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Racial and Ethnic Disparities in Interval Colorectal Cancer Incidence: A Population-Based Cohort Study

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Abstract

Background—Interval colorectal cancers (CRC) account for 3–8% of all CRCs in the US. Data on interval CRC occurrence by race/ethnicity are scant.

Objective—To examine whether interval CRC risk among Medicare patients differs by race/ethnicity and whether this potential variation, could be accounted for by differences in quality of colonoscopy, as measured by physicians' polyp detection rate (PDR).

Design, Setting and Participants—Population-based cohort study of patients 66–75 years who received a colonoscopy between 2002–2011 in SEER-Medicare data.

Measurements—Kaplan-Meier curves and adjusted Cox models were used to estimate cumulative probabilities and hazard ratios (HR) of interval CRCs, defined as a CRC diagnosis 6–59 months after colonoscopy.

Results—There were 2,735 interval CRCs identified over 235,146 person-years of follow-up. A higher proportion of blacks (52.8%) received colonoscopy from physicians with lower PDR than whites (46.2%). PDR was significantly associated with interval CRC risk. The probability of interval CRC by the end of follow-up was 7.1% in blacks and 5.8% in whites. Compared to whites, blacks had significantly higher interval CRC risk (HR= 1.31, 95% CI 1.13, 1.51), the

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disparity was more pronounced for cancers in the rectum (HR=1.70, 95% CI 1.25, 2.31) and distal (HR=1.45, 95% CI 1.00, 2.11) than in the proximal (HR=1.17, 95% CI 0.96, 1.42) colon. Adjustment for polyp detection rate did not alter HRs by race/ethnicity, but black-white differences were greater among physicians with higher polyp detection rates.

Limitations—Colonoscopy and polypectomy were identified using billing codes.

Conclusions—Among elderly Medicare enrollees, interval CRC risk was higher in blacks than in whites, with the difference more pronounced for distal colon/rectum cancers and for physicians with higher polyp detection rates.

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Introduction

Colorectal Cancer (CRC) is the third most common cancer and second leading cause of cancer-related death in the US.(1) CRC screening is effective in reducing CRC incidence and mortality by detecting pre-cancerous lesions or cancer at more curable stages.(2–7) However, some CRCs develop in screened populations because they were missed at the time of screening or developed between recommended screenings or within surveillance intervals.(8) Interval CRCs, defined as cancers that develop after a negative colonoscopy but before the next recommended test, account for 3–8% of CRCs in the US, though estimates vary by study population.(8–10) Interval CRC risk and its associations with patient demographic and clinical factors as well as physician factors, including quality of colonoscopy metrics, has been examined in a some studies.(9–13) However, patterns of interval CRC risk by race/ethnicity are not well known.(9)

Black-white disparities in interval CRC risk are of particular concern because blacks have the highest CRC incidence and mortality rates of any race or ethnicity in the US, with incidence rates 22–27% higher than whites.(14) Approximately 40% of these disparities in CRC incidence are attributed to lower screening utilization in blacks.(15) The remaining proportion has not been fully explained though likely contributors include differences in socioeconomic status, lack of follow-up after a positive test, and risk factors.(15–18) Another possible reason for this disparity is the difference in the quality of screening tests for CRC.(15) Whereas previous studies have noted poorer quality of mammography in blacks compared with whites;(19, 20) similar detailed evidence pertaining to quality of colonoscopy and interval CRCs by race/ethnicity is not available. Thus, we examined whether interval CRC risk varies by race/ethnicity in Medicare patients 66–75 years of age and whether physician's polyp detection rate accounts for the potential differences in interval CRC risk between blacks and whites in a population-based cohort study.

Methods

Study Population

Information on patients was obtained from Medicare claims files linked to data from the National Cancer Institute's Surveillance Epidemiology and End Results (SEER) program.(21) SEER is a collection of 18 population-based cancer registries, covering 28% of the US

population. Medicare is a federally administered health insurance plan covering 97% of people ≥65 years. The SEER-Medicare database containing claims and enrollment data on a 5% random sample of cancer-free beneficiaries residing in SEER registry areas was combined with the case file to create a cohort of patients receiving a colonoscopy. Claims data were used to identify receipt and dates of colonoscopies, polypectomies, and physician characteristics. (Appendix Table 1) SEER data were used to identify interval CRCs. Enrollment data were used to ascertain patients' sociodemographic characteristics. This study did not involve direct contacts with patients and was approved by Emory University's Institutional Review Board.

Cohort Selection

We selected patients who were 66–75 years of age at the time of receiving a colonoscopy between 2002– 2011. Claims data were only available for enrollees in fee-for-service (FFS) Parts A (inpatient) and B (outpatient) Medicare plans, therefore, our analyses were restricted to patients who were continuously enrolled in these plans for 12 months prior to and 6 months following their index colonoscopy to establish baseline comorbidities and to allow time for diagnostic workup of suspicious lesions found during a colonoscopy. Patients missing key data elements were excluded as outlined in Figure 1.

