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Regional variation in colorectal cancer testing and geographic availability of care in a publicly insured population☆

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Abstract

Despite its demonstrated effectiveness, colorectal cancer (CRC) testing is suboptimal, particularly in vulnerable populations such as those who are publicly insured. Prior studies provide an incomplete picture of the importance of the intersection of multilevel factors affecting CRC testing across heterogeneous geographic regions where vulnerable populations live. We examined CRC testing across regions of North Carolina by using population-based Medicare and Medicaid claims data from disabled individuals who turned 50 years of age during 2003–2008. We estimated multilevel models to examine predictors of CRC testing, including distance to the nearest endoscopy facility, county-level endoscopy procedural rates, and demographic and community contextual factors. Less than 50% of eligible individuals had evidence of CRC testing; men, African-Americans, Medicaid beneficiaries, and those living furthest away from endoscopy facilities had significantly lower odds of CRC testing, with significant regional variation. These results can help prioritize intervention strategies to improve CRC testing among publicly insured, disabled populations.

☆The findings and conclusions in this report are those of the authors and do not necessarily represent the official position of the Centers for Disease Control and Prevention.

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Keywords

Colorectal cancer screening; Medicaid; Medicare; Regional variation; Multilevel modeling; Disabled

1. Introduction

Colorectal cancer (CRC) is the third most common cancer diagnosis and the second leading cause of cancer death in the United States (Jemal et al., 2013). CRC is burdensome to human health and to the financial health of the health care system; total costs of caring for patients diagnosed with CRC in the United States are estimated to be more than $14 billion per year (Mariotto et al., 2011). Routine screening for CRC among those aged 50–75 years can reduce the financial burden of CRC, as well as reduce incidence and death caused by CRC (Pignone et al., 2002). Studies suggest that several different screening test regimens (annual high-sensitivity Fecal Occult Blood Test [FOBT]; combination of high-sensitivity FOBT every 3 years and sigmoidoscopy every 5 years; or colonoscopy every 10 years) are nearly equally effective in reducing CRC incidence and death if patients adhere to one of the regimens (Zauber et al., 2008; Whitlock et al., 2008; Pignone et al., 2002; Levin et al., 2008). Importantly, CRC testing is cost-effective and with rising costs associated with treating advanced CRC, routine testing may lead to more timely detection of early stage cancers and become cost-saving (Lansdorp-Vogelaar et al., 2009).

Despite its demonstrated effectiveness, CRC test use is suboptimal. Overall, CRC testing has increased since 2002, but current rates remain modest, with just 64.5% of age-eligible US adults being up-to-date with CRC testing in 2010 on the basis of self-reported data in the CDC Behavioral Risk Factor Surveillance Survey (BRFSS) (Joseph et al., 2012). Although overall rates have increased during recent years, the likelihood of being up-to-date with CRC testing is particularly low for those living in non-metropolitan areas (65% versus 69% in metropolitan areas), those with low educational attainment (45% for less than high school graduates vs. 72% for college graduates); those with low household income (48% for incomes less than $15,000 per year vs. 74% for incomes more than $75,000 per year); minorities (52–65% for minorities vs. 66% for white adults); and those without a regular health care provider (32% for persons without a regular care provider vs. 68% for those with a regular care provider) (Joseph et al., 2012). As such, CRC testing has become an important health care disparity issue.

Myriad factors influence disparities in CRC testing, including individual-level, community-level, and health care system-level factors (Klabunde et al., 2005). Many of these factors operate on multiple levels; for example, an individual’s minority race and whether s/he lives in a community with a more dense population of minorities both can have individual and interactive impacts on health and healthcare services received (Subramanian et al., 2009). As such, consideration of how these multilevel influences entwine is critical to understanding the probable reasons for CRC test underuse among vulnerable populations and intervening in meaningful and effective ways. Multilevel factors affecting cancer screening decisions include: gender, race, age, inability to travel to access care, competing health and non-health

demands on time and energy, rates of local poverty, unemployment, and uninsurance (all of which affect availability of and access to health services), geographic barriers to care (e.g., living far away from an endoscopy center), absence of social support resources, (such as help with transportation), social isolation, provider unwillingness to accept publicly insured patients, limited resources to support high-quality decision making (such as patient navigation programs, reminder systems, screening registries, or scheduling systems), and absence of a preventive care infrastructure within the public health system (Zapka et al., 2010, 2003; Honeycutt et al., 2013; Mobley et al., 2010; Stanley et al., 2013; Golden et al., 2009; Pagan et al., 2008).

Prior studies provide an incomplete picture of the importance of the intersection of multilevel factors affecting CRC testing across heterogeneous geographic regions where vulnerable populations live (Morrissey et al., 2012). Conducting rigorous multilevel analyses may help guide future resource allocation and community-based interventions to improve CRC testing among diverse communities with high numbers of publicly insured and medically vulnerable individuals.

Our research fills an important gap in the literature by reporting on the relative influence of individual-level and community-level predictors of CRC testing in North Carolina, (where community-level factors are operationalized at the county level) among Medicaid and Medicare enrollees turning 50 years of age. Because of eligibility criteria associated with Medicare and Medicaid enrollment, most 50-year-olds enrolled in Medicaid or Medicare in North Carolina are living with some type of disability and, thus, represent a particularly vulnerable population. Even with health insurance, disparities persist in receipt of cancer screening and other preventive services among people with disabilities. In a sample of 835 disabled women between the ages of 51–65 years, Wei et al. (2006) found that only 28.7% of women with public insurance pursued CRC testing, whereas 48.6% of women with private insurance were tested for CRC. Disability has also been found to be associated with many chronic conditions, including obesity, cancer, poor mental health, diabetes, heart disease, hypertension, and asthma (Wei et al., 2006) as well as an overall shorter cancer survival rate (McCarthy et al., 2007). In addition, persons living with disabilities are generally less compliant overall with cancer screening guidelines (Ramirez et al., 2005; Armor et al., 2009) Therefore, disabled individuals may be a particularly vulnerable subpopulation for CRC testing, even when they have access to insurance. Understanding in greater detail the multilevel determinants of CRC testing among vulnerable populations, such as those living with disabilities, can help elucidate which targeted interventions are most likely to be successful in increasing CRC testing rates among these groups.

