Risks and Benefits of Colonoscopy in Patients 90 Years or Older, Compared With Younger Patients

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BACKGROUND & AIMS: **Although the numbers of medical procedures performed on extremely elderly patients (90 years or older, nonagenarians) are increasing, there are no data on the performance, diagnostic yield, or safety of colonoscopy for these patients. We compared the performance and safety of diagnostic colonoscopy, as well as lesions detected, in nonagenarians with patients who were 75 to 79 years old.**

METHODS: **In a retrospective study, we compared data from 76 extremely elderly patients (90 years or older) with data from 140 very elderly patients (75 to 79 years old, controls), all of whom underwent diagnostic colonoscopy from January 2010 through March 2013 at Virginia Mason Medical Center. All colonoscopies were performed by 15 endoscopists. We compared rates of colonoscopy completion, bowel preparation quality, diagnostic yield, and adverse events.**

RESULTS: **In extremely elderly patients, more colonoscopies were performed under general anesthesia, compared with controls ($P < .001$). When extremely elderly patients underwent colonoscopies with moderate sedation, lower doses of midazolam and fentanyl were given, compared with controls ($P < .001$). Colonoscopies were completed in a lower proportion of extremely elderly patients (88.2% vs 99.3% for controls, $P < .001$), and these patients had a higher incidence of inadequate bowel preparation (29.7% vs 15.0% for controls, $P = .011$). Colonoscopies were also associated with cardiopulmonary events in a higher proportion of extremely elderly patients ($P = .006$) as well as overall adverse events, compared with controls ($P = .002$). A higher proportion of extremely elderly patients were found to have advanced neoplasia (28.4% vs 6.4% of controls, $P < .001$) as well as any neoplasia ($P < .001$ vs controls). A greater percentage of extremely elderly patients also had large lesions ($P = .002$) and malignancies detected by histology ($P < .001$ vs controls). Eleven extremely elderly patients (14.9%) were found to have cancer or high-grade dysplasia by colonoscopy.**

CONCLUSIONS: **In patients 90 years or older, diagnostic colonoscopy is associated with increased risk for incomplete procedure, inadequate bowel preparation, and adverse events. However, a large proportion of patients are found to have advanced neoplasia and cancer, compared with patients 75 to 79 years old.**

Keywords: Old Age; Risk Factor; Colon Cancer Detection; Complication.

With increasing life expectancy, the number of colonoscopies in the elderly has dramatically increased in the United States.[1,2] The incidence of colorectal cancer (CRC) rises steadily with age, and the detection of colorectal neoplasia is one of the major objectives of colonoscopy. However, the potential benefits of colonoscopy need to be balanced against the competing risk of mortality from other diseases in elderly individuals.[3] Generally, colonoscopy is feasible and effective in appropriately selected elderly patients[4] but may be associated with lower procedural completion rates, higher complication rates, and higher risk of inadequate bowel preparation when compared with younger patients.[5–10]

Despite decision analyses suggesting that screening colonoscopy may be cost-effective even in very elderly

Abbreviations used in this paper: ASA, American Society of Anesthesiologists; CORI, Clinical Outcomes Research Initiative; CRC, colorectal cancer; EE, extremely elderly; VE, very elderly; VMMC, Virginia Mason Medical Center.

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patients,[11] such screening is generally not advised for those older than 75 years of age.[12] However, diagnostic colonoscopy is quite feasible even in so-called very elderly patients, ie, those older than 75 years of age. In recent years, clinicians are increasingly faced with the prospect of having to perform diagnostic colonoscopy on nonagenarians, a group that potentially may be susceptible to even higher risks of adverse events than octogenarians.

The aim of this study was to assess the diagnostic yield, complication rates, and procedural success rates of diagnostic colonoscopy in patients $\geq$90 years old (termed the extremely elderly [EE] group), as compared with controls of 75- to 79-year-old patients (very elderly [VE] group).