Outcomes and Follow-Up

Patients were followed until they died, were no longer enrolled in Medicare FFS Parts A and B, or experienced an interval CRC, the outcome of interest defined as a first primary invasive CRC diagnosed 6–59 months after an index colonoscopy. Follow-up began at 6 months after the index colonoscopy to account for time for diagnostic workup of suspicious lesions found during this procedure. Follow-up ended at 59 months in accordance with previous studies.(9) (11)

Interval CRCs were categorized as early (6–35 months) or late (36–59 months after a colonoscopy). The cutoff for the early interval CRC represents the minimum amount of time that a patient would be recommended to have a surveillance colonoscopy according to guidelines, with the exception of patients with >10 adenomas.(22) Interval CRC cases were also characterized according to SEER summary stage (localized, regional, and distant) and tumor location grouped as proximal, distal and rectal.

Exposures

The primary exposures were race/ethnicity and physicians' polyp detection rate (PDR), a relative measure of colonoscopy quality. Race/ethnicity was categorized as non-Hispanic white, black, Hispanic, Asian, and Other. PDR was used as a proxy for adenoma detection rate (ADR), an established colonoscopy quality metric(23), because SEER-Medicare data do not contain histopathology information on polyps. PDR values have been shown to be highly correlated (r>0.80) with ADR.(24–27) PDRs were calculated for each physician by dividing the number of patients on whom polypectomy was performed by the total number colonoscopies performed during a 5-year period and ranked into quartiles (outlined in Appendix Table 2). A patient was assigned their physician's PDR in the 5-year period preceding the index colonoscopy. The PDR measure was calculated using data from 4,357

unique physicians who performed at least 25 colonoscopies between 1998–2011 and 10 colonoscopies within the corresponding 5-year period (representing 500 and 200 colonoscopies based on the 5% sample, respectively).

Covariates

The characteristics of the zip-code of the patient's residence were used to describe sociodemographic and geographic characteristics. Patients' state of residence, urban-rural classification [urban and non-urban (including suburban and rural)] and the percentage of persons in a zip code living below federal poverty levels [low (0–7.9%), medium (8–15.5%) and high (>15.5%)] were included. Diverticulitis diagnosis and Charlson comorbidity score prior to index colonoscopy were considered.(28) Physician's primary specialty was identified by Health Care Finance Administration specialty code and categorized as gastroenterology, CRC surgery, general surgery, general internal medicine or other. (Appendix 2) Polypectomy at index colonoscopy was used to determine if disparities in interval CRC might be due to lack of surveillance. A validated algorithm using patient characteristics and gastrointestinal conditions/symptoms within 12 months of the index colonoscopy was used to classify the test's indication (screening/non-screening). (29)

Statistical Analysis

Kaplan Meier survival curves were used to estimate the probability of interval CRC. Cox Proportional Hazard models were used to estimate hazard ratios (HR) and 95% confidence intervals (CIs). Proportional hazard assumptions were tested using log-time and covariate product terms and log-log survival curves. Year of colonoscopy violated the assumption and was adjusted for in-strata. A series of models were performed to determine how adjustment for covariates affected the association between race/ethnicity and interval CRCs. Two-way cross-product terms for race/ethnicity and each covariate were assessed and no significant interactions were identified. The association between race/ethnicity and interval CRCs stratified on timing, tumor location, stage of interval CRC, physicians' PDR quartile, and unique physician identifier was assessed. Sensitivity analyses stratified on index colonoscopy characteristics (polypectomy/no polypectomy and screening/non-screening) were conducted. Additional models were based on subsets of patients whose index colonoscopies were performed by gastroenterologists with higher (≥50 and ≥100) colonoscopy volume. We employed sub-distribution hazard regression to determine if results were altered by reason of competing risk of death.(30, 31) PDR was modeled with restricted cubic splines and compared to a model in which PDR was entered as a continuous variable to test the linearity assumption.(32) As shown in the Appendix Table 3, and Appendix Figures 1a, 1b, results support the linearity assumption. (32) Sensitivity analyses examining the influence of unmeasured confounding was carried out using a previously described bounding formula.(33) SAS version 9.4. was used for analyses. The PHREG procedure was used both for the main analyses (Cox regression) and competing risk models.(34) Data analysis was funded by the American Cancer Society.

Results

Of the 79,396 Medicare beneficiaries meeting enrollment criteria, 61,433 were included in the analytic cohort, contributing a median of 4.4 and a total of 235,146 person-years of follow-up (Figure 1). The median age at index colonoscopy was 70.0 years and 2,735 interval CRCs were identified.

Most colonoscopies, regardless of race/ethnicity, were performed by physicians whose primary specialty was gastroenterology (Table 1). Receipt of a screening colonoscopy was comparable in blacks (79.5%) and white (80.7%) and polypectomy at index was similar (23.4% in blacks and 24.7% in whites). A higher proportion of blacks (52.8%) received their index colonoscopy from physicians in the lowest two polyp detection rate quartiles compared to whites (46.2%). Relative to patients receiving a colonoscopy from physicians in the highest polyp detection rate quartile, interval CRC risk was higher in patients whose colonoscopy was performed by physicians in first (lowest) (HR=1.95, 95% CI 1.74, 2.20), second (HR=1.53, 95% CI 1.37, 1.71), and third (HR=1.21, 95% CI 1.08, 1.35) (Table 2) quartiles in dose-response manner (Test for trend: χ^2= 136.6, p-value <0.001).