2. Methods

2.1. Overview

We sought to understand differences in relative rates of CRC testing across North Carolina's publicly insured population and identify areas of need, focusing on individual and county level predictors of CRC testing among people turning 50 years of age, the age group for which the US Preventive Services Task Force (USPSTF) recommends initiating routine CRC testing (USPSTF, 2008). Accordingly, we used insurance claims data from North Carolina

Medicare and Medicaid linked to Area Resource File (ARF) and State Medical Facilities Plan (SMFP) data to examine multilevel determinants of CRC testing, including individual demographics, distance to endoscopy, availability of certain types of health care providers, and area-level poverty, education, unemployment, and racial composition. We estimated multilevel models with county level random effects and created county-specific maps depicting relative differences in multivariable-adjusted predicted probabilities of CRC testing.

2.2. Data

We acquired Medicaid and Medicare claims data from 2003 to 2008 for the population of North Carolina insured by either or both of these public insurance providers, providing us with substantial individual-level data about CRC testing. Geographic and health care service provider data from two additional sources were linked to the individual claims data by using county and ZIP code of residence. First, we used the ARF to incorporate county-specific sociodemographic and health care workforce information into our analyses. The ARF is frequently used to describe county level community contextual factors, such as income levels, employment status, and rural land. The ARF database is a collection of data from more than 50 sources, including the American Medical Association, the US Census Bureau, and the Centers for Medicare & Medicaid Services, and has more than 6000 county aggregate variables, including health measures. These data have been used frequently in prior studies of CRC testing (Hayanga et al., 2010; Koroukian et al., 2005, 2006). Second, we used historical SMFP data to identify endoscopy centers across the state and called each of these centers to verify information contained in the archived SMFP records, including, but not limited to, facility street addresses, (which were needed for geocoding), affiliate facilities (where applicable), and procedures performed. This information enabled us to calculate distance to nearest endoscopy center and to estimate annual county level endoscopy procedural rates.

2.3. Population and inclusion/exclusion criteria

The population of interest is publicly insured men and women living in North Carolina who turned 50 years of age during 2003–2008, reflecting current age-specific screening recommendations (USPSTF, 2008). Because guidelines differ on frequency of CRC testing by modality (USPSTF, 2008) (e.g., colonoscopy every 10 years, FOBT every year, flexible sigmoidoscopy every 5 years with FOBT every 3 years), we focused our analyses on tracking incident CRC testing within a cohort of individuals in North Carolina who were newly age-eligible. Importantly, given that these people were turning 50 years of age during our study period and insured by Medicare and/or Medicaid, and because of eligibility criteria associated with Medicare and Medicaid in North Carolina, more than 99% of the individuals in the sample were living with some type of disability and thus, were a particularly vulnerable population.

To ensure complete claims, we included only beneficiaries who were residents of North Carolina with valid ZIP code and county data, continuously enrolled in non-HMO plans, and alive for the entire duration of the 6-year study period, enabling the systematic examination of CRC testing practices at the individual level during multiple years. To better ensure that

our measures reflected screening test procedures rather than surveillance procedures for persons with past history of CRC, we excluded those beneficiaries with a history of CRC or colectomy. Because of the importance of county level factors in our analyses, we excluded a minority of beneficiaries who moved across county lines during the study period. Finally, a small number of individuals who had end stage renal disease (ESRD), and a very small minority of beneficiaries who were enrolled in Medicare and/or Medicaid for eligibility reasons other than disability (N=427; <1%) were excluded, leaving us with a final analytic sample of 27,178 individuals with 6 years of complete claims data (see Fig. 1).

2.4. Dependent variable

Our primary outcome measure was a binary indicator of whether the person received any type of CRC screening test procedure, including colonoscopy, FOBT, or flexible sigmoidoscopy, during the study period. Colonoscopy, FOBT, and flexible sigmoidoscopy were measured as separate procedures, each potentially indicating that screening was performed, consistent with USPSTF guidelines; subsequent follow-up and diagnostic procedures were not assessed. Dates of services were recorded for each procedural code of interest, identified by International Classification of Diseases, 9th Edition, Clinical Modification (ICD-9-CM), Current Procedural Terminology (CPT), or Healthcare Common Procedure Coding System (HCPCS) codes. The codes used are summarized in Table 1.

2.5. Independent variables

Independent variables of interest included individual-level characteristics, such as gender (male or female), race (white, black, or other), types of insurance (i.e., Medicare-only, Medicaid-only, or dually enrolled), year turned 50, and distance from patient ZIP code to nearest endoscopy facility. The latter was calculated by identifying all endoscopy facilities in North Carolina by using the 2007 SMFP Inventory of Endoscopy Rooms in Licensed Facilities; this documentation provides the facility name and county, number of rooms, as well as procedural rates in each year. Each of the 178 facilities across North Carolina's 100 counties was telephoned to obtain the physical address of the facility, verify the facility was in operation during the entire study period, and identify whether that facility operated with other group practices or was affiliated with a hospital. By using the beneficiaries' residential ZIP code and the facilities' actual physical address, we geocoded these locations to obtain X/Y coordinates by using ArcGIS Desktop Release 10.0 (Environmental Systems Research Institute, Redlands, CA, 2011). These coordinates were then used to calculate the straight-line distance from the ZIP code centroid of each beneficiary to each endoscopy facility throughout the state. By rank-ordering these distances, we were able to identify the nearest endoscopy facility to each beneficiary, employing a previously published approach (Wheeler et al., 2012). Distances to nearest endoscopy facility were further categorized as follows for subsequent analyses: less than 5 miles, 5–10 miles, 10–15 miles, 15–20 miles, 20–25 miles, and 25 or more miles.

