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Complications of Colonoscopy in an Integrated Health Care Delivery System

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Background: Information about colonoscopy complications, particularly postpolypectomy bleeding, is limited.

Objective: To quantify the magnitude and severity of colonoscopy complications.

Design: Retrospective cohort.

Setting: Kaiser Permanente of Northern California.

Patients: 16 318 members 40 years of age or older undergoing colonoscopy between January 1994 and July 2002.

Measurements: Electronic records reviewed for serious complications, including hospital admission within 30 days of colonoscopy for colonic perforation, colonic bleeding, diverticulitis, the postpolypectomy syndrome, or other serious illnesses directly related to colonoscopy.

Results: 82 serious complications occurred (5.0 per 1000 colonoscopies [95% CI, 4.0 to 6.2 per 1000 colonoscopies]). Serious complications occurred in 0.8 per 1000 colonoscopies without biopsy or polypectomy and in 7.0 per 1000 colonoscopies with biopsy or polypectomy. Perforations occurred in 0.9 per 1000 colonoscopies (CI, 0.5 to 1.5 per 1000 colonoscopies) (0.6 per 1000 without biopsy or polypectomy and 1.1 per 1000 with biopsy or polypectomy). Postbiopsy or postpolypectomy bleeding occurred in 4.8 per 1000 colonoscopies with biopsy (CI, 3.6 to 6.2 per 1000 colonoscopies). Biopsy or polypectomy was associated with an increased risk for any serious complication (rate ratio, 9.2 [CI, 2.9 to 29.0] vs. colonoscopy without biopsy). Ten deaths (1 attributable to colonoscopy) occurred within 30 days of the colonoscopy.

Limitations: 99.3% (16 204) of colonoscopies were nonscreening examinations. The rate of complications may be lower in a primary screening sample. The small number of observed adverse events limited power to detect risk factors for complications.

Conclusions: Colonoscopy with biopsy or polypectomy is associated with increased risk for complications. Perforation may also occur during colonoscopies without biopsies.

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Colonoscopy is the final step in colorectal cancer screening, regardless of the initial test chosen, and is recommended for primary colorectal cancer screening in average-risk persons (1–4). Colorectal cancer screening targets apparently healthy people; therefore, the magnitude of the risk and severity of the harms from screening are important issues to consider when selecting a screening strategy (5). Described complications of colonoscopy include colonic perforation, postbiopsy and postpolypectomy bleeding, and postpolypectomy syndrome (a transmural colonic burn, marked by localized abdominal pain without evidence of frank perforation) (6). Diverticulitis, which is caused by a microscopic perforation of the colon, can also theoretically be caused by colonoscopy in persons with preexisting diverticulosis.

Most estimates of colonoscopy complications come from referral centers (7–12) or closely monitored clinical trials (13), limiting the generalizability of the results to community practice. In a large series by a group of ambulatory endoscopy centers (14), endoscopists self-reported complications, possibly underestimating them (15). In this study, researchers were unable to evaluate postpolypectomy bleeding. Postpolypectomy bleeding is particularly difficult to assess in studies because its occurrence is often delayed. The U.S. Preventive Services Task Force (16), in a recent evidence review of colonoscopy complications, concluded that postpolypectomy bleeding was reported in relatively few studies and delayed bleeding was not reported at all. Studies using administrative databases typically lack access to detailed records, including indications, depth of insertion, and whether or how polyps are removed (17).

For the present study, we relied on the automated data of Kaiser Permanente, Northern California (KPNC), an integrated health care delivery system. Colonoscopy was most often used to follow-up other tests, such as fecal occult blood tests, flexible sigmoidoscopy, or barium enema, or to conduct surveillance in persons with a personal or family history of colorectal cancer or colorectal adenoma. Few colonoscopies were performed for primary screening. We identified patients undergoing colonoscopy and followed them for 30 days after the procedure for hospitalization for procedure-related complications. For this analysis, we defined any procedure-related complication that led to hospitalization as a "serious complication."