Methods

Subjects

We conducted a controlled study comparing diagnostic colonoscopy outcomes performed between January 2010 and March 2013 in concurrent EE and VE patients. We retrospectively identified potentially eligible subjects from the Virginia Mason Medical Center (VMMC) colonoscopy database, an ongoing, prospectively updated quality control database. For each subject, there was an extensive review of the colonoscopy database as well as all clinic notes, procedure reports, hospital admission notes, and discharge summaries in VMMC electronic medical records (Cerner Information Systems, Kansas City, MO) for a 30-day period after the colonoscopy to detect adverse events.

Data on patient demographics, American Society of Anesthesiologists (ASA) physical status classification, major comorbidities (with non–age-adjusted Charlson comorbidity index score), indication for colonoscopy, sedative dosage, colonoscopy completion, bowel preparation quality, technical difficulty, adverse events, and diagnostic yield and characteristics of detected lesions were collected for every subject. All data abstraction was done by 2 authors (J.M.C., D.L.), and discrepancies were resolved by simultaneous co-review of the records with the senior author (O.S.L.) until consensus was reached. All pathology reports were reviewed by at least 1 author (J.M.C.). Because all the colonoscopies in the EE group were diagnostic, we included only diagnostic procedures in the VE control group, excluding screening or surveillance colonoscopies. Cases were also excluded if the indication for colonoscopy was purely therapeutic, such as stent or decompression tube placement. This study was approved by the VMMC institutional review board. Because of its retrospective nature, requirements for individual informed consent were waived.

Colonoscopy Outcomes

All colonoscopies were performed by 15 endoscopists, all of whom were board-certified gastroenterology attending physicians with experience in at least 5000 previous colonoscopies. The procedures were done by using Olympus CF (Olympus America, Leeds, MA) video colonoscopes after bowel preparation with a standard split-dose polyethylene glycol regimen. The shape, size, number, and location of all detected polyps were documented. Right-sided location was defined as being proximal to the splenic flexure.

The quality of the bowel preparation was graded as excellent, good, adequate, fair/mediocre, or poor; excellent, good, or adequate grades were considered acceptable preparation. Procedures were classified as moderately or severely difficult if the endoscopist used these terms (or a synonym) to describe the procedure in the report. Procedures in which the colon was merely described as tortuous or loopy were not classified as difficult unless the endoscopist also described the procedure as being difficult. Complete colonoscopy was defined as intubation of the cecal pole or ileocecal anastomosis with photographic documentation. To achieve cecal intubation, all endoscopists had ready access to variable stiffness adult and pediatric colonoscopes and were able to freely change between the two during the course of each procedure. No single-balloon or double-balloon enteroscopes were used.

Adverse events included those caused by the bowel preparation process or the procedure itself within a 30-day window. All patients received a follow-up call by a nurse 24–72 hours after the procedure to identify immediate post-procedural complications; later adverse events were captured by review of medical records. Adverse events were classified as gastrointestinal events (such as bleeding or perforation), major cardiopulmonary events (myocardial infarction, respiratory failure, or symptomatic arrhythmia), minor cardiopulmonary events (asymptomatic transient oxygen desaturation to $<$90%, transient hypotension, or asymptomatic arrhythmias), or other problems (such as agitation or musculoskeletal injury). Any emergency department visit within the 30-day window was considered an adverse event. A severe adverse event was defined as any major cardiopulmonary event, post-polypectomy bleed or perforation, or any complication requiring unplanned hospitalization, transfusion, or abortion of the procedure.

For polyps, advanced neoplasia was defined as an adenoma or sessile serrated polyp $\geq$1 cm in size or any adenoma or sessile serrated polyp with high-grade dysplasia, $>$25% villous features (villous or tubulovillous histology), or carcinoma. Non-advanced neoplasia included tubular adenomas ($<$1 cm in size) and sessile serrated adenomas ($<$1 cm), but not hyperplastic polyps. The colonoscopic findings were categorized as (1) advanced neoplasia, including cancer, (2) non-advanced

neoplasia, and (3) benign lesions such as colitis, diverticulosis, or hemorrhoids. In the context of our study, the term *benign* denoted all non-neoplastic conditions, regardless of severity.