Additional independent variables were county level characteristics derived from the ARF data, including a population-adjusted count of medical generalists (adjusted for the population of Medicaid/Medicare enrollees living in the county and dichotomized at the median for analyses), percentage living below the federal poverty line, percentage with less

than a high school education, percentage unemployed, percentage uninsured, and percentage non-white. The latter five variables were categorized into quartiles. Finally, the SMFP data reported the total number of inpatient endoscopy cases, ambulatory endoscopy cases, and total endoscopy procedures performed annually. We used the latter measure (total endoscopy procedures performed) to create a county level measure of annual endoscopy procedural rates per 10,000 residents. Counties without any endoscopy center as reported by the SMFP (N=28) were assigned a value of zero for endoscopy procedural rate.

2.6. Statistical analyses

We stratified our analyses on the basis of insurance type (Medicare only, Medicaid only, or dually enrolled in Medicaid and Medicare for any time during our study period) because these three groups of beneficiaries are likely quite different from one another in important unmeasured ways because of eligibility criteria for these public entitlement programs. (For example, Medicaid enrollees must demonstrate their low income status and meet one of the several additional criteria of vulnerability; Medicare enrollees do not have to demonstrate low income status, but they must meet other criteria for enrollment.) (Assistance, 2013; Medicare.gov, 2012). In addition, in pooled analyses, overall use of CRC testing and the magnitude and significance of factors affecting CRC testing varied significantly by beneficiary group.

Baseline descriptive characteristics of the sample were examined first. We used Chi^2 and t-test statistics to describe the relationships between receipt of CRC testing and independent variables in bivariate analyses. Given the clustering of beneficiaries at the county level, we used multilevel multivariable logistic models to examine variation in CRC testing, controlling for individual (e.g., gender, race, distance to endoscopy) and county level (e.g., number of procedures performed at the county level per 10,000 persons per year) characteristics. We allowed the intercept to vary at the county level (e.g., we estimated a random intercepts model). The equation can be described as follows:

$$\text{Logit}\,(\pi_{ij}) = \beta_{0j} + \beta_1 Age_{ij} + \beta_2 Race_{ij} + \ldots + \beta_{p+1} ProcVol_j + \beta_{p+2} GenCount_j + \ldots + e_{ij}$$

where π_{ij} is the probability of the binary outcome (CRC testing) for person i living in county j, β_{0j} is the intercept for county j, β_1 is the coefficient for the person-level predictor Age, β_2 is the coefficient for the person-level predictor Race, β_{p+1} is the coefficient for the county level predictor Procedural Rate in county j, β_{p+2} is the coefficient for the county level predictor Generalist in county j, and e_{ij} is the error term.

Interaction terms were considered to examine possible joint effects of individual variables (e.g., gender and race), but because of a lack of statistical significance and improvement of model fit, these interactions were not included in the final model estimations.

Final models were used to derive average predicted probabilities of CRC testing for each county in North Carolina. From these multivariable adjusted county-specific predicted probabilities, we categorized predictions into tertiles across the 100 North Carolina counties and generated maps illustrating differences in predictions by tertiles. The maps also depict

the number of endoscopy centers in each county, as well as the nine largest cities in North Carolina designated as urban centers (with population sizes more than 100,000). All statistical analyses were conducted in SAS software (version 9.2; SAS Institute, Inc., Cary, North Carolina). Maps were created by using ArcGIS Desktop Release 10.0 (Environmental Systems Research Institute, Redlands, CA, 2011).

3. Results

Of the 27,178 individuals included in our sample, 45% were male, and 56% were white (Table 2). For insurance type, 26% of beneficiaries were enrolled in Medicare only, 24% were enrolled in Medicaid only, and 50% were dually enrolled at some point during the study period. Medicare-only enrollees were predominantly male and white, whereas Medicaid-only enrollees were predominantly female and black. Of those individuals dually enrolled in Medicaid and Medicare, 52% were female and 56% were white. Nearly half of our sample lived within 5 miles of an endoscopy facility, but more than 25% of the sample lived more than 10 miles away from the nearest endoscopy facility, with 422 individuals living more than 25 miles away from the nearest endoscopy facility.

Fig. 2 is a map of North Carolina depicting numbers of endoscopy facilities in each county. Mecklenburg and Wake counties have the most endoscopy facilities (17 and 12, respectively), whereas 28 counties have none. County level endoscopy volume procedural rates ranged from 0 to 1462 endoscopies performed annually per 10,000 residents, where darker red shading reflects fewer endoscopy procedures performed at the county level and lighter pink shading reflects more endoscopy procedures performed at the county level. The color of shading (i.e., red, orange, yellow) indicates the density of the study population (i.e., publicly insured 50-year-olds) as a function of the general population (per 10,000 residents) living in the county, where red indicates greater density of publicly insured individuals and yellow indicates lower density of publicly insured individuals. From this map, it is clear that several counties (particularly in the northeastern, western, and southeastern regions of the state) contain the greatest density of publicly insured 50-year-olds and that those individuals have poorest access to endoscopy facilities. This map indicates significant variation in access to endoscopy, endoscopy procedural rates across counties, and in the distribution of our study population across counties.

Overall, according to the insurance claims data, 49% of our total sample received at least one CRC test during the 6-year study period, with 36% receiving at least one colonoscopy, 25% receiving at least one FOBT, and less than 5% receiving other test modalities, such as CT colonography (results not shown). Table 3 presents results from the multilevel multivariable logit model with random effects and the adjusted odds ratios (OR) of predictor variables on the receipt of CRC testing, presented in total and stratified by insurance type (Medicare-only, Medicaid-only, or dual insurance). In the total sample, individuals insured by Medicaid only had significantly lower odds of having been tested for CRC compared with Medicare-only enrollees (OR: 0.86; 95% CI=0.79, 0.95). In the total sample, women had 2.15 greater odds of CRC testing (95% CI=2.04, 2.26) compared with men. In the Medicare-only stratified model, women had 2.65 greater odds of CRC testing (95% CI=2.38, 2.94) (Table 3).