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METHODS

We used KPNC electronic medical records to select patients who had undergone colonoscopies between 1 January 1994 and 16 July 2002. This was an observational study, conducted in medical centers throughout the KP health care system, evaluating practice patterns as they existed at the time the included colonoscopies were performed by the endoscopists in the study. Electronic records were reviewed to identify immediate complications, outpatient visits, or hospital admission within 30 days of colonoscopy. Colonoscopies were included in the analysis if they were performed for patients 40 years of age or older who were undergoing coloscopy because of a family history of colorectal cancer or adenomatous polyp, as a follow-up to a positive screening test (that is, polyp or cancer at sigmoidoscopy, positive results on a fecal occult blood test, or abnormal barium enema radiography), for surveillance because of a previously detected adenomatous polyp or colorectal cancer, or for primary screening. Colonoscopies were not included if the procedure was being performed to diagnose symptoms (for example, diarrhea, abdominal pain, gastrointestinal bleeding, history of rectal bleeding, or anemia) or if patients had outpatient visits 6 months before the procedure for abdominal pain, anemia, diarrhea, or constipation.

A total of 35 945 procedures performed at KPNC between 1 January 1994 and 16 July 2002 were identified by using 2 electronic KPNC endoscopy databases. The first database, the Colorectal Cancer Prevention (CoCaP) program database, contains detailed information from 1994 to 1996 on sigmoidoscopies, follow-up colonoscopies, and the results of pathologic testing. Information available in the CoCaP database includes depth of insertion; size, number, and treatment of polyps; limitations of the procedure; and identity of the examiner. The second database, the EndoLog Pro database, includes colonoscopy reports from 1995 to 2002 from 5 KP facilities. The database contains information on number of polyps found and their treatment, depth of insertion, quality of bowel preparation, identity of the examiner, and any immediate complications.

Some patients underwent more than 1 colonoscopy during the study period. If a colonoscopy was incomplete because of poor bowel preparation, and a second colonoscopy was performed within 3 months, only the second colonoscopy was included in the cohort. If a patient required a second colonoscopy to complete removal of a polyp, only the first colonoscopy was included in the cohort. Patients requiring frequent surveillance may have been screened more than once during the 7-year study period; colonoscopies were included for these patients if the interval between the colonoscopies was greater than 6 months.

Identification of Eligible Cases

Of the 35 945 procedures, 4646 were excluded because patients were younger than 40 years of age; 9499 were excluded because the procedures were performed for excluded indications or for symptoms; and 2411 were excluded because of poor preparation (with a second examination rescheduled in 90 days), interval since previous procedure was less than 6 months, previous colon surgery, or because the procedure was for follow-up removal of residual polyps or for marking polyp site for surgery. Inpatient procedures ($n = 125$) and procedures for KPNC nonmembers ($n = 57$) were excluded. Procedures were also excluded if patients had inpatient or outpatient visits for lower gastrointestinal bleeding, abdominal pain, anemia, diarrhea, or constipation 6 months before the procedures ($n = 2689$). A total of 16 318 procedures were included in the analysis.

Identification of Possible Complications

A 2-step procedure was used to identify serious complications. First, we analyzed KP electronic databases for evidence of patients being admitted to the hospital (a KPNC or nonprogram hospital) within 30 days of colonoscopy. We focused on admissions that could be associated with colonoscopy complications or complications of procedural sedation, including colonic perforation (International Classifications of Diseases, 9th revision, [ICD-9] codes 569.83 and 998.2]; lower gastrointestinal bleeding (ICD-9 558.9, 578.1, 995.2, 995.89, and 998.1 to 998.13); anemia, not explained by preexisting conditions (ICD-9 280.0 and 285.0 to 285.9); diverticulitis (ICD-9 562.11); colitis, not present during initial endoscopy (ICD-9 556 to 556.9); aspiration pneumonia (ICD-9 507); pneumonia, organism unspecified (ICD-9 486); infection (ICD-9 780.6, 790.7, and 424.9 to 424.99); ab-

Context

Data on the frequency of colonoscopy complications from population-based samples are lacking.

Contribution

The authors searched electronic health records at Kaiser-Permanente of Northern California for patients who died or who had complications due to colonoscopy within 30 days of the procedure. Almost all procedures were diagnostic or for surveillance of previous abnormal findings. Of 16 318 eligible procedures, 82 involved serious complications (5 in 1000 procedures). Of the 82 complications, 95% followed biopsy or removal of polyps, and 62% of the polyps removed were smaller than 10 mm. The perforation rate was 1 in 1000 procedures. One death was related to colonoscopy.

Cautions

Less than 1% of procedures studied were screening colonoscopies, so these complication rates might not apply to screening examinations.

