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Predictors of Colorectal Cancer Screening Variation Among Primary Care Providers and Clinics

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Abstract

Objectives—Colorectal cancer (CRC) screening is underutilized. To effect change, we must understand reasons for underuse at multiple levels of the healthcare system. We evaluated patient, provider, and clinic factors that predict variation in CRC screening among primary care clinics and primary care providers (PCPs).

Methods—We analyzed electronic medical record (EMR) data for 34,319 adults eligible for CRC screening, 19 clinics, and 97 PCPs in a large, academic physician group. Detailed data on potential patient, provider, and clinic predictors of CRC screening were obtained from the EMR. PCP perceptions of CRC screening barriers were measured via survey. The outcome was

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completion of CRC screening at the patient level. Multivariate logistic regression with clustering on clinics obtained adjusted odds ratios and 95% confidence intervals for potential predictors of CRC screening at each level.

Results—Seventy-one percent of patients completed CRC screening. Variation in screening rates was seen among clinics (51–80%) and among PCPs (51–82%). Significant predictors of completing CRC screening were identified at all levels: patient (older age, white race, being married, primarily English-speaking, having commercial insurance plans versus Medicare or Medicaid, and higher healthcare resource utilization), provider (larger panel size of patients eligible for CRC screening), and clinic (hospital-owned, shorter distance to nearest optical colonoscopy center).

Conclusions—Variation in CRC screening exists among primary care clinics and providers within a single clinic. Predictors of variation can be identified at patient, provider, and clinic levels. Quality improvement interventions addressing CRC screening need to be directed at multiple levels of the healthcare system.

Keywords

Colon cancer screening; practice patterns; health system; variation; quality improvement

INTRODUCTION

Colorectal cancer (CRC) is the second leading cause of cancer-related deaths for both men and women in the United States, claiming nearly 50,000 lives each year (1). If optimally employed, available CRC screening modalities have the potential to significantly reduce CRC mortality (2–10). Screening is underutilized despite the variety of screening tools available, existing evidence on the effectiveness of these tools, and recommendations from multiple professional societies supporting CRC screening. A recent NIH Conference, “Enhancing Use and Quality of Colorectal Cancer Screening”, highlighted the importance of monitoring trends in CRC screening in order to better understand factors leading to underuse of this life-saving preventive service (11). In addition, a current National Cancer Institute priority calls for further understanding of the factors that influence cancer prevention at each level of the healthcare system (12, 13).

CRC screening is a complex process involving multiple factors at multiple levels of the health care system (i.e. clinic, provider, and patient). Existing literature focuses on predictors of CRC screening at the patient level with few studies addressing potential provider factors (14). Minimal data on the combination of patient, provider, and clinic factors that influence CRC screening rates exists. Such information is important because it can direct interventions to improve CRC screening at each level of the health care system.

The aim of this study is to evaluate patient, provider, and clinic level factors that predict variation in CRC screening practices among primary care clinics and primary care providers (PCPs). To address these objectives, we use data from the Wisconsin Collaborative for Healthcare Quality (WCHQ). Through WCHQ, Wisconsin is the only state that publicly reports CRC screening at the health system level for all patients and all payers (15). WCHQ is a voluntary, state-wide partnership of health care organizations (16) that has been tracking CRC screening rates across multiple health systems since 2005.

METHODS

Study Setting

We retrospectively analyzed CRC screening practices within UW Health, a long-standing WCHQ participant. UW Health is one of the twelve largest multi-specialty physician groups in the US, comprised of both multi-specialty and community-based primary care clinics that provide 1.7 million ambulatory visits per year. Primary care is delivered by over 300 providers in more than 40 primary care clinic sites. Primary care clinics are owned and managed by either the hospital or the physician group practice. Differences in ownership and management are associated with different clinic infrastructure and populations served. We report on 19 primary care clinics with >300 patients eligible for CRC screening and 97 primary care providers with >100 eligible patients in their panels. The use of these thresholds confers stability of results from clinics and providers by excluding those with small numbers of eligible patients (17). The Institutional Review Board at the University of Wisconsin – Madison approved this study with a waiver of consent.