In the total sample, living more than 25 miles from an endoscopy facility was associated with 0.78 times the odds of CRC testing compared with those living 0–5 miles from a facility (95% CI=0.63, 0.96); this finding appeared to be entirely driven by the Medicaid-only sample, as the distance-to-endoscopy effect was even more pronounced in the Medicaid-only analytic stratum (even at the 15–20 mile level), whereas distance-to-endoscopy was not a statistically significant predictor in the Medicare-only or dual stratified analytic models.

In general across the insurance strata, African-American individuals had lower odds of CRC testing, with little variation in the magnitude of effect across insurance-stratified models: Medicare-only (OR=0.83, 95% CI=0.74, 0.94), Medicaid-only (OR=0.88, 95% CI=0.78, 0.99), and dual insurance (OR=0.89, 95% CI= 0.82, 0.97).

Finally, individuals insured by Medicare-only and Medicaid-only living in counties that performed more than 800 procedures annually had 1.54 and 1.39 higher odds of CRC testing, respectively, compared with those individuals who lived in counties without any CRC facility or 0 procedures performed (95% CI=1.07, 2.20, and 95% CI=1.01, 1.91, respectively). Importantly, for the Medicare-only stratum, higher endoscopy procedural rates (as compared with living in counties without any CRC facility or 0 procedures performed) corresponded to significantly higher odds of CRC testing at almost every procedural rate level.

Table 4 depicts the average predicted probabilities of receiving CRC testing on the basis of varying distance to the nearest endoscopy facility and calculated for a typical person in the sample with the following characteristics held constant: female; white; turned 50 years of age in 2003; resident of a county where the population-adjusted generalist count is above median, the population-adjusted endoscopic procedure rate is 1–200 in a given year, and the county is in the lowest quartile of high school education; percentage living in poverty; uninsurance rate; unemployment rate; and percentage non-white. In the total sample, 62% of individuals with these characteristics who lived 0–5 miles away from an endoscopy facility would be predicted to get tested for CRC, compared with 56% of those living 25 or more miles away from a facility. Individuals insured by Medicare only had the highest predicted probability of getting CRC testing: 73% when living 0–5 miles away from an endoscopy facility and 65% when living 25 or more miles from a facility. By contrast, only 59% of individuals insured by Medicaid were predicted to receive CRC testing when living 0–5 miles away from an endoscopy facility compared with 51% of those living 25 or more miles away.

Fig. 3 shows four county-specific maps of North Carolina, detailing the adjusted, county-specific predicted probabilities of CRC testing for the total sample (Fig. 3a), Medicaid insurance only (Fig. 3b), Medicare insurance only (Fig. 3c), and dual enrollment in Medicare and Medicaid (Fig. 3d). We calculated county-specific predicted probabilities by averaging the individual predicted probabilities from the final model for each county. A few interesting findings warrant discussion. First, Wake county (where Raleigh is located, the state capital, and second largest city in the state) and Mecklenburg county (where the state's largest city, Charlotte, is located) have the highest concentrations of endoscopy facilities in

the state, but relatively low predicted probabilities for CRC testing. Upon further examination of the maps stratified by insurance type, it is clear that these extremely low predicted probabilities are limited to the Medicaid and dual insured samples. For example, Fig. 3b and d shows that Wake county is in the lowest tertile (has the lowest predicted probability) for CRC testing among Medicaid-only patients (0.36–0.45) and among dual insured patients (0.43–0.48), but in Fig. 3c, individuals solely insured by Medicare in Wake county have a higher predicted probability of CRC testing (0.46–0.50). In addition and worth noting, across all of these maps, the predicted probabilities of CRC testing were consistently low in the westernmost counties of North Carolina (in the mountains) and among isolated counties in the eastern part of the state (near the coast). Other regions, including some northeastern counties and north-central counties, have few to no endoscopy facilities and low predicted probabilities for CRC testing across all Medicare, Medicaid, and dually insured populations.

4. Discussion

We analyzed Medicare and Medicaid data linked to ARF and SMFP data to understand CRC testing patterns and multilevel predictors of CRC testing among individuals turning 50 years of age during 2003–2008, the age at which CRC testing should commence, according to USPSTF guidelines. In particular, we were interested in regional variation in CRC testing rates and in geographic access to CRC testing across a large, diverse state. In other words, we sought to understand where there may be areas of opportunity according to CRC testing underuse, where there may be “endoscopy deserts” with poor access to endoscopy, and to what extent distance to endoscopy and county-specific factors were associated with receipt of CRC testing.

Our findings highlight a number of important preventive health issues. First, less than half of all newly eligible individuals in this publicly insured, disabled sample received *any* CRC testing during a 6-year study period, indicating poor use of preventive health care services. In general, this is slightly lower than what has previously been reported in national BRFSS data among similar age groups in the general population (Joseph et al., 2012; Stanley et al., 2013). In addition, prior data have shown that approximately one-third of North Carolinians aged 50–75 years are not up-to-date with CRC screening (Joseph et al., 2012). Differences in our data as compared with other studies may be explained by underlying differences between our disabled population and the general population or by the self-reported nature of BRFSS, which may be subject to recall bias or social desirability bias. In contrast, our data are claims-based and, therefore, reflect actual services received and paid for by public insurers. On the other hand, our estimates may underestimate CRC testing rates because claims data capture services only if they were billed for reimbursement. Some FOBTs that were performed, for example, may not have been billed to insurance because of their low reimbursement rates, and our analysis cannot capture services not billed to and paid by Medicare and/or Medicaid. In addition, individuals who turned 50 years of age towards the end of our study period may have delayed but eventually had evidence of CRC testing after our study period ended—the implications of delaying guideline-recommended cancer testing for months or several years are unknown. Likewise, it is possible that a minority of individuals in our sample were screened before our data window began, (for example, if they

had a family history of CRC). Unfortunately, we were not able to capture such services if they happened before our observation period; nevertheless, we expect this to be a small number of people.