The probability of interval CRC by the end of follow-up was 7.1% in blacks, 5.8% in whites, 4.4% in Hispanics, and 3.8% in Asians. (Figure 2) In the Cox regression, interval CRC risk was significantly higher in blacks (HR= 1.32, 95% CI 1.15, 1.51) than in whites after accounting for age, gender and year of colonoscopy (Table 2). Results did not substantially change with further adjustment for characteristics of the zip-code of the patient's residence (state, poverty level and urban-rural classification), comorbidity and polypectomy at index colonoscopy. Further adjustment for polyp detection rate (Table 2) did not meaningfully affect the black-white differences in interval CRC occurrence (HR=1.31, 95% CI 1.13, 1.51). In the model stratified on individual physicians (Table 3), the point estimate for the black-white difference was farther from the null, but less precise (HR= 1.47, 95% CI 1.13,1.92). In analyses stratified on polyp detection rate quartiles, blacks had higher interval CRC risk relative to whites when colonoscopies were performed by physicians in PDR quartiles three (medium-high) (HR=1.35, 95% CI 1.01,1.82) or four (high) (HR=1.74, 95% CI 1.28–2.37), but not at lower PDR categories. (Table 3)

In analyses stratified on tumor location (Table 4), black patients had higher interval CRC risk for lesions in the distal colon (HR=1.45, 95% CI 1.00, 2.11) and rectum (HR=1.70, 95%CI 1.25, 2.31), but not significantly different for proximal CRCs (HR=1.17, 95% CI 0.96, 1.42). When stratified on stage, compared with whites, blacks had significantly higher risk of interval CRC diagnosed as distant (HR=1.60, 95% CI 1.12, 2.29), but not regional or local disease (Appendix Table 4). Black-white differences were observed for early and late interval CRCs (Appendix Table 5).

Black-white differences were more pronounced among patients who had polypectomy at index colonoscopy (HR=1.41, 95% CI 1.13,1.77) than patients who did not (HR=1.21, 95% CI 0.99, 1.47), but a test for interaction was not significant (p-value for heterogeneity=0.26) (Appendix Table 6). In analyses according to test indication, black-white disparities were similar in patients with screening (HR=1.21, 95% CI 0.97, 1.50) and non-screening

colonoscopies (HR=1.21, 95% CI 0.99, 1.48) (Appendix Table 6). Results of analyses restricted to patients receiving their index colonoscopy from a higher-volume gastroenterologist (≥50 or ≥100 colonoscopies) were similar to the main findings (Appendix Tables 7a and 7b) as were analyses that accounted for competing risk of death (Appendix Table 8). Analyses estimating the impact of unmeasured confounding revealed that the confounder-interval CRC and confounder-race/ethnicity associations would each need to exceed 1.50 for the higher risk of interval CRC among blacks to no longer be statistically significant.

Compared to whites, Asians had significantly lower interval CRC risk (HR=0.72, 95% CI 0.57, 0.90) (Table 2). There was no significant difference between interval CRC risk in Hispanics, relative to whites, in the main analyses, or by tumor location or stage.

Discussion

In this population-based study of elderly Medicare enrollees, interval CRC risk was 31% higher in blacks compared to whites, while risk among Asians was lower. Blacks were more likely than whites to have colonoscopies performed by physicians with lower polyp detection rates, a surrogate measure for the quality of colonoscopy. A black-white difference was observed among patients receiving a colonoscopy from physicians with higher polyp detection rates, but not among those who received care from physicians with lower polyp detection rates. However, differences in polyp detection rate of the physician did not explain the observed black-white disparity. Black-white differences in interval CRC risk were more pronounced for distal colon and rectal cancers than for proximal colon cancer.

Missed lesions and polyp detection rate are especially important factors for proximal lesions because the proximal colon is harder to reach endoscopically and it is the most common location of difficult-to-detect sessile polyps.(35–37) A previous study reports that behavioral factors (e.g. smoking, obesity) account for a greater proportion of differences in proximal colon cancer incidence by measures of SES, raising the possibility that lower colonoscopy utilization could account for these differences.(18) Additionally, a SEER-Medicare study reported a protective effect of ever receiving a colonoscopy, relative to not receiving a colonoscopy, that was closer to the null in blacks compared to whites, particularly for distal colon cancers after accounting for physician specialty but not polyp detection rate.(38)

We observed greater black-white differences in distal colon and rectal cancer interval CRC risk than in the proximal colon. This observation, along with greater black-white differences among patients receiving colonoscopies from physicians with higher but not lower polyp detection rates, aligns with previous observations that disparities in outcomes and healthcare utilization often manifest as higher quality or new interventions become available. (39–42) Whether this finding attributable to physician factors, including lower quality of examination, is unknown and warrants exploration.

Blacks and other minorities more frequently received colonoscopies from physicians with lower polyp detection rates and thus lower quality of care. These findings are consistent with

previous reports that blacks were more likely to receive healthcare from physicians in lower resource settings and also experienced poorer outcomes.(19) (43)

It is possible that quality factors other than polyp detection rate contribute to this pattern. Cecal intubation rates, withdrawal time and patient quality factors such adequacy of bowel preparation may vary by race, and be correlated with polyp detection rate.(44) Data on incomplete resection of polyps, the second most common reason for interval CRCs,(9) by race/ethnicity are not available in the published literature nor is it captured in SEER-Medicare data. Polyp detection rate is an indirect measure of lesions missed during a colonoscopy, the most commonly cited reason for interval CRCs, though other reasons include incomplete resection of polyps, or rapidly developing or “de-novo” tumors.(8, 9) A study estimated that 37% of interval rectal CRCs were attributable to incomplete polyp detection, compared to 10–16% of proximal tumors, possibly contributing to blacks’ higher risk of interval rectal cancer (45) and interval CRCs diagnosed at an advanced stage compared to whites in our study.