—The Editors

Table 1. **Number of Procedures and Percentage with Biopsy or Polypectomy by Indication for Colonoscopy**

Variable	Total Number of Procedures	Total Procedures, %	Biopsy or Polypectomy, %
Polyp seen on sigmoidoscopy	7306	44.8	91.5
History of polyps	3805	23.3	53.1
Family history of colorectal cancer	3099	19.0	35.7
Unspecified follow-up to sigmoidoscopy	747	4.6	83.9
Stool positive for occult blood	565	3.6	44.2
History of cancer	371	2.3	47.2
Abnormal results on barium enema	258	1.6	56.2
Primary screening	117	0.7	33.3
Cancer seen on sigmoidoscopy	50	0.3	70.0
Total eligible procedures	16 318	100.0	67.9

dominal pain (ICD-9 789.0 to 789.09); complications of procedure (E872, E872.8, E872.9, E879, E879.8, and E879.9); complications secondary to anesthesia (ICD-9 995.4, 997.1, and 997.3); myocardial infarction (ICD-9 410 to 410.92 and 414); and stroke (ICD-9 436). Deaths within 30 days of colonoscopy were identified through linkage with the National Death Index.

After possible cases were identified from electronic records, medical records analysts at KPNC reviewed the hardcopy medical records, computerized medical records, and laboratory records of 183 patients by using chart review forms. Analysts made photocopies of histories and physicals, discharge summaries, colonoscopy reports, operative notes, and pathology reports, and these were used to make decisions. Two physicians reviewed the photocopied records to determine whether the hospitalization or death was related to colonoscopy. Clinical judgment was used in making these decisions through a collaborative process, and decisions were made by mutual agreement. A third physician adjudicated the 1 case in which there were ongoing questions. A subsample of 44 records was reviewed by both physicians independently. The κ-statistic for this statistical analysis was 0.71 (CI, 0.52 to 0.89).

Statistical Analysis

Individual complication measures were created to reflect the incidence of serious complications in the first 30 days after colonoscopy for the following: 1) colonic perforation; 2) the postpolypectomy syndrome; 3) bleeding requiring overnight hospitalization, overall and separately for patients with or without surgery or transfusion; 4) diverticulitis requiring overnight hospitalization, overall and separately for patients with or without surgery; and 5) any other hospitalization within 30 days that was likely to have been caused or exacerbated by the procedure. Two aggregate measures were used. The first was for all of the above categories combined and the second for the most serious complications, including perforation, bleeding with transfusion, and diverticulitis requiring surgery.

For each complication measure, we calculated the incidence per 1000 colonoscopies and estimated maximum likelihood 95% CIs according to the binomial distribution. We calculated exact 95% CIs when no events were observed. Unless otherwise specified, procedures in which tissue was removed (by hot or cold biopsy or polypectomy) were referred to as colonoscopy with biopsy. Colonoscopies in which no tissue was removed were referred to as colonoscopy without biopsy. We used Poisson regression analysis to describe the bivariate association among serious complications and age, sex, and the performance of biopsy or polypectomy for 3 complication measures: 1) perforation only; 2) perforation, bleeding requiring surgery or transfusion, or diverticulitis requiring surgery; and 3) any serious complication. Because colonoscopists performed more than 1 procedure in this study, we used a generalized estimating equations approach that fit a Poisson regression model in the presence of correlated outcomes (18, 19). We used Proc Genmod in SAS, version 8.2, (SAS Institute, Inc., Cary, North Carolina), to perform all analyses. The significance level was set at 0.05. Only bivariate analyses are reported because there were too few events to allow multivariable analyses.

Role of the Funding Source

This work was funded by the Centers for Disease Control and Prevention through a contract with the Battelle Memorial Institute and a subcontract with the Kaiser Foundation Research Institute. Personnel from all organizations were involved in the design, conduct, and reporting of this study.

RESULTS

Patient and Procedure Characteristics

Among eligible patients, the 3 most common indications were polyp seen on sigmoidoscopy, previous polyp, and a family history of colorectal cancer (**Table 1**). Indication for colonoscopy and whether biopsy or polypectomy was performed were closely linked. The indications with the highest rates of biopsy or polypectomy included polyp seen on sigmoidoscopy (91.5%) and an unspecified sigmoidoscopy follow-up (83.9%). The indications with the lowest biopsy or polypectomy rate included primary

screening (33.3%) and family history of colorectal cancer (35.7%).

