; M = 1; severe diverticulosis
3: 75 yo W	bradycardia	atropine/ naloxone	28	19 (191)	n/a	OU	ASA II; BMI 20.8; past abd surgery	F = 100, M = 4; stopped at ascending; severe diverticulosis
4: 48 yo W	bradycardia	none	1	94 (452)	n/a	OU	ASA I; BMI 21; high risk screening	no meds
5: 83 yo M	bradycardia	atropine	7	1 (20)	n/a	UNC	ASA I; BMI 22.7; multiple comorbidities; past abd surgery	F = 25; M = 1.5; stopped at transverse
6: 48 yo W	bradycardia	none	8	39 (490)	n/a	UNC	ASA II; BMI 30.9; high risk screening; multiple comorbidities; past abd surgery	F= 150; M = 4; stopped at sigmoid
7: 47 yo W	bradycardia	atropine	28	1 (2)	34 wks (419)	UNC	ASA II; BMI 20; past abd surgery	F = 125; M = 4
8: 57 yo W	hypotension‡	none	21	2 (14)	52 wks (630)	UNC	ASA II; BMI 30.1; multiple comorbidities	F = 50; M = 2; stopped at transverse
9: 53 yo M	hypotension‡	none	25	500 (n/a)	n/a	OU	ASA I; BMI 24; multiple comorbidities	no meds; stopped at hepatic flexure
10: 63 yo W	respiratory	naloxone	18	45 (391)	n/a	UNC	ASA I; BMI 22.3; past abd surgery	F = 75; M = 4
11: 50 yo W	respiratory	naloxone	23	18 (159)	216 wks (n/a)	UNC	ASA I; BMI 23	F = 150; M = 6
12: 72 yo M	respiratory	naloxone	12	1 (11)	12 wks (204)	UNC	ASA I; BMI 24.3; past abd surgery	F = 100; M = 3

Patient	Complication	Reversal	Nurse ID code	Weeks nurse experience (procedure number)	Second nurse experience (proc. number)	Location	Patient details	Procedure details†
13: 50 yo M	respiratory	naloxone	3	27 (225)	n/a	OU	ASA I; BMI 30.5	F = 125; M = 4
14: 56 yo M	respiratory	naloxone	10	521 (n/a)	n/a	UNC	ASA I; BMI 27.1; past abd surgery	F = 200; M = 6
15: 62 yo W	respiratory#	naloxone/ flumazenil	17	233 (n/a)	n/a	UNC	ASA II; BMI 19.2; past abd surgery	F = 150; M = 4; stopped at hepatic flexure
16: 27 yo M	respiratory	naloxone	7	12 (135)	n/a	UNC	ASA I; BMI 19.8; high risk screening	F = 250; M = 9

*Abbreviations: UNC = University of North Carolina Hospital-based GI procedures unit; OU = off-site endoscopy unit; ASA = American Society of Anesthesiologists classification; BMI = body mass index; F = fentanyl (dosed in micrograms); M = midazolam (dosed in milligrams).

†All procedures performed by experienced attending physicians without fellow involvement.

‡Both cases of hypotension responded to IV fluid boluses prior to the use of dopamine.

#This patient required transient bag-mask ventilation; the other patients with respiratory depression responded to reversal agents and supplemental oxygen.

Table 5

Bivariate associations between outcomes and selected patient/procedure/nurse characteristics*

Characteristic	Patients having any complication†			Procedures not reaching the cecum, given attempt made‡			Time to cecum > 1 SD (18 minutes)#			Total procedure time > 1 SD (34 minutes)††		
	n	% or mean	p**	n	% or mean	p**	n	% or mean	p**	n	% or mean	p**
Mean age												
complication, cecum not reached, or prolonged time	16	59.4	0.7	219	60.0	0.009	449	60.1	< 0.001	478	60.6	< 0.001
no complication, cecum reached, or no prolonged time	3615	58.4		3145	58.2		2794	58.0		3077	58.1	
Sex												
Male	1533	0.5	0.5	1421	6.3	0.6	1382	9.8	< 0.001	1506	13.5	0.9
Female	2098	0.4		1943	6.7		1861	16.9		2049	13.4	
Two nurses present during the procedure												
No	3284	0.3	0.003	3033	6.2	0.05	2938	13.3	0.01	3224	12.9	0.003
Yes	347	1.4		331	9.1		305	18.7		331	18.7	
Procedure difficulty (physician-assessed)												
Not difficult	2881	0.5	0.9	2733	4.0	< 0.001	2632	7.6	< 0.001	3829	8.4	< 0.001
Difficult	382	0.5		328	19.5		297	58.2		372	48.7	
Bowel preparation quality												
Excellent	1449	0.5	0.7	1449	2.8	< 0.001	1335	7.6	< 0.001	1430	8.3	< 0.001
Good	1372	0.3		1372	3.2		1256	15.4		1339	14.6	
Fair	428	0.7		428	4.7		360	24.4		415	23.4	
Poor	84	0.0		84	100.0		70	40.0		81	28.4	
Unsatisfactory	31	0.0		31	100.0		4	50.0		28	3.6	
Mean fentanyl dose												
complication, cecum not reached, or prolonged time	16	101.5	0.1	219	123.7	0.9	449	151.8	< 0.001	478	142.1	< 0.001
no complication, cecum reached, or no prolonged time	3615	124.1		3145	123.9		2794	119.2		3077	121.6	
Mean midazolam dose												
complication, cecum not reached, or prolonged time	16	3.5	0.2	219	4.1	0.6	449	4.9	< 0.001	478	4.6	< 0.001