Identification of Screen-Eligible Population

Electronic medical record (EMR) data were used to identify the potential pool of eligible patients in 2009 using the WCHQ definition created for public reporting which is based on the Healthcare Effectiveness Data and Information Set (HEDIS) metrics (15, 18). Adults age 50–75 years were included if they were “currently managed” by the physician group. Patients were considered “currently managed” if they had at least 2 primary care office visits in an outpatient, non-urgent care setting within the previous 36 months, with at least 1 of those visits in the prior 24 months. For example, to be included as currently managed for 2009, the patient needed to have at least 2 visits in the combined years 2007, 2008, and 2009, with at least one being in 2008 or 2009. This definition ensures that patients who have a single visit to a clinic but seek care permanently elsewhere are not included in our screening measures (19). We identified primary care clinics and providers by specialty (Internal Medicine and Family Medicine). Patients were excluded if they had a history of a total colectomy based on ICD-9 codes (45.8x) and CPT codes (44150, 44151, 44155–44158, 44210–44212, 44799).

Identification of CRC Screening Completion

From the pool of patients eligible for CRC screening, completion of screening was determined by (a) fecal occult blood test (FOBT) in the prior 12 months, (b) flexible sigmoidoscopy, double contrast barium enema, or computed tomographic (CT) colonography in the past 5 years (20), or (c) optical colonoscopy in the prior 10 years. This was obtained through review of EMR data using the codes identified by WCHQ which are consistent with the HEDIS metrics (see Supplemental Table 1). All primary care providers have open access to optical and CT colonography in our system, and most local third party payers cover CT colonography as a CRC screening modality (21).

Explanatory Variables

We examined the relationship between the likelihood of a patient completing a CRC screening test and several predictors at the patient, primary care provider (PCP), and clinic levels of our health care system. Patient and clinic predictors obtained from the EMR included age, gender, race/ethnicity (White, Non-White), marital status, primary language (English, Non-English), comorbidities (congestive heart failure (CHF), diabetes mellitus (DM), hypertension (HTN)), insurance coverage (Commercial, Medicare, Medicaid or Uninsured), clinic management (hospital-owned versus physician-owned), and the number of providers within the clinic that care for patients who are eligible for CRC screening. A

healthcare resource utilization score was assigned to each patient through the use of Ambulatory Care Groups (ACGs) (22, 23) on the basis of outpatient and inpatient diagnoses from the 12 months prior to 2009. This score is based on evidence that certain groups of medical conditions have similar healthcare resource utilization. Clinic distance to the nearest optical colonoscopy facility was calculated using geographical software.

PCP predictors obtained from the EMR included gender, specialty (Internal Medicine, Family Medicine), years in practice, and size of their patient panel eligible for CRC screening. PCP perceptions of major barriers to CRC screening at the patient, provider, and system levels were measured by survey. We administered a survey to all PCPs within UW Health in February 2010 with a 70% response rate (N=226/322) to examine their CRC screening beliefs and practices in the previous year. The survey was based on the National Cancer Institute Survey of Colorectal Cancer Screening Practices developed in collaboration with the CDC and Centers for Medicare and Medicaid Services and has been used extensively in prior research (24–27). Survey items were organized into four sections: (1) Cancer screening beliefs and practices – perceived value of CRC screening and perceptions of their own (and their peers') CRC screening practice; (2) Attitudes toward CRC screening – importance of perceived barriers to CRC screening at the patient-, provider-, and system-levels; (3) CRC screening modalities – recommendations for and use of each CRC screening method; and (4) Provider characteristics – short validated 10-item personality inventory (28). Survey items were adapted to address issues relevant to UW Health (such as the option to choose CT colonography).