It is important to point out that some interval CRCs (13–24%) are believed to be “de novo” cancers and are thus unavoidable. It is not clear if risk of such lesions differs by race.(9) Previous studies suggest that blacks have more aggressive tumors, because they tend to be younger at diagnosis(46) and have higher prevalence of large polyps.(47) However, overall prevalence estimates for colorectal polyps and adenomas in blacks and whites are similar,(17, 48) findings consistent with similar polypectomy prevalence in our study. There is evidence that sessile serrated polyps are more aggressive and interval CRCs are more likely to exhibit micro-satellite insatiability (MSI) and CpG island methylator phenotype (CIMP).(49) Whether or not these factors account for higher interval CRC risk among black patients is not clear as studies on racial differences in MSI and CIMP are equivocal(50–52) and our study was not designed to directly answer this question. MSI tumors tend to be proximally located, and if this factor was driving racial disparities in interval CRCs, we would have expected especially elevated proximal interval CRC tumor risk among blacks relative to whites. Our data provide little evidence that this may be the case.

Polypectomy at index colonoscopy was similar between blacks and whites, though black-white differences were more apparent among patients with polypectomy than without polypectomy. Depending on the size and number of polyps detected, surveillance colonoscopy is recommended at intervals of up to 10 years of an index procedure in most instances.(22) We were not able to directly measure adherence to recommended follow-up intervals due to a lack of information on histology and polyp size in Medicare claims. Black-white differences were observed within three years following a colonoscopy in our study and two previous SEER-Medicare studies noted that blacks were more likely to undergo a surveillance colonoscopy within three or five years of polyp removal.(53, 54) Taken together, this suggests that differences in recommended surveillance colonoscopy may only moderately contribute to higher risk of interval CRC among blacks, though further study of the utility of race-specific surveillance colonoscopy recommendations is needed.

Lower interval CRC risk among Asians relative to whites observed in the current study is consistent with the previously reported lower overall CRC incidence in this group (55), a

pattern commonly attributed to differences in risk factors. Our findings agree with previous studies reporting similar polyp prevalence in Asians and whites.(48, 56) These findings raise the possibility that polyps progress more slowly in Asians, though detailed information on tumor characteristics (e.g.: MSI) in Asians is not available.

In our study, the probability of interval CRCs within 5 years of an index colonoscopy was 5.8% and the majority were proximally located. This observation is consistent with current literature.(9–11) Our findings and those reported elsewhere (11) highlight the importance of attentive examination of the colon and rectum during a colonoscopy to achieve the optimal benefit of this test. A previous SEER-Medicare study covering the period from 1994–2005 noted higher odds of interval CRC relative to screen-detected CRCs for blacks relative to whites.(11) Our findings are consistent with this observation.

There are some limitations of this study. Colonoscopy and polypectomy were identified using billing codes. Compared to an endoscopic database, Medicare data have high sensitivity (>93%) and specificity (98%) for identifying colonoscopy and polypectomy.(57, 58) Research supports the use of administrative data to estimate polyp detection rate (27) as a proxy for adenoma detection rate as the two measures are highly correlated (24–27, 59). The PDR-ADR correlation is stronger in the proximal (r>0.90) than the distal (r=0.58–0.59) colon, (24, 26) likely due to a greater proportion of non-adenomatous polyps in distal colon. (60) However, proximal ADR is more strongly associated with interval CRC risk than distal ADR (10). Test indication was not directly available, though results incorporating algorithm-based indication did not alter our main findings. Further, the minimum number of colonoscopies required to determine polyp and adenoma detection rates is unclear. One study estimated that ≥500 examinations would be needed to determine ADR(61) and the study that served as the basis for establishing the American Gastroenterology Association's quality metrics included physicians with ≥300 colonoscopies(10), while others have used a threshold of 50 procedures.(25, 27) In the current study, we used a threshold of 500 colonoscopies, represented by 25 colonoscopies in the 5% Medicare sample. Varying the threshold and restricting analyses to higher volume gastroenterologists did not alter our main findings. Polyp detection rates were based on Medicare FFS patients, which may not represent physicians' total patient population, though relative measures of procedural volume in SEER-Medicare and Medicare were similar and procedural volume in patients <65 and ≥65 years were correlated in previous studies. (62) (63) We did not have information on the involvement of gastroenterology fellows that may increase adenoma detection rates (64) and could vary by institution and patient race. Information on tumor characteristics and polyp histopathology that presumably influence CRC risk(9) were not available in SEER-Medicare data. We also used area-based measures of SES as individual-level measures as were not available.(65, 66) Data on behavioral factors (e.g: smoking, obesity) that clearly increase overall CRC risk were also not available, though the influence of these factors on interval CRCs is unexplored. Analyses estimating the impact of such unmeasured confounders revealed that each of the confounder-interval CRC and confounder-race/ethnicity associations would need to exceed 1.50 to substantially alter our main findings (33), a level not observed in most studies of overall CRC risk.(67) We did not have data on receipt of colonoscopy prior to Medicare enrollment. Receipt of colonoscopy and polypectomy prior to Medicare disrupts the natural history of colorectal carcinogenesis

and increases the opportunities to detect and remove polyps, and thus a lower prevalence of polyps. It is possible that lower colonoscopy use prior to Medicare enrollment among blacks, if present, may result in more accumulated lesions and thus the potential for a higher chance of missed lesions in this population, but this requires study. Lastly, our results may not represent disparities occurring in younger populations.