Patient age ranged from 40 to 100 years; the mean patient age was 62 years. Of the 16 318 eligible procedures, 5587 (34.2%) were performed on patients 50 to 59 years of age, 5683 (34.8%) were performed on patients 60 to 69 years of age, and 3673 (22.5%) were performed on patients 70 years of age or older (**Table 2**). Only 1375 (8.4%) of the patients were between 40 and 49 years of age, and 59.7% (9791) of the patients in the cohort were men and 40.3% (6575) were women. More than one half of the colonoscopies was done as a follow-up to a positive colorectal cancer screening test (for example, polyp or cancer seen on flexible sigmoidoscopy, occult blood–positive stool, abnormal barium enema, or sigmoidoscopy follow-up with missing indication); whereas 44.6% (7278) were performed for surveillance (history of cancer or polyp or family history of colorectal cancer). Fewer than 1% (117) were primary screening colonoscopies. In 2.8% (464) of the procedures it was noted that the cecum was not reached; however, information on depth of insertion was missing in approximately one quarter of the procedures.

Incidence of Serious Complications

Of the 16 318 eligible colonoscopies, we identified 183 (1.1%) cases with possible complications, according to electronic review. After chart review, 101 were determined to be unrelated to the procedure. We identified 82 patients with serious complications—78 (95%) of which had undergone colonoscopy with biopsy or polypectomy. The average age of patients with serious complications was 63 years (compared with an average age of 62 years for those without complications).

Among all patients, the incidence of serious complications was 5.0 per 1000 procedures (CI, 4.0 to 6.2 per 1000 procedures), or 1 in 200 examinations (**Table 3**). The 82 cases with complications included 15 cases of colonic perforation; 6 cases of the postpolypectomy syndrome; 53 cases of bleeding requiring hospitalization (15 cases of bleeding required surgery or transfusion and 38 cases of bleeding required inpatient observation only); 6 cases of diverticulitis (2 cases that required surgery and 4 cases that required inpatient observation and antibiotics); and 2 other serious complications related to the procedure. The 2 serious complications included a case in which the snare became caught in a large polyp resulting in the need for a right colectomy to remove the snare and the polyp, and a case of diabetic ketoacidosis associated with the colonoscopy preparation. No complications were observed among the 117 screening colonoscopy procedures.

Death occurred within 30 days in 10 patients (0.6 per 1000 examinations). The death of 1 patient who developed congestive heart failure and sepsis after a transfusion for postpolypectomy bleeding was directly related to colonoscopy. Other deaths were due to a variety of causes, some of which may have been the underlying indication for colonoscopy (for example, a disseminated malignant condition). Myocardial infarction occurred after 9 colonoscopies. One myocardial infarction was fatal; hospitalization had occurred 6 days following colonoscopy. The remaining 8 were not fatal. Patients with myocardial infarction were hospitalized an average of 16.6 days after the colonoscopy (range, 6 to 24 days).

Colonoscopy with biopsy was associated with increased risk for serious complications ($P < 0.0001$). The incidence of serious complications was 7.0 per 1000

Table 2. **Patient Demographic and Clinical Characteristics by Biopsy or Polypectomy Status**

Characteristic	Total Cohort (*n* = 16 318), *n* (%)	No Biopsy or Polypectomy (*n* = 5235), *n* (%)	Biopsy Only (*n* = 1614), *n* (%)	Single Polypectomy (*n* = 3997), *n* (%)	Several Polypectomies (*n* = 5472), *n* (%)
Age, y					
40–49	1375 (8.4)	763 (14.6)	185 (11.5)	245 (6.1)	182 (3.3)
50–59	5587 (34.2)	1739 (33.2)	476 (29.5)	1508 (37.7)	1864 (34.1)
60–69	5683 (34.8)	1634 (31.2)	531 (32.9)	1381 (34.6)	2137 (39.1)
≥70	3673 (22.5)	1099 (21.0)	422 (26.2)	863 (21.6)	1289 (23.6)
Sex					
Male	9743 (59.7)	2615 (50.0)	919 (56.9)	2383 (59.6)	3826 (69.9)
Female	6575 (40.3)	2620 (50.0)	695 (43.1)	1614 (40.4)	1646 (30.1)
Indication					
Follow-up to positive test*	8926 (54.7)	1184 (22.6)	450 (27.9)	2,838 (71.0)	4454 (81.4)
Primary screening/surveillance†	7392 (45.3)	4051 (77.4)	1164 (72.1)	1159 (29.0)	1018 (18.6)
Depth of insertion					
Cecum	11 420 (70.0)	3398 (64.9)	1130 (70.0)	2831 (70.8)	4061 (74.2)
Before cecum	464 (2.8)	139 (2.7)	41 (2.5)	158 (4.0)	126 (2.3)
Unknown	4434 (27.2)	1698 (32.4)	443 (27.5)	1008 (25.2)	1285 (23.5)

* Follow-up to a positive test includes polyp seen on flexible sigmoidoscopy, occult blood–positive stool, cancer seen on flexible sigmoidoscopy, abnormal results on barium enema, and sigmoidoscopy follow-up with missing indication.
† Primary screening or surveillance includes history of polyps, history of cancer, family history of colorectal cancer, and primary screening colonoscopy.