The survey question included in this analysis had the following stem: “In the US today, many adults over the age of 50 are not screened for colorectal cancer. In your opinion, how important are each of the following as potential barriers to colorectal cancer screening?” Respondents could rank the following potential barriers as a “major barrier”, “minor barrier”, or “not a barrier”. Patient barriers included fear of finding cancer, belief that screening is not effective, embarrassment or anxiety about screening tests, unaware of screening or does not perceive colorectal cancer as a serious health threat, fear of an invasive test, and concern about tolerating prep. Provider barriers included not enough time in clinic to discuss screening and the perception that many primary care providers do not actively recommend screening to their patients. System barriers included long wait times between ordering and scheduling a test, financial costs to the patient, shortage of trained providers to conduct screening tests, and lack of a systematic way to identify patients eligible for screening. Responses were counted as 1 for indicating a “major barrier” and 0 for indicating “minor/not a barrier”.

Statistical Analysis

CRC screening rates for individual primary care clinics and individual PCPs within clinics are presented for the year 2009. The frequency of different CRC screening modalities is described. We compared the frequency of all patient, provider, and clinic variables for the screened and unscreened patient population by using χ^2 tests for categorical variables and two-way ANOVA tests for continuous variables. Multivariate logistic regression with robust estimation of the standard errors and clustering at the clinic level was performed with the logit procedure in Stata to obtain odds ratios (ORs) and 95% confidence intervals (CIs) for the patient, provider, and clinic predictors of our primary outcome, completion of CRC screening at the patient level. All variables listed in Table 3 were included in the multivariate logistic regression model. Analyses were carried out with Stata 12.0 (StataCorp, College Station, TX) and SAS 9.3 (SAS Institute, Cary, NC) software. All tests of significance used two-sided *P* values at the *P* < .05 level.

RESULTS

CRC Screening Modalities

The most common CRC screening modality in our healthcare system was optical colonoscopy (86%). CT colonography (8%) and FOBT (4%) were used infrequently, and flexible sigmoidoscopy and double contrast barium enema almost never.

Overall Sample Characteristics

Over 34,000 patients were identified as eligible for CRC screening in 2009 according to the methodology previously described. The majority of patients were between 50 and 60 years of age, 58% were women, 93% were white, most were married, 94% speak English as their primary language, and more than two-thirds had commercial insurance coverage (Table 1). For the 97 PCPs, 49% were female, over half practice in Internal Medicine (59%) with 41% in Family Medicine, >50% have been in practice for more than 20 years, and the average number of patients in a provider's panel that are eligible for CRC screening is over 480. On average, PCPs perceived more major barriers to CRC screening to exist at the patient-level compared to the provider- and system-levels. Two thirds of the primary care clinics were physician-owned (as compared with hospital-owned), the average number of providers caring for patients eligible for CRC screening in each clinic was 10, and the average distance of the clinics to the nearest optical colonoscopy facility was 6.5 miles.

Sample Characteristics by Screening Status (Screened vs. Not Screened)

All patients were assigned to PCPs using the plurality provider algorithm described by Pham et al. (29) PCPs were assigned to clinics by the clinic at which the provider billed most of his or her Evaluation & Management (E&M) visits during the year. Seventy-one percent of patients (N=24,372) completed their CRC screening and 29% (N=9,947) were not screened (Table 2). Significant differences were observed between the screened and not screened patients in patient, provider, and clinic variables. Although statistically significant due to the large sample size, some of these differences were not clinically significant (e.g., patient race).

Patient variables—Patients who completed screening were older (48% of screened patients were between 60 and 75 years old vs 45% of patients who were not screened, $p<0.001$), more often white (94% vs 92%, $p<0.001$), more often married (74% vs 65%, $p<0.001$), spoke English as a primary language (95% vs 91%, $p<0.001$), had more commercial insurance coverage (74% vs 68%, $p<0.001$), and more healthcare resource utilization (ACG Resource Utilization Score of 0.6 vs 0.5, $p<0.001$).

Provider variables—Patients who were screened were more likely to be seen by PCPs who have been in practice longer (87% of screened patients are seen by PCPs who have been in practice for 10 years vs 83% of patients who were not screened, $p<0.001$), are female (50% vs 48%, $p=0.01$), practice Internal Medicine (63% vs 50%, $p<0.001$), and have larger panels of patients eligible for CRC screening (500 vs 460, $p<0.001$). Patients who completed screening were also seen by PCPs who perceived more major barriers to CRC screening at the patient- and system- levels (2.5 vs 2.3, $p<0.001$ and 1.8 vs 1.6, $p<0.001$ respectively).