Second, we have shown significant heterogeneity in CRC testing across counties and among different types of publicly insured groups in North Carolina. Among Medicaid-only enrolled individuals, average predicted probabilities for CRC testing varied from 0.36 to 0.62 across counties, and among Medicare-only enrolled individuals, average predicted probabilities ranged from 0.24 to 0.61 across counties. Several counties were consistently poor performers for CRC testing, including counties in the western and north-central parts of the state, as well as several isolated counties in the eastern coastal regions. In many cases these poor performing counties had either no endoscopy facility or very low endoscopy rates, perhaps indicating “endoscopy deserts”, a supply-side problem. Importantly, some of the lowest predicted probabilities were observed in counties with the highest densities of endoscopy centers, such as Wake and Mecklenburg counties, indicating that availability of endoscopy centers alone does not lead to higher CRC testing uptake. This finding was even more pronounced in the Medicaid-only and dual-insured samples, perhaps reflecting providers’ unwillingness to accept Medicaid insurance in these endoscopy center-rich areas, or urban patients’ limited awareness of the benefits of CRC testing. This finding is consistent with some studies that have suggested urban disadvantages in cancer care (McLafferty and Wang, 2009; McLafferty et al., 2011), but different from other studies that have found rural areas to be most underserved (Cole et al., 2012, Meilleur et al., 2013).

For multilevel predictors of CRC testing in the total sample, men, African-Americans, Medicaid enrollees, and those individuals living more than 25 miles from an endoscopy facility had significantly lower odds of CRC testing. In addition, among Medicare-only enrollees and to a lesser extent, Medicaid-only enrollees, increasing county level endoscopy procedural rates were predictive of CRC testing. And among Medicaid enrollees in particular, living more than 25 miles away from an endoscopy center was associated with lower odds of CRC testing. We expected shorter distances of 10 miles or more to endoscopy centers to be significantly predictive of CRC testing, but did not find this to be the case in this North Carolina sample, which may reflect more willingness to travel for healthcare services or substitution of FOBT instead of colonoscopy for CRC screening among these individuals. Other findings, particularly those for men, African-Americans, and lower income (Medicaid-insured) individuals, are consistent with other studies conducted in different settings (Joseph et al., 2012). To our knowledge, this is one of the first studies to examine county-specific endoscopy procedural rates and distance between individual residence and endoscopy centers as potential predictors of CRC testing. Our extensive model specification testing (not detailed here) further justified and underscored the importance of using a multilevel, random effects model with county-specific intercepts for estimation. Studies not considering the multilevel influence of various relevant factors on CRC testing may be biased (Morrissey et al., 2012).

Despite the strengths of the overall approach, including the use of multilevel modeling and multiple large data set links, several important limitations accompany our findings. Although claims data have been shown to provide an accurate portrayal of CRC testing practices

(Schenck et al., 2007), there are limitations to analyses that use Medicare and Medicaid claims data, including the following: limited ability to directly assess patient-provider decision making in the absence of medical record reviews or patient-provider interviews; limited number of years available to validate that CRC testing as measured in the claims reflects whether individuals are up-to-date with screening; and inability to understand CRC testing patterns among the uninsured, and HMO-enrolled, and populations not continuously enrolled (i.e., excluded populations). Medicaid and Medicare claims data also cannot reflect services not covered or not reimbursed by Medicaid or Medicare, or services provided during a time in which the individual was ineligible or not enrolled in the entitlement program, so any services paid for out-of-pocket or by another third-party payer cannot be identified. This concern is particularly relevant for those excluded individuals transitioning in and out of the program month-to-month (most relevant for the Medicaid population), for whom we know nothing during the time when insurance coverage lapsed. Given this issue, our results may not be representative of those publicly insured populations whose coverage is transient over time. In addition, our data were unable to provide detailed health care system-level information that may affect CRC testing, such as additional endoscopy facility-level information (e.g., number and qualifications of staff; quality of scheduling and outreach services; wait times) and community-level health educational, social support (e.g., transportation), and decision-making resources. Lastly, because individuals often cross county-lines to obtain healthcare, county level resource availability and numbers of endoscopy procedures performed in a single county may be imperfect measures of access to CRC screening. Future studies should consider identifying referral networks and clusters of cancer prevention services and characterizing preventive healthcare seeking behavior across county lines (for example, do patients bypass closer providers to obtain preventive services and how often and how far do they travel to other counties to obtain preventive services?) Regardless, it is possible to characterize relative differences in CRC testing rates at the individual and county levels and identify communities in North Carolina where publicly insured, disabled individuals eligible for CRC testing appear to be most underserved.

5. Conclusion

Our results suggest that receipt of CRC testing among publicly insured individuals across one socioeconomically and geographically diverse state is highly variable, and that certain vulnerable populations may be more at risk than others and, therefore, particularly suitable for intervention targeting. Interventions that may be most effective are perhaps those that help patients overcome transportation and other physical access barriers, (e.g., at-home testing by using stool sample kits that can be mailed to providers), or those that target African-Americans, males, and Medicaid-insured or low-income subgroups employing culturally competent approaches to improve awareness, patient-provider communication, and trust, (e.g., individualized patient navigation) (Dubard et al., 2008). For example, one such collaborative learning intervention implemented in federally qualified health centers led to increased clinical tracking and documentation and a 12.6% increase in CRC screening test uptake (Taplin et al., 2008). More broadly, considering that our study sample represented a disabled, medically vulnerable population, all of whom had lower rates of CRC testing than expected as compared with general populations, tailoring CRC testing interventions to all

publicly insured individuals in this age group may be an important prevention strategy. Although the Community Guide task force recommendations (Taskforce, 2012) are useful and broadly applicable among the general population, they may not be as responsive to the unique needs of vulnerable populations. In addition, because multiple colorectal cancer testing modalities create a preference-sensitive decision-making environment, it is important to understand preferences for CRC testing among vulnerable populations. Understanding the CRC-related decisions and preferences made by vulnerable and hard-to-reach populations will likely improve CRC testing rates over time among the most at-risk groups.