Characteristic	Patients having any complication†			Procedures not reaching the cecum, given attempt made‡			Time to cecum > 1 SD (18 minutes)#			Total procedure time > 1 SD (34 minutes)††		
	n	% or mean	p**	n	% or mean	p**	n	% or mean	p**	n	% or mean	p**
no complication, cecum reached, or no prolonged time	3615	4.0		3145	4.0		2794	3.8		3077	3.9	
Multiple comorbidities present												
No	1796	0.6	0.3	1657	5.7	0.03	1623	14.1	0.4	1758	11.5	< 0.001
Yes	1558	0.3		1455	7.6		1379	13.1		1527	15.9	
Multiple past abdominal surgeries												
No	2278	0.4	0.03	2116	6.0	0.2	2063	13.3	0.001	2243	12.8	0.012
Yes	427	1.2		382	7.9		354	19.8		413	17.4	
Past hysterectomy												
No	2131	0.4	0.6	1988	5.7	0.06	1932	12.7	< 0.001	2099	13.1	0.05
Yes	685	0.6		615	7.8		586	19.8		665	16.1	
Mean BMI												
complication, cecum not reached, or prolonged time	16	23.8	0.01	206	28.2	0.2	440	26.6	< 0.001	463	27.5	0.6
no complication, cecum reached, or no prolonged time	3499	27.7		3051	27.6		2710	27.8		2984	27.7	
ASA score												
I (normal)	1609	0.6	0.6	1473	4.9	0.001	1452	15.2	0.06	1573	12.9	0.4
II (mild disease)	1827	0.4		1714	7.8		1627	12.4		1799	13.5	
III (severe disease)	100	0.0		90	11.1		86	16.3		97	17.5	
Any diverticulosis												
No	2162	0.5	0.8	1987	6.7	0.5	1909	14.9	0.03	2115	13.6	0.7
Yes	1469	0.4		1377	6.2		1334	12.3		1440	13.2	
Severe diverticulosis												
No	3366	0.4	0.4	3112	6.5	0.9	3007	13.5	0.07	3295	13.2	0.2
Yes	265	0.2		252	6.8		236	17.8		260	16.2	
Polypectomy performed												
No	2028	0.5	0.7	2552	6.7	0.02	1795	14.8	0.09	1981	9.7	< 0.001
Yes	1603	0.4		811	5.8		1448	12.7		1574	18.2	

Characteristic	Patients having any complication†			Procedures not reaching the cecum, given attempt made‡			Time to cecum > 1 SD (18 minutes)#			Total procedure time > 1 SD (34 minutes)††		
	n	% or mean	p**	n	% or mean	p**	n	% or mean	p**	n	% or mean	p**
Nursing experience												
0-2 weeks	157	3.2	< 0.001	152	9.2	< 0.001	134	20.1	< 0.001	152	20.4	< 0.001
3 weeks - 6 months	912	0.3		827	9.3		789	17.7		879	17.2	
7-12 months	418	1.0		384	7.0		354	14.7		406	13.5	
13-24 months	542	0.2		503	3.6		508	6.5		537	6.5	
25-36 months	61	0.0		57	1.8		55	18.2		59	28.8	
37-48 months	383	0.0		356	5.6		345	17.1		375	15.7	
49-60 months	289	0.3		268	11.2		273	12.5		286	11.5	
> 60 months	869	0.2		817	3.9		785	12.0		861	11.6	

*Abbreviations: HTN = hypertension; CAD = coronary artery disease; DM = diabetes mellitus; OSA = obstructive sleep apnea; COPD = chronic obstructive pulmonary disease; BMI = body mass index; ASA = American Society of Anesthesiologists

†Other covariates not associated with complications include: screening indication, having individual comorbidities present (HTN, CAD, DM, OSA, COPD), and having previous individual surgeries other than hysterectomy (bowel resection, hernia repair, cholecystectomy, appendectomy).

‡Other covariates not associated with failure to reach the cecum include: having previous individual surgeries other than hysterectomy (bowel resection, hernia repair, cholecystectomy, appendectomy).

#Other covariates not associated with prolonged cecal intubation time include: screening indication, having individual comorbidities present (HTN, CAD, DM, OSA, COPD), and having previous individual surgeries other than hysterectomy (bowel resection, hernia repair, cholecystectomy, appendectomy).

††Other covariates not associated with prolonged total procedure time include: screening indication, individual comorbidities of OSA and COPD, and having previous individual surgeries other than hysterectomy (bowel resection, hernia repair, cholecystectomy, appendectomy).

**Tests based on chi-square for categorical variables and t-test for continuous variables

Table 6

Multivariate analysis of nursing experience and screening colonoscopy outcomes*

	OR_{crude}	95% CI	$OR_{adjusted}$†	95% C I
Immediate procedural complication				
0-2 weeks experience / > 2 weeks experience	10.4	3.55, 30.2	10.5	2.26, 49.1
Time to cecum > 1 SD (18 minutes)				
0-6 months experience / > 6 months experience	1.60	1.30, 1.97	1.34	1.01, 1.78
Total procedure time > 1 SD (34 minutes)				
0-6 months experience / > 6 months experience	1.61	1.32, 1.97	1.54	1.18, 2.01
Cecal intubation rate, given that an attempt was made**				
0-6 months experience / > 6 months experience	1.81	1.37, 2.39	1.90	1.15, 3.15

*Multivariate analysis performed using logistic regression with an analysis of covariance strategy

†Adjusted for age, gender, bowel preparation, BMI, ASA score, presence of multiple comorbidities, multiple past abdominal surgeries, past hysterectomy, severe diverticulosis, and polypectomy

**Defined as reaching the cecum given adequate bowel preparation and the recto-sigmoid junction was passed