Clinic variables—Patients who were screened were significantly more likely to receive their primary care at a hospital-owned clinic (36% vs 26%, $p<0.001$) and a clinic that is closer to the nearest optical colonoscopy center (6.2 miles vs 7.2 miles, $p<0.001$).

CRC Screening Rates among Primary Care Clinics

Variation in CRC screening rates was seen across 19 primary care clinics within the health system (Figure 1). CRC screening rates by primary care clinic ranged from 51% to 80%.

CRC Screening Rates among Primary Care Providers

Variation in CRC screening rates also existed among PCPs across the system and within each clinic (Figure 2). CRC screening rates by PCP ranged from 51–82% in the clinic with the largest spread, compared to a range of 60–64% in the clinic with the smallest spread.

Predictors of CRC Screening Variation

Logistic regression with clustering on clinics, controlling for all patient, provider, and clinic variables revealed significant predictors of CRC screening variation at each level. Significant patient-level predictors for completing screening were increasing age, White race, being married, primarily English speaking, having commercial insurance coverage, not having congestive heart failure or diabetes, and utilizing more healthcare resources (Table 3). The only significant provider-level predictor of CRC screening completion after controlling for multiple patient and clinic factors was increasing panel size of patients eligible for CRC screening. Clinic-level predictors of CRC screening completion were that the clinic was hospital-owned rather than physician-owned, and shorter distance to the nearest optical colonoscopy center.

DISCUSSION

The overall CRC screening rate in our healthcare system is relatively high (71% in 2009). Even in this setting we found variation in screening rates among primary care clinics (51–80%) and among providers within a clinic (51–82% in the clinic with the largest spread). We also show that predictors of this variation exist at the patient (age, race, marital status, primary language, insurance coverage, comorbidities, healthcare resource utilization), provider (panel size eligible for CRC screening); and clinic (physician- vs hospital-owned and distance to nearest optical colonoscopy center) levels. In response to the NIH call to monitor trends in the use of CRC screening to better understand factors leading to underuse of this preventive service (11), our study shows that examination needs to occur at all levels of the healthcare system and confirms the National Cancer Institute priority for multilevel analysis and multilevel interventions to improve the cancer care continuum (12, 13, 30).

Previous studies have shown that patient characteristics associated with higher CRC screening rates include increasing age, gender, marriage, white race, insurance coverage, and presence of comorbidities (31–37). Our study shows age is a significant predictor of CRC screening. In an earlier model, the relationship between age and CRC screening was determined to be non-linear and might represent competing health demands with increasing age (38–40). We also confirmed prior findings of the relationship between marital status, race, and insurance coverage and CRC screening. In contrast to some previous reports, we found no significant association between gender and CRC screening in our multivariate model. Christman et al. (37) reported that patients with more chronic illnesses, as measured by the Charlson comorbidity score, were more likely to be screened for CRC. Similarly, we found that patients with higher healthcare resource utilization by ACG scores were more likely to be screened. This score is based on evidence that certain groups of medical conditions have similar healthcare resource utilization and our findings are consistent with the overall idea that patients who have more contact with the healthcare system are more likely to receive preventive services. However, we decided to further examine the relationship between a few specific comorbidities and CRC screening and found that patients with congestive heart failure were significantly less likely to complete CRC

screening which probably reflects the overwhelming use of optical colonoscopy, which uses sedation, in our system. We also found that patients with diabetes were significantly less likely to be screened which may represent the effect of competing demands in patient care.