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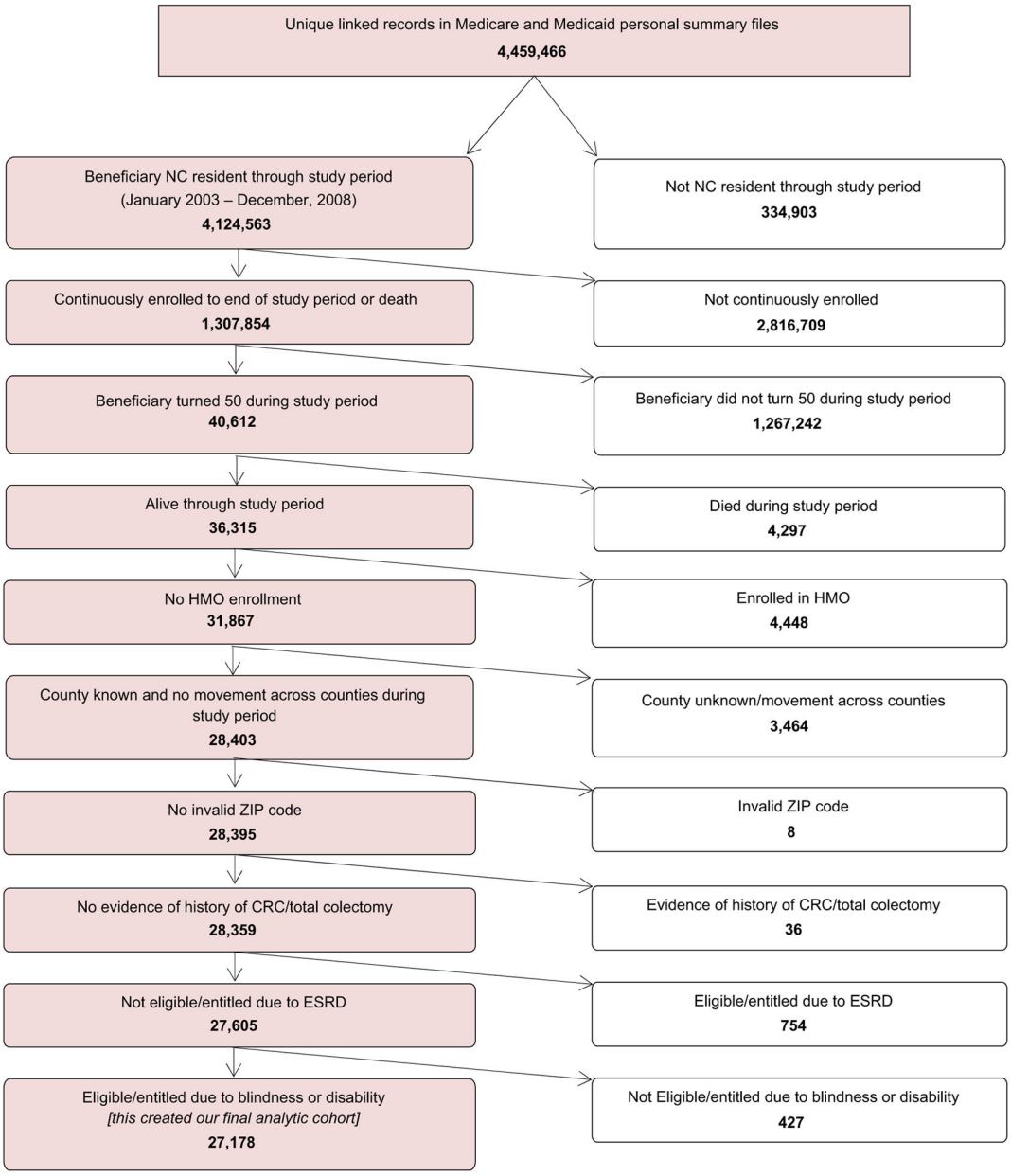

Fig. 1.

Inclusion or exclusion criteria applied to generate analytic sample. Notes: CRC (colorectal cancer); ESRD (end state renal disease); HMO (Health Maintenance Organization); NC (North Carolina); ZIP (Zone Improvement Plan).

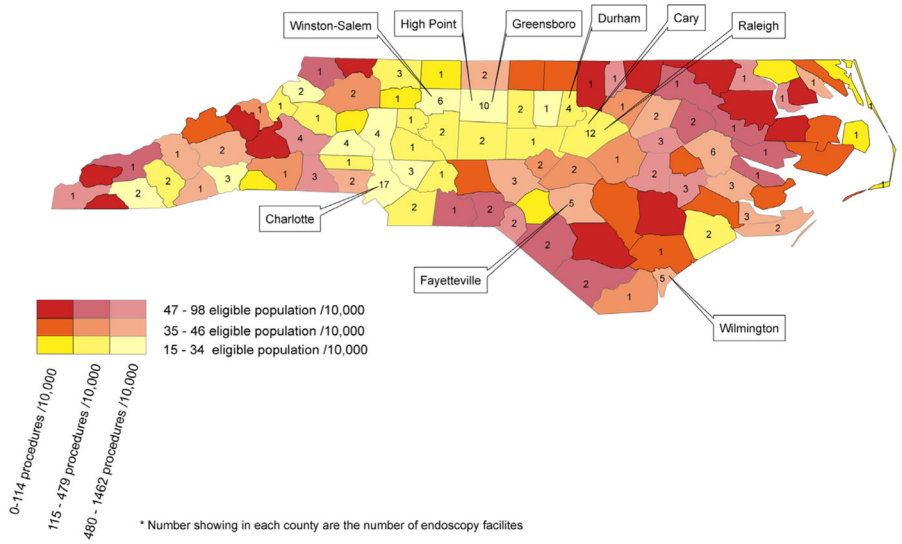

Fig. 2.

County-specific location of endoscopy facilities, endoscopy procedural rates, density of Medicare and Medicaid beneficiaries, and major urban cities in North Carolina. Notes: this map was generated by using 2007 data from the State Medical Facilities Plan (SMFP) about the location and endoscopy procedural rates throughout North Carolina. The total number of endoscopy centers in each county is indicated in the center of each county. County level endoscopy procedural rates ranged from 0 to 1462 endoscopies performed annually per 10,000 residents, where darker shading reflects fewer endoscopy procedures performed at the county level and lighter shading reflects more endoscopy procedures performed at the county level. The color of shading (i.e., red, orange, yellow) indicates the density of the study population (i.e., publicly insured 50-year-olds) as a function of the general population (per 10,000 residents) living in the county, where red indicates greater density of publicly insured individuals and yellow indicates lower density of publicly insured individuals. (For interpretation of the references to color in this figure legend, the reader is referred to the web version of this article.)