Table 3. **Number and Incidence of Serious Complications in the First 30 Days following Colonoscopy with and without Biopsy***

Variable	All Colonoscopies (*n* = 16 318)		Colonoscopy without Biopsy (*n* = 5235)		Colonoscopy with Biopsy (*n* = 11 083)	
	Number	Incidence (95% CI)	Number	Incidence (95% CI)	Number	Incidence (95% CI)
All serious complications	82	5.0 (4.0–6.2)	4	0.8 (0.2–1.8)	78	7.0 (5.6–8.7)
Any bleeding	53	3.2 (2.5–4.2)	0	0.0 (0.0–0.6)	53	4.8 (3.6–6.2)
Surgery or transfusion	15	0.9 (0.5–1.5)	0	0.0 (0.0–0.6)	15	1.4 (0.8–2.2)
No surgery or transfusion	38	2.3 (1.7–3.1)	0	0.0 (0.0–0.6)	38	3.4 (2.5–4.6)
Perforation	15	0.9 (0.5–1.5)	3	0.6 (0.1–1.5)	12	1.1 (0.6–1.8)
Postpolypectomy syndrome	6	0.4 (0.1–0.7)	0	0.0 (0.0–0.6)	6	0.5 (0.2–1.1)
Any diverticulitis	6	0.4 (0.1–0.7)	1	0.2 (0.0–0.8)	5	0.5 (0.2–1.0)
Surgery	2	0.1 (0.0–0.4)	1	0.2 (0.0–0.8)	1	0.1 (0.0–0.4)
No surgery	4	0.2 (0.1–0.6)	0	0.0 (0.0–0.6)	4	0.4 (0.1–0.8)
Other serious illness	2	0.1 (0.0–0.4)	0	0.0 (0.0–0.6)	2	0.2 (0.0–0.6)

* Incidence per 1000 procedures.

colonoscopies with biopsy (CI, 5.6 to 8.7 per 1000 colonoscopies with biopsy), compared with only 0.8 serious complications per 1000 colonoscopies without biopsy (CI, 0.2 to 1.8 per 1000 colonoscopies without biopsy). Postbiopsy or postpolypectomy bleeding occurred in 4.8 per 1000 procedures (CI, 3.6 to 6.2 per 1000 procedures) (**Table 3**).

The most common serious complication for colonoscopy without biopsy was perforation, with an incidence rate of 0.6 serious complications per 1000 procedures (CI, 0.1 to 1.5 per 1000 procedures). The 3 perforations in colonoscopy without biopsy included a case in which the colonoscopist noted a "narrow/tortuous sigmoid colon," and depth of insertion was reported as the transverse colon. In another case, perforation occurred in an area of unsuspected colitis that was not seen because of poor preparation. In the final case, no difficulty was noted with the colonoscopy. Diverticulitis occurred once.

The serious complication rate after the removal of polyps larger than 10 mm (11.4 per 1000 procedures) was higher than the serious complication rate after removal of smaller polyps (6.5 per 1000 procedures) ($P = 0.025$). However, because most polyps removed are less than 10 mm in size, 33 of 53 bleeding episodes (62% of bleeding episodes and 40% of all serious complications) occurred following removal of polyps smaller than 10 mm. In our sample, polyps removed from the cecum were not associated with a higher rate of serious complications than those removed from other locations in the colon.

Most serious complications occurred in the first 7 days following colonoscopy, and few occurred after 14 days. The incidence of serious complications in the first 7 days following colonoscopy was 3.1 per 1000 colonoscopies (CI, 2.4 to 4.1 1000 colonoscopies), increasing to 4.7 per 1000 colonoscopies (CI, 3.7 to 5.9 per 1000 colonoscopies) by 14 days and 5.0 per 1000 colonoscopies (CI, 4.0 to 6.2 per 1000 colonoscopies) within 30 days. All perforations were noticed within 7 days of the colonoscopy; later serious complications were due to bleeding. Of the 53 patients experiencing postpolypectomy bleeding, 31 (58.5%) were hospitalized more than 7 days after colonoscopy.