Statistical Analysis

We performed a sample size calculation to make sure that non-significant P values resulting from comparison of the 2 cohorts would reflect true similarity between the cohorts rather than lack of statistical power (type 2 error). We assumed a 2-fold difference in the prevalence of advanced neoplasia between the EE and VE cohorts might be present. Previous studies have shown advanced neoplasia prevalence of 11.7% in patients 76 to 80 years old.[13] On the basis of these assumptions, a minimum total sample size of 178 was required for a statistical power of 80% at the $P < .05$ level of significance.

Variables in the 2 groups were compared by using Student t test for continuous variables and the χ^2 test for categorical variables. Two-tailed P values $< .05$ were considered statistically significant. Statistical analysis was performed by using the Statistical Package for the Social Sciences 19.0 (SPSS, Chicago, IL).

Results

Demographics, Procedural Indications, and Sedation

During the study period, 140 colonoscopies in the VE group and 76 in the EE group were included. Supplementary Figure 1 shows a flow diagram of the recruitment process for EE subjects. In the VE group, the mean age was 77.4 ± 1.5 years, and 64 patients (45.7%) were male; in the EE group, the mean age was 92.6 ± 2.5 years, and 37 (48.7%) were male. As shown in Table 1, the EE group had a much higher proportion of ASA class ≥III subjects than the VE controls ($P < .001$) and also more inpatients ($P < .001$). Diagnostic colonoscopy was more frequently performed for diarrhea or abdominal pain in the VE group but more frequently for rectal bleeding in the EE group (Table 1). In the EE group, general anesthesia was more frequently required ($P < .001$), and for those who had moderate sedation, significantly lower doses of midazolam and fentanyl were used compared with VE controls (both $P < .001$). Table 1 shows the racial background and attendant major comorbidities (diabetes, cardiac, pulmonary, or renal conditions) of the subjects. The mean non–age-adjusted Charlson comorbidity score was slightly higher in the EE group than in the VE group (1.8 vs. 1.4, $P = .047$).

Table 1. Demographic Data, Comorbidities, Indications, and Sedative Doses for Colonoscopy

	VE group (n = 140)	EE group (n = 76)	*P* value
Age (*y*), mean ± SD	77.4 ± 1.5	92.6 ± 2.5	<.001
Sex (male), n (%)	64 (45.7)	37 (48.7)	.676
ASA class ≥III, n (%)	7 (5.0)	20 (26.3)	<.001
Indications for colonoscopy, n (%)			
Anemia, occult blood loss	35 (25.0)	19 (25.0)	1.000
Diarrhea	17 (12.1)	3 (3.9)	.047
Altered bowel habit	21 (15.0)	10 (13.2)	.712
Rectal bleeding	41 (29.3)	32 (42.1)	.057
Abdominal pain	22 (15.7)	4 (5.3)	.024
Abnormal imaging test	3 (2.1)	6 (7.9)	.043
Undefined	1 (0.7)	2 (2.6)	.250
Racial background, n (%)			
White	99 (70.7)	61 (80.3)	.126
Black	5 (3.6)	5 (6.6)	.315
Asian American	10 (7.1)	7 (9.2)	.590
Not stated or undefined	26 (18.6)	3 (3.9)	.003
Inpatient status, n (%)	30 (21.4)	34 (44.7)	<.001
Comorbidities, n (%)			
Diabetes	37 (26.4)	13 (17.1)	.121
Cardiac conditions[a]	15 (10.7)	25 (32.9)	<.001
Pulmonary conditions	12 (8.6)	5 (6.6)	.604
Renal diseases	12 (8.6)	9 (11.8)	.438
Charlson score, mean ± SD	1.4 ± 1.43	1.8 ± 1.76	.047
Sedative medications[a]			
General anesthesia,[b] n (%)	0 (0.0)	5 (6.6)	<.001
Propofol deep sedation,[c] n (%)	2 (1.4)	1 (1.3)	.946
Midazolam dose (*mg*), mean ± SD	3.5 ± 1.6	2.4 ± 1.4	<.001
Fentanyl dose (*μg*), mean ± SD	84.0 ± 28.6	57.5 ± 31.2	<.001

SD, standard deviation.
[a]Including congestive heart failure or coronary artery disease with previous myocardial infarction.
[b]Refers to general anesthesia with endotracheal intubation.
[c]Refers to propofol deep sedation without intubation, administered by an anesthesia professional.