In conclusion, we observed higher risk of interval CRCs in blacks compared to whites in a population-based study of elderly Medicare enrollees. Proximal tumors represented the majority of interval CRCs. Black-white differences were most pronounced for distal colon and rectal cancers and in patients receiving colonoscopies from higher quality physicians, as measured by polyp detection rate. While quality of colonoscopy was associated with interval CRC, it did not account for the racial disparities. Futures studies examining this issue are warranted given the higher overall risk of interval CRC in black populations as well as larger disease burden in this group.

Supplementary Material

Refer to Web version on PubMed Central for supplementary material.

Acknowledgments

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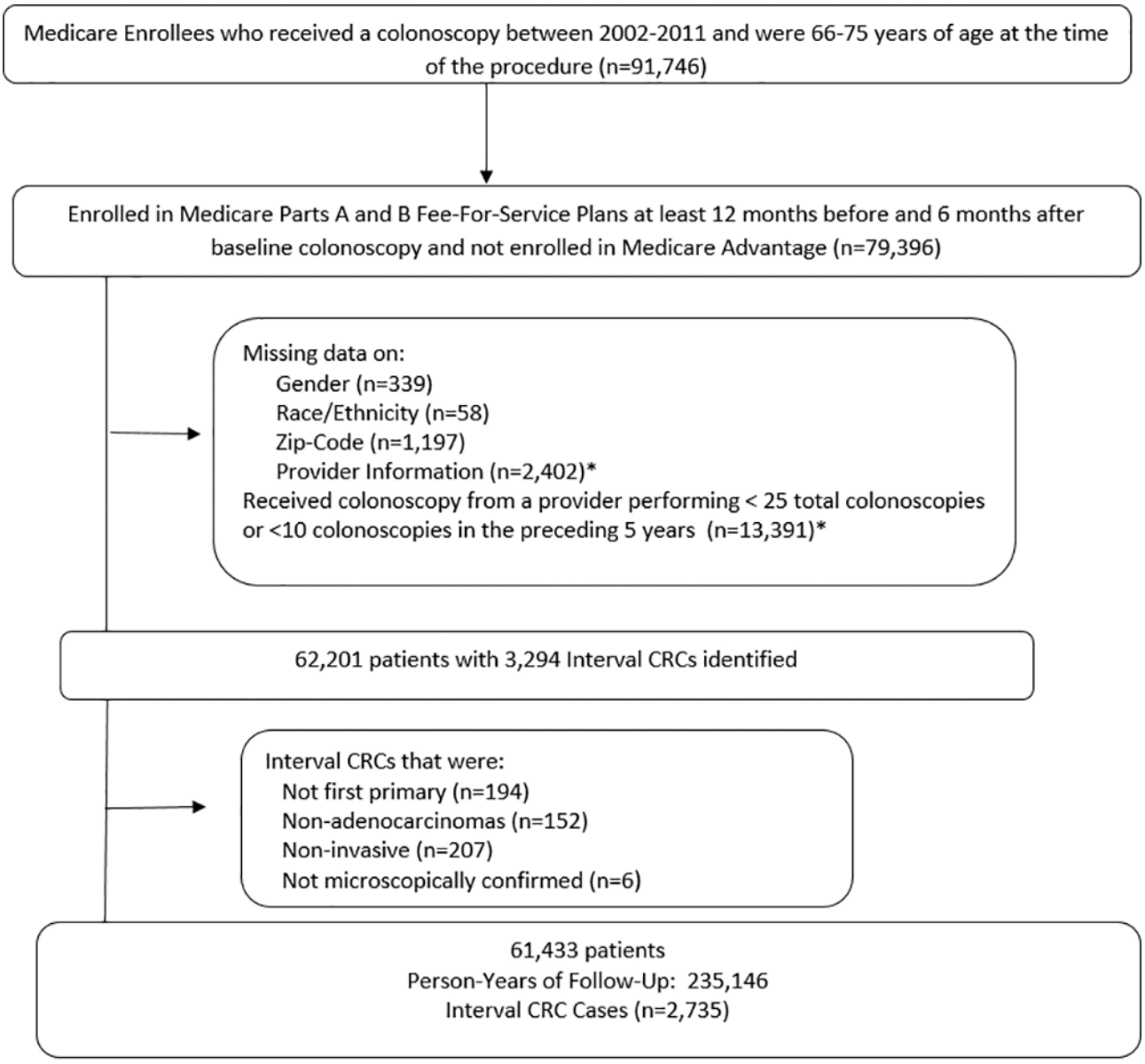

*There were 10,946 physicians in the initial selection. There were 6,458 physicians performing <10 colonoscopies, 130 were missing provider type and 1 missing National Provider Index number who were excluded. The analytic sample included data from 4,357 unique physicians.

Figure 1.