Current literature on PCP factors influencing CRC screening focuses on the physician recommendation for screening (25, 41, 42). Little data exists on other PCP characteristics such as demographics and practice patterns. In our study, after adjusting for patient and clinic characteristics, the main PCP predictor of CRC screening was the size of the provider's panel eligible for screening. PCPs that see more patients suitable for CRC screening are more likely to engage in the process. When comparing patients who were screened to those who were not, we found that screened patients were more likely to be seen by PCPs who perceive more major barriers at the system-level. One explanation may be that PCPs with higher CRC screening rates can identify more system level barriers because they are encountering them in their daily practice. However, in the final multivariate logistic regression model there was no significant relationship between number of perceived major barriers at the patient-, provider, or system-levels and patient receipt of CRC screening. Also in the final multivariate model we did not find an association between CRC screening rates and PCP gender, specialty, or years in practice.

In addition to patient and PCP characteristics, we identified two major clinic-level factors associated with CRC screening – clinic management and distance to the nearest optical colonoscopy center. Hospital-owned clinics were more likely to screen patients for CRC than physician-owned clinics. One possible explanation is that there are stronger relationships between PCPs in these clinics with the specialists, such as gastroenterologists and radiologists who provide the majority of the screening exams. We also found that patients who received their primary care at a clinic farther away from an optical colonoscopy center had lower CRC screening rates, indicating that geographic distance may be a significant barrier. However, this may be confounded by the fact that patients who are seen at more distant clinic sites are more likely to have their CRC screening exams completed at facilities outside of our system which may not have been accurately captured in our EMR.

Our study has important implications for quality improvement interventions in CRC screening. Existing research aimed at improving CRC screening shows that single interventions tend to have small effects and that to achieve large, sustainable effects, a multi-pronged approach is necessary (43, 44). Selby et al. (45) looked within a large health care system to describe variance at the provider level for quality indicators in hypertension, hyperlipidemia, and breast cancer screening. They found variation in all of these indicators and concluded that although quality improvement programs primarily targeting organized systems can be effective, “greater attention to understanding and reducing variability among individual physicians would be a useful additional approach for internal quality improvement efforts.” Our results confirm this need to understand the extent of and reasons for variation at additional levels (patient, provider, and clinic) of the health system in order to design optimal approaches for CRC screening programs.

There are limitations to this study. First, we report findings from a large, academic physician group which may not be generalizable. However, large multi-specialty systems are becoming a preferred way to provide high quality health care and are increasingly recognized as critical to the understanding and improvement of health care delivery (46). Second, our estimates are based on EMR data which may result in misclassification of a completed screening test and may not capture individuals whose screening was done outside of our system. This is more likely to impact the physician-owned clinics located at a further distance from our central optical colonoscopy centers. However, all of our clinics use a

fully-integrated EMR that has been populated with all data from 1991, including scanned documents that are manually reviewed and added to our dataset and would indicate CRC screening completion outside of UW Health. Third, the nearly all White patient population and overall high CRC screening rates for our healthcare organization may limit the potential generalizability of our findings to systems with more diverse patient populations and systems with much lower overall screening rates. Fourth, while the algorithm used to define our sample population ensures that patients attributed to UW Health and a PCP have been seen in our clinical facilities at least twice in the past three years, there is a potential for selection bias against patients who obtain all of their care from UW Health but do not regularly utilize our healthcare system. However, this is unlikely to result in a systematic bias across clinical settings. Fifth, while our definition of CRC screening completion is consistent with a patient being considered up to date for CRC screening in the study year, it does provide a longer time frame for a patient to have completed an optical colonoscopy than for an FOBT. Also, by looking back only 12 months for FOBT completion we give the same weight to patients who have had one FOBT in the prior year as patients who have had multiple annual FOBTs in previous years. Finally, we only adjusted for a portion of the case-mix at the provider and clinic levels. A recent study published in *JAMA* by Hong et al. (47) investigated the relationship between patient panel characteristics and relative physician clinical performance rankings within a large academic primary care network and found that although adjustment for patient variables may have contributed to a more accurate estimation of provider performance, it only accounted for a fraction of the total variability at the physician level. Taken together, the results of our study and the study by Hong et al. (47) leaves room to explore other potential factors that could explain the observed variation.