Nearly all endoscopists performing colonoscopy at KPNC were board-certified gastroenterologists (96% of the colonoscopies were performed by gastroenterologists, 2% by internists, and 2% were not identified), more than 80% of whom performed at least 150 colonoscopies per year. The number of serious complications identified for each endoscopist in the study dataset ranged from none (39 endoscopists) to 6 (1 endoscopist). The average number of study-related colonoscopies per endoscopist highly correlated with the number of complications recorded for each endoscopist ($R^2 = 0.98$). Colonoscopists with no complications averaged 79 study colonoscopies. The colonoscopist with 6 complications performed 808 study-related colonoscopies. There was no statistically significant association between facility of colonoscopy and complication rate. Within-facility variation in rate by endoscopist was explained by procedure volume.

We were unable to determine whether years of experience since board certification, yearly volume of colonoscopies, or specialty status were statistically significantly associated with the occurrence of serious adverse events because of the uniformity of experience and specialty status across colonoscopists in our study.

Bivariate Poisson Regression

The strongest predictor for a serious complication in the first 30 days following colonoscopy was whether a biopsy or polypectomy was performed (**Table 4**). The risk for any serious complication was 9.2 times higher following colonoscopy with biopsy than colonoscopy without biopsy (CI, 2.9 to 29.0). The risk for perforation increased 5-fold in patients 60 years of age and older compared with patients 40 to 59 years of age. Bleeding requiring transfusion and diverticulitis were also more common among older patients (risk ratio, 1.8), but this was not statistically significant (CI, 0.81 to 3.9).

DISCUSSION

The principal finding of this study was that perforations occurred nearly once in every 1000 colonoscopies and that serious complications occur in 5 of every 1000. Removal of polyps through biopsy with a snare or forceps increases the risk for a serious complication nearly 9-fold compared with colonoscopy without biopsy. Postpolypectomy bleeding was the most common complication. Most bleeding was self-limited, not requiring surgery or transfusion. Patients age 60 years or older had an increased risk for perforation. Bleeding accounted for all observed serious complications more than 7 days after colonoscopy throughout the 30-day observation period. Our results are consistent with other recent reports of colonoscopy complications (16) in which researchers found a range of 0.07% to 0.72% for colonic perforations in therapeutic colonoscopy and a range of 0.2% to 2.67% for postpolypectomy bleeding. Our sample size, detailed data, and follow-up time allowed us to evaluate the association of polyp removal with the incidence of procedure-related serious complications, particularly delayed postpolypectomy bleeding. Of interest, patients with 10 mm or larger polyps were twice as likely as patients with smaller polyps to experience postpolypectomy bleeding. However, because smaller polyps are more common, most postpolypectomy bleeding occurred in patients with small, potentially unimportant polyps. Delayed postpolypectomy bleeding suggests a need for longer postprocedure monitoring. Experts have recommended cold snare polypectomy for small polyps as a possibly safer alternative to electrocautery (20).

Our study had several limitations. We lacked detailed information on comorbid conditions among patients, and therefore, we were unable to evaluate whether a particular condition was associated with increased risk for complications. Of importance, this was not a screening colonoscopy sample and we had very few screening colonoscopies available for study, limiting our ability to investigate the risk factors for serious complications in primary screening colonoscopies. Kaiser Permanente Northern California launched a screening program in 1994. However, screening colonoscopy was not encouraged for average-risk patients because of concern for complications, feasibility, and the small magnitude of incremental benefit of colonoscopy over flexible sigmoidoscopy. Kaiser Permanente Northern California continued to emphasize flexible sigmoidoscopy as the screening test of choice throughout the study period. In a screening population, one would expect the prevalence of neoplasia to be much lower (21, 22). However, as reimbursement has changed and primary screening colonoscopy has become more commonplace, the prevalence of neoplasia found at colonoscopy is decreasing (23). In a population with a lower prevalence of neoplasia, one would expect fewer complications.

There was no uniform biopsy or polypectomy protocol in place across KPNC during the observation period. A variety of techniques have been proposed for removal of small or large polyps (20, 24). A uniform approach to biopsy or polypectomy might have reduced the incidence of postpolypectomy bleeding or perforation, although this has never been studied prospectively. Because of the limitations of our databases, we were unable to evaluate the contribution of hot biopsies, cold snares, or submucosal injection to our observed complication rate.