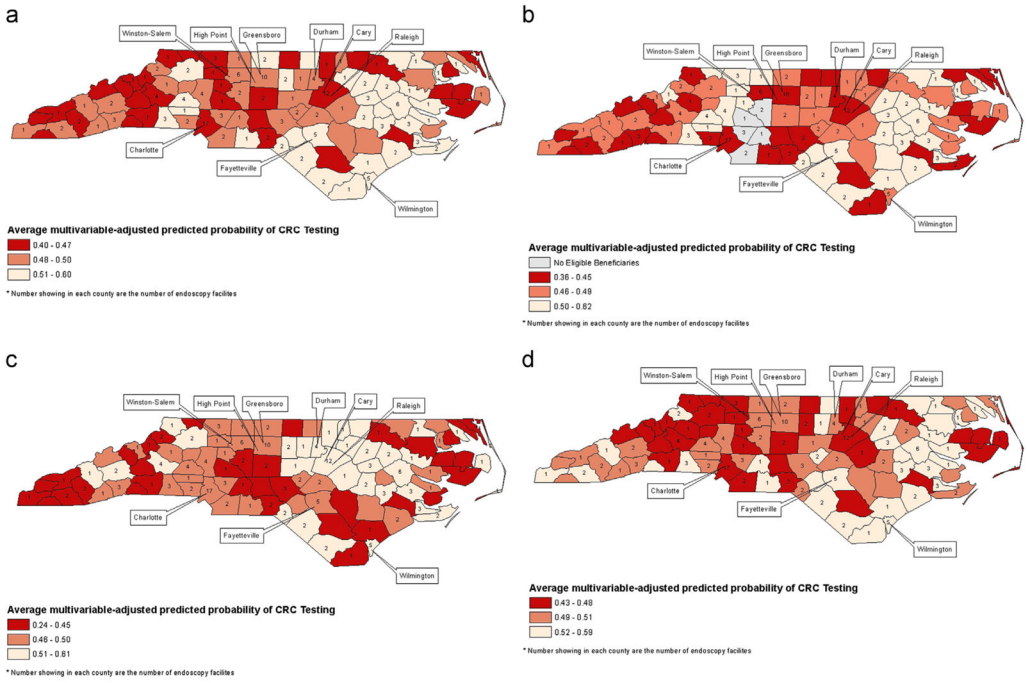

Fig. 3.

Multivariable-adjusted predicted probabilities of colorectal cancer testing by county. Panel a: total sample (all insurance providers). Panel b: Medicaid-only sample, Panel c: Medicare-only sample, and Panel d: dually insured by Medicaid and Medicare sample. Notes: these maps depict multivariable-adjusted regional variation by county in individual colorectal cancer testing during a 6-year period among people turning 50 years of age who were publicly insured during 2003–2008 (panel a: all providers; panel b: Medicaid only; panel c: Medicare only; and panel d: dually insured by Medicaid and Medicare). Shading reflects county-specific predicted probabilities in tertiles, as generated from multivariable models. Predicted probabilities were calculated by averaging the individual predicted probabilities from the final model for each county. Increasingly darker red shading indicates lower levels of CRC testing across the state, whereas increasingly lighter pink shading indicates higher levels of CRC testing across the state, controlling for all other person-level and county level factors. Major urban cities (more than 100,000 persons) are designated by callouts, and numbers indicate the count of endoscopy centers in each county. In panel 3b, the lack of any eligible beneficiaries in the 5-county Piedmont area consisting of Cabarrus, Davidson, Rowan, Stanley, and Union (shaded in gray) is indicative of a special, prepaid managed care plan operating in the Piedmont Behavioral Healthcare catchment area during the study period. As such, we excluded Medicaid-only beneficiaries in this region due to special program features operating in that region. (For interpretation of the references to color in this figure legend, the reader is referred to the web version of this article.)

Table 1

Billing codes indicating colorectal cancer testing procedures.

Screening test modality	Codes
Fecal occult blood test (FOBT)	82270, 82272, 82273, 82274, G0328, G0107
Colonoscopy	44388, 44389, 44392, 44393, 44394, 44397, 45355, 45378, 45379, 45380, 45381, 45382, 45383, 45384, 45385, 45392, G0105, G0121, 45.21, 45.22, 45.23, 45.25, 45.41, 45.43, 48.36
Flexible sigmoidoscopy	45300, 45303, 45305, 45307, 45308, 45309, 45315, 45317, 45320, 45321, 45327, 45330, 45331, 45332, 45333, 45334, 45335, 45337, 45338, 45339, 45340, 45341, 45342, 45345, G0104, 45.24, 48.21, 48.22, 48.23, 48.24

Table 2

Sample characteristics.

Variable		Overall cohort		Medicare only		Medicaid only		Dual	
	Category	***N***	**%**	***N***	**%**	***N***	**%**	***N***	**%**
	Total	**27,178**	**100**	**7110**	**100**	**6457**	**100**	**13,611**	**100**
Gender	Male	12,320	45.33	3709	52.17	2124	32.89	6487	47.66
	Female	14,858	54.67	3401	47.83	4333	67.11	7124	52.34
Race	White	15,099	55.56	5082	71.48	2457	38.05	7560	55.54
	African-American	10,607	39.03	1801	25.33	3221	49.88	5585	41.03
	Other	1472	5.42	227	3.19	779	12.06	466	3.42
Insurance type	Medicare only	7110	26.16						
	Medicaid only	6457	23.76						
	Dually enrolled	13,611	50.08						
Year turned 50	2003	4793	17.64	1465	20.6	1106	17.13	2222	16.33
	2004	4708	17.32	1305	18.35	1107	17.14	2296	16.87
	2005	4560	16.78	1255	17.65	1062	16.45	2243	16.48
	2006	4503	16.57	1114	15.67	1091	16.9	2298	16.88
	2007	4379	16.11	1004	14.12	1009	15.63	2366	17.38
	2008	4235	15.58	967	13.6	1082	16.76	2186	16.06
Distance from nearest endoscopy facility in miles	0–5	12,473	45.89	3037	42.71	3041	47.1	6395	46.98
	>5–10	7540	27.74	2116	29.76	1607	24.89	3817	28.04
	>10–15	4192	15.42	1231	17.31	981	15.19	1980	14.55
	>15–20	1976	7.27	469	6.6	560	8.67	947	6.96
	>20–25	575	2.12	170	2.39	142	2.2	263	1.93
	25+	422	1.55	87	1.22	126	1.95	209	1.54