In conclusion, despite high overall rates of CRC screening in our healthcare system, there are variations in screening rates among primary care clinics and primary care providers within a single clinic. Interventions to improve CRC screening rates will need to address the patient, provider, and clinic level sources of this variation. The combination of multilevel factors influencing CRC screening will be unique to each healthcare system. Our approach to examining variation in CRC screening within our system can serve as a guide for future investigations to identify reasons for screening variation in other healthcare systems.

Supplementary Material

Refer to Web version on PubMed Central for supplementary material.

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STUDY HIGHLIGHTS

1. WHAT IS CURRENT KNOWLEDGE

- Colorectal cancer screening is underutilized nationally.
- Predictors of CRC screening have been identified at the patient and provider levels.

2. WHAT IS NEW HERE

- Variation in colorectal cancer screening rates exist among primary care clinics and among providers within each clinic, even in health systems with high overall screening rates.
- Significant predictors of colorectal cancer screening variation can be identified at multiple levels of the healthcare system (patient, provider, and clinic).
- Identification of multilevel predictors of colorectal cancer screening can guide development of quality improvement programs.

Figure 1.

Variation in CRC screening rates by primary care clinic in 2009. Each bubble in the graph represents a separate primary care clinic and the size of the bubble corresponds to the relative size of that clinic's eligible patient population. Data from providers with <100 eligible patients and clinics with <300 eligible patients were excluded.

Figure 2.

Variation in CRC screening rates by primary care provider within primary care clinics in 2009. Each blue bubble in the graph represents an individual primary care provider and the size of the bubble corresponds to the relative size of that provider's eligible patient population. Providers within the same primary care clinic are arranged vertically. The red X for each clinic represents the average CRC screening rate for that clinic. Data from providers with <100 eligible patients and clinics with <300 eligible patients were excluded.

Table 1

Overall sample characteristics for patients, providers, and clinics

Patient Characteristics	N=34,319
Age, %	
50–54	26
55–59	27
60–64	21
65–69	15
70–75	11
Gender, %	
Female	58
Race, %	
White	93
Marital Status, %	
Married	71
Language, %	
English (as primary language)	94
Insurance, %	
Commercial	72
Medicare	26
Medicaid or Uninsured	2
Comorbidities, %	
Congestive Heart Failure	1
Diabetes Mellitus	10
Hypertension	37
ACG Resource Utilization Score, (mean, SD)	0.6 (0.4)
Primary Care Provider Characteristics	N=97
Gender, %	
Female	49
Specialty, %	
Internal Medicine	59
Family Medicine	41
Years in practice, %	
< 10 yrs	14
10–20 yrs	32
> 20 yrs	54
Number of patients eligible for CRC screening in a provider's panel, (mean, SD)	489 (223)
Number of perceived major barriers at the patient level, (mean, SD)	2.5 (1.5)
Number of perceived major barriers at the provider level, (mean, SD)	0.2 (0.4)
Number of perceived major barriers at the system level, (mean, SD)	1.8 (1.2)
Primary Care Clinic Characteristics	N=19

Patient Characteristics	N=34,319
Clinic Management, %	
Physician-owned	67
Hospital-owned	33
Distance to nearest optical colonoscopy center in miles, (mean, SD)	6.5 (4.5)
Number of providers with patients eligible for CRC screening, (mean, SD)	9.9 (6.1)