There are 3 important implications of this research. First, the rate of complications following colonoscopy, even colonoscopy without biopsy, is higher than that for other colorectal cancer screening tests, including flexible sigmoidoscopy (25). Although inherent differences among these endoscopic tests limit the ability to directly compare complication rates, the risks associated with colonoscopy should be considered when its incremental benefit over less invasive screening procedures is being evaluated (2). Second, delayed bleeding was not uncommon, suggesting that patients should be advised about this risk, and screening centers should have follow-up procedures in place to monitor delayed complications. Finally, most bleeding episodes occurred after the sampling or removal of polyps that were smaller than 10 mm, most of which lacked neoplastic po-

Table 4. **Poisson Regression Analyses of Predictors for Various Outcomes**

Characteristic	Bivariate Rate Ratio (95% CI)
Perforation only	
Age, *y*	
40–59	1.0
≥60	5.2 (1.4–19.2)
Sex	
Female	2.3 (0.9–6.0)
Male	1.0
Polyp removal	
None	1.0
Biopsy or polypectomy	1.9 (0.3–10.9)
Perforation, bleeding with transfusion, and diverticulitis requiring surgery	
Age, *y*	
40–59	1.0
≥60	2.7 (1.4–1.5)
Sex	
Female	1.0
Male	1.1 (0.6–2.3)
Polyp removal	
None	1.0
Biopsy or polypectomy	3.4 (1.0–11.7)
Any serious complications	
Age, *y*	
40–59	1.0
≥60	1.2 (0.9–1.7)
Sex	
Female	1.0
Male	1.4 (0.9–2.2)
Polyp removal	
None	1.0
Biopsy or polypectomy	9.2 (2.9–29.0)

tential (26–28). Continued efforts should be made to reduce the risks associated with biopsy and polypectomy in patients with small, less clinically important lesions. Techniques of noninvasive evaluation of polyps, such as chromoendoscopy (26), and confocal laser endoscopy continue to improve (29, 30). In the foreseeable future, colonoscopists may be able to study small colon polyps in situ, reducing the incidence of postpolypectomy complications.