Procedural Success Rates

As shown in Table 2, the colonoscopy completion rate was lower in the EE group than in the VE controls (80.3% vs 99.3%, $P < .001$). When patients with impassable lesions were excluded, the adjusted completion rate was still lower in the EE group (88.2% vs 99.3%, $P < .001$). Overall, pediatric colonoscopes were more commonly used in the EE group than in the VE controls (48.6% vs 27.1%, $P = .002$). Of the 15 incomplete colonoscopies in the EE group, 4 were due to poor bowel preparation, 3 to intraprocedural adverse events, and 6 to impassable colonic masses, and 2 were never started because of complications with the bowel preparation. In 10 of these incomplete colonoscopies, the CF180 adult colonoscope was used, whereas the PCF180 pediatric colonoscope was used in the other 3; there were no cases in which the endoscopist used both adult and pediatric colonoscopes. The only incomplete colonoscopy in the VE group was due to colonic tortuosity and was performed using the pediatric colonoscope. Inadequate bowel preparation was much more common in the EE group than in the VE group (29.7% vs 15.0%,

Table 2. Performance Outcomes and Adverse Events of Colonoscopy

	VE group (n = 140)	EE group (n = 76)	*P* value
Overall completion rates, n (%)	139 (99.3)	61 (80.3)	<.001
Adjusted completion rates,[a] n (%)	139 (99.3)	67 (88.2)[a]	<.001
Reason for incompletion[b]			
Technical difficulty	1 (0.7)	0 (0.0)	.460
Poor preparation	0 (0.0)	4 (5.3)	.006
Impassable mass	0 (0.0)	6 (7.9)	.001
Adverse events	0 (0.0)	3 (3.9)	.018
Other[b]	0 (0.0)	2 (2.6)	.054
Adequate preparation, n (%)	119 (85.0)	52 (70.3)[c]	.011
Difficulty of procedure ≥ moderate, n (%)	8 (5.7)	8 (10.8)[c]	.178
Type of colonoscope used			
Olympus CF180 adult colonoscope	102 (72.9)	38 (51.4)[c]	.002
Olympus PCF180 pediatric colonoscope	38 (27.1)	36 (48.6)[c]	
Overall adverse events, n (%)	1 (0.7)	7 (9.2)	.002
Gastrointestinal events	1 (0.7)	1 (1.3)	.659
Cardiopulmonary events	0 (0.0)	4 (5.3)	.006
Other adverse events[d]	0 (0.0)	2 (2.6)	.054
Severe adverse events[e]	0 (0.0)	4 (5.3)	.006

[a]When calculating adjusted completion rates, patients with impassable strictures or masses were not considered to be cases of incomplete colonoscopies.
[b]Two colonoscopies were canceled because of complications during bowel preparation.
[c]These percentages were calculated by using the number of patients who actually underwent colonoscopy (74) after 2 patients whose colonoscopies were canceled because of bowel preparation complications were excluded.
[d]These included 1 case of intraprocedural agitation and 1 post-procedural musculoskeletal complication in the form of shoulder pain.
[e]Severe adverse event was defined as any symptomatic cardiopulmonary event, post-polypectomy bleed or perforation, or any complication requiring hospitalization, transfusion, or abortion of the procedure.

$P = .011$), but there was no difference in the proportion of procedures noted as being technically difficult in the 2 groups.