SD = Standard Deviation, ACG = Ambulatory Care Group

Table 2

Patient sample characteristics by screening status

Characteristic	Screened (N=24,372)	Not Screened (N=9,947)	p-value
Patient Characteristics			
Age, %			<0.001
50–54	25	30	
55–59	27	25	
60–64	22	19	
65–69	15	14	
70–75	11	12	
Gender, %			0.14
Female	58	57	
Race, %			<0.001
White	94	92	
Marital Status, %			<0.001
Married	74	65	
Language, %			<0.001
English (as primary language)	95	91	
Insurance, %			<0.001
Commercial	74	68	
Medicare	25	29	
Medicaid or Uninsured	1	3	
Comorbidities, %			
Congestive Heart Failure	1	2	<0.001
Diabetes Mellitus	9	11	<0.001
Hypertension	37	11	0.58
ACG Resource Utilization Score, (mean, SD)	0.6 (0.4)	0.5 (0.4)	<0.001
Primary Care Provider Characteristics			
Gender, %			0.01
Female	50	48	
Specialty, %			<0.001
Internal Medicine	63	50	
Family Medicine	37	50	
Years in practice, %			<0.001
< 10	13	17	
10–20	32	32	
> 20	55	51	
Number of patients eligible for CRC screening in a provider's panel, (mean, SD)	500 (223)	460 (219)	<0.001
Number of perceived major barriers at the patient level, (mean, SD)	2.5 (1.5)	2.3 (1.5)	<0.001
Number of perceived major barriers at the provider level, (mean, SD)	0.2 (0.4)	0.2 (0.4)	0.28
Number of perceived major barriers at the system level, (mean, SD)	1.8 (1.2)	1.6 (1.2)	<0.001

Characteristic	Screened (N=24,372)	Not Screened (N=9,947)	p-value
Primary Care Clinic Characteristics			
Clinic Management, %			
Physician-owned	64	74	<0.001
Hospital-owned	36	26	
Distance to nearest optical colonoscopy center in miles, (mean, SD)	6.2 (4.4)	7.2 (4.8)	<0.001
Number of providers with patients eligible for CRC screening, (mean, SD)	9.8 (5.9)	9.9 (6.4)	0.61

SD = Standard Deviation, ACG = Ambulatory Care Group

Table 3

Multivariate logistic regression clustering on clinics predicting receipt of CRC screening (N=34,319 patients, N=97 providers, N=19 clinics)

Variables	Odds Ratios	95% Confidence Intervals	p-value
Patient Characteristics			
Age			
50–54	1.00		
55–59	1.25	1.16, 1.35	<0.001
60–64	1.38	1.28, 1.50	<0.001
65–69	1.70	1.54, 1.88	<0.001
70–75	1.53	1.33, 1.76	<0.001
Gender			
Male	1.00		
Female	1.03	0.96, 1.09	0.34
Race			
White	1.00		
Non-White	0.83	0.75, 0.87	<0.001
Marital Status			
Single	1.00		
Married	1.40	1.32, 1.49	<0.001
Language			
English (as primary language)	1.00		
Primarily Non-English	0.55	0.50, 0.60	<0.001
Insurance			
Commercial	1.00		
Medicare	0.63	0.56, 0.71	<0.001
Medicaid or Uninsured	0.32	0.24, 0.41	<0.001
Comorbidities			
Congestive Heart Failure	0.44	0.35, 0.55	<0.001
Diabetes Mellitus	0.82	0.75, 0.89	<0.001
Hypertension	0.99	0.93, 1.06	0.94
ACG Resource Utilization Score	1.40	1.29, 1.52	<0.001
Primary Care Provider Characteristics			
Gender			
Male	1.00		
Female	0.99	0.85, 1.16	0.98
Specialty			
Family Medicine	1.00		
Internal Medicine	1.05	0.88, 1.26	0.56
Years in practice			
< 10 yrs	1.00		
10–20 yrs	0.99	0.85, 1.16	0.92

Variables	Odds Ratios	95% Confidence Intervals	p-value
> 20 yrs	0.95	0.78, 1.16	0.63
Number of patients eligible for CRC screening in a provider's panel (divided by 100)	1.05	1.01, 1.08	<0.001
Number of perceived major barriers at the patient level	1.02	0.95, 1.10	0.55
Number of perceived major barriers at the provider level	0.89	0.74, 1.07	0.22
Number of perceived major barriers at the system level	1.07	0.98, 1.18	0.15
Primary Care Clinic Characteristics			
Clinic Management			
Physician-owned	1.00		
Hospital-owned	1.43	1.23, 1.67	<0.001
Distance to nearest optical colonoscopy center	0.97	0.95, 0.98	<0.001
Number of providers with patients eligible for CRC screening	1.01	0.99, 1.02	0.26

ACG = Ambulatory Care Group