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References

1. **Winawer S, Fletcher R, Rex D, Bond J, Burt R, Ferrucci J, et al.** Colorectal cancer screening and surveillance: clinical guidelines and rationale—Update based on new evidence. Gastroenterology. 2003;124:544-60. [PMID: 12557158]
2. Screening for colorectal cancer: recommendation and rationale. Ann Intern Med. 2002;137:129-31. [PMID: 12118971]
3. **Rex DK, Johnson DA, Lieberman DA, Burt RW, Sonnenberg A.** Colorectal cancer prevention 2000: screening recommendations of the American College of Gastroenterology. American College of Gastroenterology. Am J Gastroenterol. 2000;95:868-77. [PMID: 10763931]
4. **Smith RA, von Eschenbach AC, Wender R, Levin B, Byers T, Rothenberger D, et al.** American Cancer Society guidelines for the early detection of cancer: update of early detection guidelines for prostate, colorectal, and endometrial cancers. Also: update 2001—testing for early lung cancer detection. CA Cancer J Clin. 2001;51:38-75; quiz 77-80. [PMID: 11577479]
5. **Woolf SH.** The best screening test for colorectal cancer—a personal choice [Editorial]. N Engl J Med. 2000;343:1641-3. [PMID: 11096175]
6. **Waye JD, Kahn O, Auerbach ME.** Complications of colonoscopy and flexible sigmoidoscopy. Gastrointest Endosc Clin N Am. 1996;6:343-77. [PMID: 8673332]
7. **Waye JD, Lewis BS, Yessayan S.** Colonoscopy: a prospective report of complications. J Clin Gastroenterol. 1992;15:347-51. [PMID: 1294644]
8. **Anderson ML, Pasha TM, Leighton JA.** Endoscopic perforation of the colon: lessons from a 10-year study. Am J Gastroenterol. 2000;95:3418-22. [PMID: 11151871]
9. **Araghizadeh FY, Timmcke AE, Opelka FG, Hicks TC, Beck DE.** Colonoscopic perforations. Dis Colon Rectum. 2001;44:713-6. [PMID: 11357034]
10. **Cobb WS, Heniford BT, Sigmon LB, Hasan R, Simms C, Kercher KW, et al.** Colonoscopic perforations: incidence, management, and outcomes. Am Surg. 2004;70:750-7; discussion 757-8. [PMID: 15481289]
11. **Farley DR, Bannon MP, Zietlow SP, Pemberton JH, Ilstrup DM, Larson DR.** Management of colonoscopic perforations. Mayo Clin Proc. 1997;72:729-33. [PMID: 9276600]
12. **Lo AY, Beaton HL.** Selective management of colonoscopic perforations. J Am Coll Surg. 1994;179:333-7. [PMID: 8069431]
13. **Nelson DB, McQuaid KR, Bond JH, Lieberman DA, Weiss DG, Johnston TK.** Procedural success and complications of large-scale screening colonoscopy. Gastrointest Endosc. 2002;55:307-14. [PMID: 11868001]
14. **Korman LY, Overholt BF, Box T, Winker CK.** Perforation during colonoscopy in endoscopic ambulatory surgical centers. Gastrointest Endosc. 2003;58:554-7. [PMID: 14520289]
15. **Zubarik R, Fleischer DE, Mastropietro C, Lopez J, Carroll J, Benjamin S, et al.** Prospective analysis of complications 30 days after outpatient colonoscopy. Gastrointest Endosc. 1999;50:322-8. [PMID: 10462650]
16. **Pignone M, Rich M, Teutsch SM, Berg AO, Lohr KN.** Screening for colorectal cancer in adults at average risk: a summary of the evidence for the U.S. Preventive Services Task Force. Ann Intern Med. 2002;137:132-41. [PMID: 12118972]
17. **Gatto NM, Frucht H, Sundararajan V, Jacobson JS, Grann VR, Neugut AI.** Risk of perforation after colonoscopy and sigmoidoscopy: a population-based study. J Natl Cancer Inst. 2003;95:230-6. [PMID: 12569145]
18. **Liang KY, Zeger SL.** Longitudinal data analysis using generalized linear models. Biometrika. 1986;73:13-22.
19. **Zeger SL, Liang KY.** Longitudinal data analysis for discrete and continuous outcomes. Biometrics. 1986;42:121-30. [PMID: 3719049]
20. **Rex DK, Bond JH, Winawer S, Levin TR, Burt RW, Johnson DA, et al.** Quality in the technical performance of colonoscopy and the continuous quality improvement process for colonoscopy: recommendations of the U.S. Multi-Society Task Force on Colorectal Cancer. Am J Gastroenterol. 2002;97:1296-308. [PMID: 12094842]
21. **Lieberman DA, Weiss DG, Bond JH, Ahnen DJ, Garewal H, Chejfec G.** Use of colonoscopy to screen asymptomatic adults for colorectal cancer. Veterans Affairs Cooperative Study Group 380. N Engl J Med. 2000;343:162-8. [PMID: 10900274]
22. **Imperiale TF, Wagner DR, Lin CY, Larkin GN, Rogge JD, Ransohoff DF.** Risk of advanced proximal neoplasms in asymptomatic adults according to the distal colorectal findings. N Engl J Med. 2000;343:169-74. [PMID: 10900275]
23. **Harewood GC, Lieberman DA.** Colonoscopy practice patterns since introduction of medicare coverage for average-risk screening. Clin Gastroenterol Hepatol. 2004;2:72-7. [PMID: 15017635]
24. **Waye JD.** New methods of polypectomy. Gastrointest Endosc Clin N Am. 1997;7:413-22. [PMID: 9177143]
25. **Levin TR, Conell C, Shapiro JA, Chazan SG, Nadel MR, Selby JV.** Complications of screening flexible sigmoidoscopy. Gastroenterology. 2002;123:1786-92. [PMID: 12454834]
26. **Eisen GM, Kim CY, Fleischer DE, Kozarek RA, Carr-Locke DL, Li TC, et al.** High-resolution chromoendoscopy for classifying colonic polyps: a multicenter study. Gastrointest Endosc. 2002;55:687-94. [PMID: 11979251]
27. **Weston AP, Campbell DR.** Diminutive colonic polyps: histopathology, spatial distribution, concomitant significant lesions, and treatment complications. Am J Gastroenterol. 1995;90:24-8. [PMID: 7801943]
28. **Waye JD, Lewis BS, Frankel A, Geller SA.** Small colon polyps. Am J Gastroenterol. 1988;83:120-2. [PMID: 3341333]
29. **Kiesslich R, Burg J, Vieth M, Gnaendiger J, Enders M, Delaney P, et al.** Confocal laser endoscopy for diagnosing intraepithelial neoplasias and colorectal cancer in vivo. Gastroenterology. 2004;127:706-13. [PMID: 15362025]
30. **Sakashita M, Inoue H, Kashida H, Tanaka J, Cho JY, Satodate H, et al.** Virtual histology of colorectal lesions using laser-scanning confocal microscopy. Endoscopy. 2003;35:1033-8. [PMID: 14648417]

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