Adverse Events

Compared with the VE controls, the EE group showed a higher overall complication rate (9.2% vs 0.7%, $P = .002$), most of which could be attributed to cardiopulmonary adverse events (5.3% vs 0%, $P = .006$). Severe adverse events were significantly more frequent in the EE group (5.3% vs 0%, $P = .006$). In the EE group, 3 patients had major cardiopulmonary complications (1 non-fatal myocardial infarction, 1 case of symptomatic bradycardia, and 1 case of tachycardia), 1 had a post-polypectomy bleed 1 day after the colonoscopy, and 3 had minor complications (1 transient intraprocedural oxygen desaturation, 1 case of severe intraprocedural agitation, and 1 post-procedural musculoskeletal event in the form of shoulder pain, possibly a result of awkward positioning during the colonoscopy) (Table 2). Furthermore, 2 of the patients had to have their colonoscopies canceled because the adverse events developed during the bowel preparation. In the VE control group, 1 patient had a post-polypectomy bleed 2 days after the procedure, but there were no cardiopulmonary complications. There were no deaths in either group within 30 days of the procedure. There were no post-procedural emergency department visits or unplanned hospitalizations in either group, partly because many of the patients with complications were already inpatients. Because of the small number of complications, multivariate logistic regression was not possible. On univariate analysis, the 8 patients (7 from the EE group and 1 from the VE group) who had complications had Charlson scores ranging from 0 to 3, with a mean score of 1.48; 5 of 8 patients (62.5%) with complications were inpatients, including all the patients with major complications.

Diagnostic Yields

Advanced neoplasias were significantly more common in the EE group than in the VE controls ($P < .001$) (Table 3). If we considered only subjects with neoplasia, the EE group had significantly more neoplastic polyps ($P < .001$), larger lesions ($P = .002$), and more polyps with malignant (high-grade dysplastic or cancerous) histology ($P = .037$) than the VE controls. However, the shape and anatomic (right vs left colon) distribution of lesions were similar between the 2 groups (all $P > .1$). The EE group had 10 cases of CRC (13.5%) and 1 of high-grade dysplasia (1.4%) out of the 74 who actually went through colonoscopy, whereas the VE group had only

Table 3. Diagnostic Yields of Colonoscopy

	VE group (n = 140)	EE group[a] (n = 74)	*P* value
Diagnostic yield, n (%)			
Advanced neoplasia	9 (6.4)	21 (28.4)	<.001
High-grade dysplasia	0 (0.0)	1 (1.4)	.168
CRC	3 (2.1)	10 (13.5)	<.001
Non-advanced neoplasia	37 (26.4)	23 (31.1)	.471
Overall benign disease, n (%)			
Diverticulosis	95 (67.9)	50 (67.6)	.966
Hemorrhoids	54 (38.7)	29 (39.2)	.930
Ischemic colitis	13 (11.4)	2 (2.7)	.073
Characteristics of neoplasia			
Patients with neoplasia, n (%)	46 (32.9)	44 (59.5)	<.001
Number of lesions per patient, mean ± SD	1.9 ± 1.6	2.4 ± 2.6	.257
Size (*mm*), mean ± SD	7.7 ± 7.3	14.8 ± 12.6	.002
Shape, non-polypoid, n (% *of neoplasia*)	23 (50.0)	20 (45.5)	.666
Location, right-sided, n (% *of neoplasia*)	29 (63.0)	29 (65.9)	.776

SD, standard deviation.
[a]Two cases were excluded from analysis because their colonoscopies were canceled after bowel preparation complications.

3 cases of CRC (2.1%) and no cases of high-grade dysplasia ($P < .001$ for CRC). Two patients in the EE group had ischemic colitis versus 13 in the VE group ($P = .073$). Because of the small number of subjects in the EE group, multivariate logistic regression was not performed, but on univariate analysis, age and procedural indication seemed to be associated with significant neoplastic findings. Of 9 VE patients with advanced neoplasia, 6 presented with some form of gastrointestinal bleeding, whereas in the EE group, 11 of 21 had bleeding. In contrast, male sex and family history were not associated with increased risk for advanced neoplasia (data not shown).