Cohort Selection Criteria, SEER-Medicare 2002–2011

Abbreviations: Surveillance Epidemiology and End Results (SEER), Colorectal Cancer (CRC)

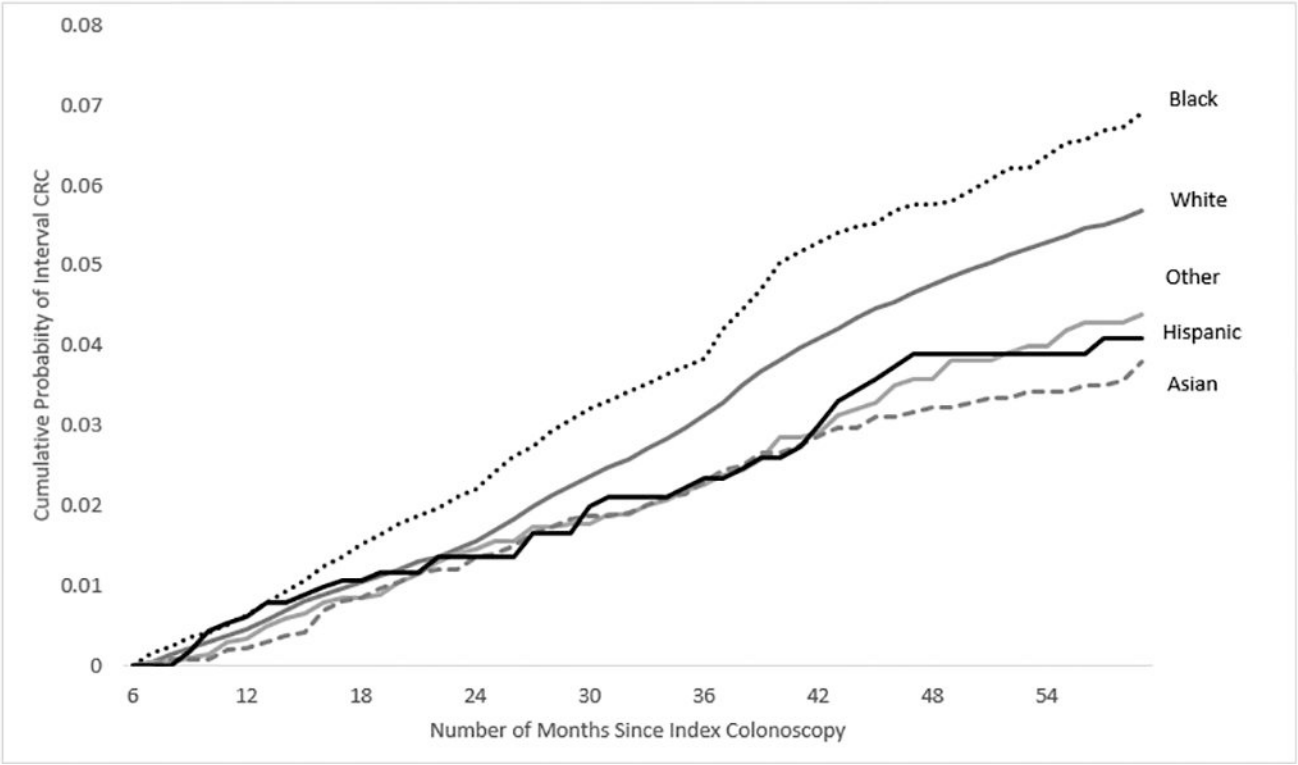

Figure 2.

Cumulative Probability of Interval Colorectal Cancer by Race/Ethnicity, SEER-Medicare 2002–2011*

Abbreviations: Surveillance Epidemiology and End Results (SEER), Colorectal Cancer (CRC)

*Log Rank p-value <0.001

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Table 1

Baseline Characteristics of Eligible Medicare Beneficiaries with Colonoscopy by Race/Ethnicity, 2002–2011 (n=61,433)

Categories	White	Black	Other	Asian	Hispanic
	N=51,313 %	N=4,196 %	N=2,064 %	N=2,696 %	N=1,164 %
Colonoscopy Characteristics					
PDR Quartile					
Q1 Low	19.1	22.6	22.6	23.3	26.8
Q2 Medium Low	27.1	30.2	26.8	26.4	35.2
Q3 Medium High	27.9	25.7	23.0	21.3	22.1
Q4 High	25.9	21.5	27.6	29.0	15.9
Provider Specialty					
GI	77.1	81.3	79.4	75.7	84.8
CRC Surgery	4.5	3.7	3.0	1.6	*
General Internal	8.0	7.8	12.4	19.1	11.2
General Surgery	8.4	5.5	3.0	1.4	*
Other	1.9	1.8	2.3	2.3	*
Age at Colonoscopy					
66–69	39.8	40.8	41.5	38.0	38.3
70–75	60.2	59.3	58.5	62.0	61.7
Colonoscopy Year					
2002–2003	12.4	11.9	9.8	10.8	12.9
2004–2005	15.5	17.1	13.7	14.1	13.8
2006–2007	20.9	21.4	22.7	20.8	18.0
2008–2009	24.0	22.7	26.3	27.1	25.3
2010–2011	27.2	26.9	27.5	27.3	30.1
Polyp Removed	24.7	23.4	22.8	23.9	18.0
Screening Colonoscopy†	80.7	79.5	81.8	78.9	77.7
Sociodemographic Characteristics and Comorbidity					
Gender					