Discussion

This is a controlled study evaluating the performance and safety of diagnostic colonoscopy in nonagenarians, with a concurrent comparison group consisting of 75- to 79-year-old patients who, although described as very elderly, would still be commonly encountered in daily colonoscopy practice. Previous studies have mostly focused on octogenarians, with a meta-analysis showing that the colonoscopy completion rate was 84.7% for patients ≥80 years old.[10] For those older than 85 years, a retrospective study reported only a 69% completion rate, mostly because of poor bowel preparation and severe diverticular disease,[14] whereas a prospective study comparing octogenarians and non-octogenarians also showed a lower completion rate in the former, again mostly attributed to preparation quality.[6] In fact, inadequate bowel preparation was a major factor in many studies that demonstrated lower colonoscopy completion rates in VE patients.[6,8,15] In a meta-analysis, suboptimal bowel preparation was documented in 12.1% of patients ≥80 years old,[10] with one study showing as many as 25.9% of such patients failing the bowel preparation.[16] A recent review suggested that inadequate bowel preparation in octogenarians may be due to delayed gastrointestinal motility, greater difficulty understanding preparation instructions, and more comorbidities.[17] Nonagenarians, who are more likely to have comorbid conditions that make them ineligible for small-volume alternative osmotic laxatives, may find ingestion of 4 L pegylated ethylene glycol more challenging than younger patients.[18] In our study, colonoscopy in EE patients was associated with lower completion rates and higher likelihood of inadequate bowel preparation than in VE patients, showing that the trend of worsening difficulties with procedural completion and bowel preparation continues and even accelerates as one gets into the tenth decade of life.

It is well-established that increasing prevalence of colorectal neoplasia accompanies increasing age.[7,14,19–23] The reported prevalence of CRC in octogenarians undergoing colonoscopy has ranged from 3.7% to 14.2%.[19–22] In terms of diagnostic yield for advanced neoplasia, reported values varied from 50.9% in a small prospective study (n = 110)[9] to 13.0% in a large retrospective study (n = 1112).[7,19] In another study on patients ≥85 years old,[14] colonoscopy revealed a finding that explained the patient's symptoms in 37% of cases. Previous studies were limited by a number of factors, including small sample size,[7,22,23] uncontrolled study design,[14,19,21] or inclusion of different indications (screening, surveillance, and diagnostic) for colonoscopy.[19] These limitations might explain the wide range of yields reported in VE patients. In our study, one of very few controlled studies on this topic, colonoscopy in EE patients showed even higher yields of advanced neoplasia when compared with VE controls, who themselves had very high yields relative to middle-aged patients. As expected, patients in both groups had high prevalence of benign conditions such as diverticulosis and hemorrhoids. Only 15 patients overall were found to have ischemic colitis; these small numbers reflect our strategy of performing abdominal computed tomography first on elderly patients whose presentations suggest ischemic colitis (abdominal pain accompanied by hematochezia); if the imaging shows colitis, we try to avoid colonoscopy unless absolutely necessary.

The safety issues associated with colonoscopy in the elderly are of critical importance. At the extremes of age, a 10-year increment in age may represent a greater increased risk for complications and morbidity than a similar age increment for middle-aged patients. In other words, whereas we may not expect much difference in risks between 50-year-old and 60-year-old patients, there may be much more significant risk differences between 80-year-old and 90-year-old patients. Indeed, in our study, EE patients showed a significantly higher rate of cardiopulmonary and severe adverse events compared with VE patients, as well as higher overall complication rates. Previously reported complication rates in octogenarians have been inconsistent, with some earlier studies reporting no increased adverse event risks for VE patients.[23–27] More recently, a meta-analysis of 20 studies concluded that patients ≥80 years old were at increased risk for overall adverse events, perforation, and cardiopulmonary incidents.[10] Asian studies have also reported higher risks of cardiovascular complications, despite the fact that elderly patients received lower doses of sedatives.[25] In a large study that had an overall perforation rate of 0.082%, advanced age was a significant predictor of perforation.[27] In contrast, a Clinical Outcomes Research Initiative (CORI) database study, which included 85 centers and 530 physicians,[24] found that adverse events directly or potentially related to colonoscopy were noted in only 0.5% of 1147 patients ≥80 years old. However, only perforation, bleeding, post-polypectomy syndrome, and diverticulitis incidents were recorded in the CORI data; cardiovascular complications, one of the most significant dangers of colonoscopy in elderly patients, were not analyzed.[24] In other studies,[19,26] the overall major adverse event rate in

octogenarians was relatively low, between 0.2% and 0.6%. Our study suggests that colonoscopy in nonagenarians should be performed only after careful consideration of potential risks. In our study sample, the proportion of ASA III or higher patients was relatively low, a reflection of our attempts to avoid performing colonoscopies on the sickest elderly patients unless absolutely necessary (if at all possible, we use noninvasive methods to evaluate the colon). Because ASA classes are subjective and known to have only mediocre interobserver reliability,[28] the non–age-adjusted Charlson comorbidity score was also recorded for each subject. Because of the small number of adverse events, it is difficult to demonstrate any correlation between complication risks and Charlson comorbidity scores; the mean Charlson score of 1.48 for the 8 patients who had complications is not noticeably different from the mean score of 1.4–1.8 in the entire study sample. Nevertheless, when determining risk, the overall health status of the patient should be considered instead of relying on rigid age cutoffs.[17]