Categories	White	Black	Other	Asian	Hispanic
	N=51,313 %	N=4,196 %	N=2,064 %	N=2,696 %	N=1,164 %
Female	58.0	65.9	54.0	61.5	69.2
Male	42.0	34.1	46.0	38.5	30.8
State					
CA	28.8	15.7	53.7	76.3	76.6
CT	6.4	4.0	2.9	1.2	1.6
MI	5.6	13.6	3.3	1.0	*
HI	0.4	*	18.6	5.9	*
IA	5.9	0.7	0.8	*	*
NM	2.2	*	1.6	*	3.6
WA	5.7	1.3	5.5	4.7	0.7
UT	3.2	*	0.9	0.6	*
GA	12.8	27.0	3.4	2.3	1.8
KY	8.3	4.7	*	0.5	*
LA	6.1	14.1	*	0.9	*
NJ	14.5	18.4	8.0	6.3	13.6
Poverty Level					
Low	35.1	10.9	40.0	29.4	10.0
Medium	33.4	20.2	31.7	34.5	23.1
High	31.6	69.0	28.3	36.1	66.9
Urban/Rural Status					
Metro	82.8	89.2	92.5	98.0	97.7
Suburban/Rural	17.2	10.8	7.5	2.0	2.3
Diverticulitis Diagnosis	62.7	58.2	46.8	36.2	59.5
Charlson Comorbidity Score					
0	87.7	77.4	85.4	84.7	75.5
1	9.9	16.1	11.2	12.3	18.5
2+	2.5	6.5	3.4	3.0	6.0

Characteristics among Interval CRCs

Categories	White	Black	Other	Asian	Hispanic
	N=51,313 %	N=4,196 %	N=2,064 %	N=2,696 %	N=1,164 %
Tumor Location					
Proximal	66.1	56.4	57.8	45.7	62.2
Distal	13.8	15.9	18.3	16.1	18.9
Rectal	17.7	25.0	21.1	34.6	*
Unknown	2.5	2.7	2.8	3.7	*
Tumor Stage					
Localized	50.6	46.4	52.1	49.4	54.1
Regional	33.7	30.0	32.4	34.6	32.4
Distant	14.1	17.7	9.9	12.4	10.8
Unknown	1.6	5.9	5.6	3.7	2.7
Interval CRC Timing					
Early (6–35 months)	65.5	70.5	62.0	71.6	64.9
Intermediate (36–59 months)	34.5	29.6	38.0	28.4	35.1

Abbreviations: Surveillance Epidemiology and End Results (SEER), Polyp Detection Rate (PDR), Quartile (Q), Gastroenterology (GI), Colorectal Cancer (CRC), California (CA), Connecticut (CT), Michigan (MI), Hawaii (HI), Iowa (IA), New Mexico (NM), Washington (WA), Utah (UT), Georgia (GA), Kentucky (KY), Louisiana (LA), New Jersey (NJ)

*Data suppressed to protect patient confidentiality

†Screening colonoscopy was determined using an algorithm

Table 2

Hazard Ratios for the Association with Interval Colorectal Cancer, SEER-Medicare 2002–2011

	No. of Cases	*Person Years*	*Model 1* Adjusted for age, gender and colonoscopy year*			*Model 2* Model 1+ geographic factors, poverty, and comorbidity†			*Model 3* Model 2+ PDR and Physician Specialty‡		
			HR	**95%CI**		**HR**	**95%CI**		**HR**	**95%CI**	
Race/Ethnicity											
White	2,326	197,609	1.00			1.00			1.00		
Asian	81	10,289	0.70	0.56	0.87	0.71	0.56	0.89	0.72	0.57	0.90
Black	220	15,088	1.32	1.15	1.51	1.37	1.18	1.59	1.31	1.13	1.51
Hispanic	37	4,196	0.76	0.55	1.05	0.79	0.57	1.10	0.77	0.55	1.07
Other	71	7,964	0.81	0.64	1.03	0.89	0.69	1.13	0.87	0.68	1.12
Physicians' PDR											
Q1 Low	640	46,493							1.95	1.74	2.20
Q2 Medium Low	775	64,178							1.53	1.37	1.71
Q3 Medium High	708	64,323							1.21	1.08	1.35
Q4 High	612	60,153							1.00		
Provider Specialty											
GI	1,925	182,230							1.00		
CRC Surgeon	132	9,955							1.18	0.98	1.41
General Internal Medicine	252	20,441							1.13	0.99	1.29
General Surgery	286	18,078							1.33	1.16	1.53
Other	140	4,442							3.07	2.59	3.66
Polypectomy	1,242	55,290				2.58	2.39	2.79	3.04	2.80	3.29
Diagnosed with Diverticulitis	1,620	142,147				0.96	0.88	1.03	0.96	0.89	1.03

Abbreviations: Surveillance Epidemiology and End Results (SEER), Quartile (Q), Polyp Detection Rate (PDR), Colorectal Cancer (CRC), Gastroenterologist (GI)

*Model 1 adjusts for age and year of colonoscopy and race/ethnicity (white, black, Hispanic, Asian and other).

†Model 2 adjusts for year, age of colonoscopy, gender, race/ethnicity (white, black, Hispanic, Asian and other), geographic state, poverty level (Low, Medium High), urban/rural status (urban, non-urban), Charlson comorbidity score (0,1,2+), diverticulitis (yes/no), and polyp removal at index colonoscopy (yes/no).

‡Model 3 adjusts for year, age of colonoscopy, gender, race/ethnicity (white, black, Hispanic, Asian and other), geographic state, poverty level (Low, Medium High), urban/rural status (urban, non-urban), Charlson comorbidity score (0,1,2+), diverticulitis (yes/no), and polyp removal at index colonoscopy (yes/no), physician specialty (GI, CRC Surgeon, General Internal Medicine, General Surgery and Other) and PDR (Q1, Q2, Q3, Q4).

Table 3

Association between Race/Ethnicity and Interval Colorectal Cancer by Polyp Detection Rate Quartile and Adjusted for Unique Physician Identifier, SEER-Medicare 2002–2011

	Models Stratified by Physician Polyp Detection Rate Quartiles												Model Stratified on Unique Physician Identifier//		
	Quartile 1 Low PDR*			Quartile2 Medium-Low PDR†			Quartile 3 Medium High PDR‡			Quartile 4 High PDR§					
	HR	95%CI		HR	95%CI		HR	95%CI		HR	95%CI		HR	95%CI	
Race/Ethnicity															
White	1.00			1.00			1.00			1.00			1.00		
Asian	0.57	0.35	0.93	0.95	0.63	1.44	0.83	0.52	1.31	0.57	0.35	0.93	0.59	0.37	0.93
Black	1.17	0.86	1.58	1.14	0.86	1.51	1.35	1.01	1.82	1.74	1.28	2.37	1.47	1.13	1.92
Hispanic	1.01	0.59	1.73	0.55	0.29	1.03	0.73	0.34	1.55	0.81	0.33	1.98	0.81	0.50	1.33
Other	0.71	0.43	1.19	0.83	0.52	1.32	0.84	0.49	1.44	1.08	0.67	1.73	0.97	0.66	1.43

Abbreviations: Surveillance Epidemiology and End Results (SEER), Hazard Ratio (HR), Confidence Interval (CI), Polyp Detection Rate (PDR)

*Adjusted for age and year of colonoscopy, gender, urban/rural status, zip-code poverty, comorbidity, diverticulitis, index polypectomy and physician specialty. Model includes 640 cases and 46,493 person years of follow-up among patients who received their baseline colonoscopy from a physician in the first PDR quartile.

†Adjusted for age and year of colonoscopy, gender, urban/rural status, zip-code poverty, comorbidity, diverticulitis, index polypectomy and physician specialty. Model includes 775 cases and 64,178 person years of follow-up among patients who received their baseline colonoscopy from a physician in the second PDR quartile.

‡Adjusted for age and year of colonoscopy, gender, urban/rural status, zip-code poverty, comorbidity, diverticulitis, index polypectomy and physician specialty. Model includes 708 cases and 64,323 person years of follow-up among patients who received their baseline colonoscopy from a physician in the third PDR quartile.

§Adjusted for age and year of colonoscopy, gender, urban/rural status, zip-code poverty, comorbidity, diverticulitis, index polypectomy and physician specialty. Model includes 612 cases and 60,153 person years of follow-up among patients who received their baseline colonoscopy from a physician in the fourth PDR quartile.

//Adjusted for age and year of colonoscopy, gender, urban/rural status, zip-code poverty, comorbidity, diverticulitis, and index polypectomy. Model is stratified on unique physician identifiers and includes 2,735 interval CRC and 235,146 Person Years of Follow-Up.

Table 4

Hazard Ratios for the Association with Interval Colorectal Cancer by Tumor Location, SEER-Medicare 2002–2011

	Proximal*, †			Distal*, ‡			Rectal*, §		
	HR	**95%CI**		**HR**	**95%CI**		**HR**	**95%CI**	
Race/Ethnicity									
White	1.00			1.00			1.00		
Asian	0.50	0.36	0.70	0.89	0.50	1.58	1.33	0.89	2.00
Black	1.17	0.96	1.42	1.45	1.00	2.11	1.70	1.25	2.31
Hispanic	0.73	0.48	1.11	1.21	0.56	2.62	0.75	0.35	1.59
Other	0.78	0.57	1.08	1.20	0.66	2.15	0.97	0.56	1.66
Physicians' PDR									
Q1 Low	1.93	1.66	2.24	1.71	1.26	2.33	2.38	1.82	3.13
Q2 Medium Low	1.57	1.37	1.81	1.25	0.94	1.67	1.69	1.30	2.19
Q3 Medium High	1.24	1.08	1.42	1.10	0.83	1.45	1.22	0.94	1.59
Q4 High	1.00			1.00			1.00		

Abbreviations: Surveillance Epidemiology and End Results (SEER), Quartile (Q), Polyp Detection Rate (PDR)

*Model is adjusted for age and year of colonoscopy, race/ethnicity, gender, urban/rural status, zip-code poverty, comorbidity, diverticulitis, index polypectomy, physician polyp detection rate, and physician specialty.

†Model includes 1762 cases and 235,146 Person Years of Follow-Up

‡Model includes 389 cases and 235,146 Person Years of Follow-Up

§Model includes 516 cases and 235,146 Person Years of Follow-Up