This study has some limitations. First, the generalizability of this study may be limited, because the procedures were all done in a tertiary referral center by highly experienced endoscopists. Second, because the required sample size was calculated by using advanced neoplasia prevalence, there is the possibility of a type 2 error when comparing rare end points such as adverse events. As it turned out, the number of EE subjects in our study was slightly less than the sample size calculation requirements because of the small number of nonagenarians undergoing colonoscopy every month. However, a type 2 error does not appear to be an issue in this study because even with the smaller sample size, we demonstrated significant differences in most of the compared parameters (such as advanced neoplasia prevalence, complication rates, and colonoscopy completion rates). Third, we chose to use 75- to 79-year-olds in our control group because we believe that comparing our EE nonagenarians against patients who, although VE, would still be commonly encountered in gastroenterology practices would be more meaningful than comparing nonagenarians against middle-aged patients (eg, 50- to 60-year-olds). Previous studies from our center have already demonstrated that septuagenarians have higher colonoscopic yields than middle-aged patients.[29] Also, 75- to 79-year-olds are the youngest group of patients not advised to undergo routine screening colonoscopy according to United States Preventive Services Task Force guidelines (which recommend screening up to age 75)[12] but are still often referred for diagnostic colonoscopy. Finally, bowel preparation quality was not measured by using a validated quantitative scale such as the Boston Bowel Preparation score.

In conclusion, even when compared against 75- to 79-year-old controls, colonoscopy in EE nonagenarians was associated with a significantly higher risk of incomplete colonoscopy, inadequate bowel preparation, and adverse events, although the yield for advanced neoplasia was correspondingly higher as well. In addition to age, bleeding indications were associated with an increased risk of advanced neoplasia or CRC and may serve to identify EE patients more likely to benefit from colonoscopy. On the other hand, inpatient status and age were associated with adverse events. Therefore, careful assessment of the risks and benefits must precede any attempt at colonoscopy in EE patients. Alternative noninvasive methods of evaluating the colon, such as computed tomographic colonography, should be considered before resorting to colonoscopy.

Supplementary Material

Note: To access the supplementary material accompanying this article, visit the online version of *Clinical Gastroenterology and Hepatology* at www.cghjournal.org, and at http://dx.doi.org/10.1016/j.cgh.2015.06.036.

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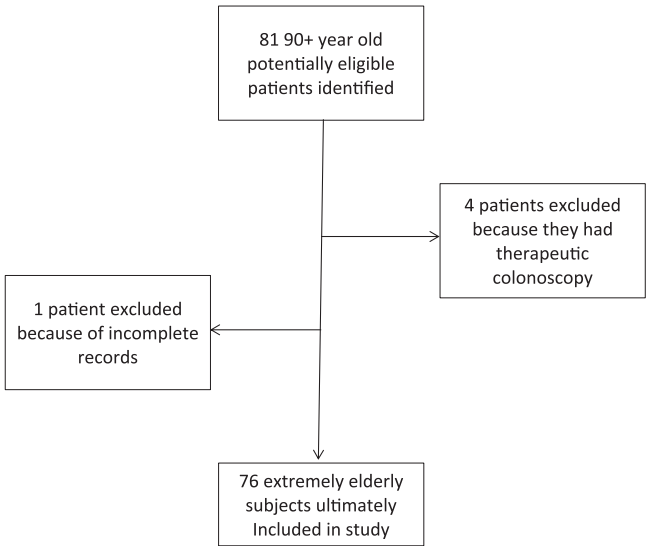
Conflicts of interest
The authors disclose no conflicts.



Supplementary Figure 1. Flow diagram for subject recruitment in the Extremely Elderly group.