Table 3

Multilevel multivariable logit model with random effects: odds ratios for receipt of CRC testing in total sample and stratified by insurance type.

Variable	Category	Total sample			Medicare only			Medicaid only			Dual		
		N=27,178			*N*=7110			*N*=6457			*N*=13,611		
		OR	95% CI		OR	95% CI		OR	95% CI		OR	95% CI	
Insurance	Medicare-only	Reference											
	Medicaid-only	0.86	0.79	0.95									
	Dual	1.06	0.98	1.15		N/A			N/A			N/A	
Gender	Male	Reference											
	Female	2.15	2.04	2.26	2.65	2.38	2.94	1.98	1.77	2.20	1.99	1.86	2.13
Race	White	Reference											
	AA	0.86	0.81	0.92	0.83	0.74	0.94	0.88	0.78	0.99	0.89	0.82	0.97
	Other	0.91	0.79	1.04	0.83	0.54	1.27	0.95	0.83	1.09	0.96	0.71	1.31
Year turned 50	2008	Reference											
	2003	1.91	1.76	2.08	2.35	1.94	2.85	1.80	1.51	2.14	1.80	1.58	2.05
	2004	1.76	1.59	1.95	2.08	1.74	2.48	1.66	1.37	2.01	1.70	1.48	1.95
	2005	1.48	1.38	1.59	1.64	1.40	1.92	1.52	1.30	1.78	1.42	1.25	1.60
	2006	1.49	1.37	1.63	1.73	1.43	2.09	1.64	1.39	1.93	1.35	1.18	1.56
	2007	1.23	1.13	1.34	1.27	1.03	1.56	1.27	1.07	1.51	1.20	1.07	1.35
Distance in miles	0–5 Miles	Reference											
	>5–10	0.97	0.92	1.03	0.92	0.82	1.02	0.93	0.83	1.04	1.05	0.96	1.14
	>10–15	0.98	0.91	1.07	1.00	0.86	1.15	0.93	0.80	1.07	1.03	0.91	1.16
	>15–20	0.93	0.84	1.02	0.99	0.84	1.16	0.80	0.66	0.96	1.02	0.86	1.21
	>20–25	1.14	0.90	1.44	1.33	0.88	2.00	1.13	0.74	1.73	1.03	0.75	1.41
	25+	0.78	0.63	0.96	0.70	0.39	1.26	0.72	0.53	0.98	0.82	0.66	1.00
Procedural rate[a]	0 Proc.	Reference											
	1–200	1.09	0.90	1.31	1.30	1.00	1.68	1.33	0.98	1.80	0.98	0.76	1.25
	>200–400	0.98	0.81	1.19	1.14	0.89	1.46	1.17	0.87	1.56	0.90	0.71	1.15
	>400–600	1.06	0.87	1.28	1.36	1.06	1.76	1.10	0.83	1.45	0.95	0.75	1.20
	>600–800	1.12	0.91	1.38	1.37	1.00	1.89	1.19	0.87	1.63	1.03	0.79	1.33

Variable	Category	Total sample			Medicare only			Medicaid only			Dual		
		N=27,178			*N*=7110			*N*=6457			*N*=13,611		
		OR	95% CI		OR	95% CI		OR	95% CI		OR	95% CI	
	800+	1.20	0.95	1.52	1.54	1.07	2.20	1.39	1.01	1.91	1.11	0.83	1.48
Count of generalists per county[a]	Below median	Reference											
	Above median	0.97	0.84	1.12	0.95	0.75	1.19	0.99	0.82	1.21	0.95	0.80	1.13
% Poverty	Low	Reference											
	Low-Med	1.02	0.91	1.15	0.96	0.82	1.12	0.94	0.79	1.11	1.12	0.98	1.27
	Med-Hi	1.15	0.98	1.34	1.01	0.81	1.27	1.23	0.97	1.55	1.19	1.00	1.41
	High	1.18	0.95	1.48	1.05	0.80	1.39	1.16	0.87	1.55	1.28	0.98	1.68
% with less than HS education	Low	Reference											
	Low-Med	1.07	0.90	1.27	0.93	0.71	1.22	1.02	0.82	1.27	1.18	0.96	1.44
	Med-Hi	1.10	0.94	1.29	0.85	0.63	1.15	1.01	0.78	1.30	1.31	1.08	1.59
	High	1.11	0.88	1.41	0.87	0.61	1.24	0.90	0.67	1.22	1.26	0.96	1.66
% Unemployed	Low	Reference											
	Low-Med	0.94	0.79	1.12	0.81	0.65	1.02	0.98	0.80	1.21	0.98	0.82	1.17
	Med-Hi	1.01	0.85	1.21	0.89	0.71	1.13	1.06	0.83	1.37	1.02	0.84	1.23
	High	0.90	0.72	1.12	0.76	0.56	1.03	0.90	0.67	1.20	0.94	0.74	1.19
% Uninsured	Low	Reference											
	Low-Med	1.12	0.96	1.29	1.16	0.95	1.40	1.31	1.09	1.57	1.05	0.89	1.24
	Med-Hi	1.05	0.87	1.25	1.07	0.88	1.31	1.14	0.86	1.52	1.02	0.84	1.24
	High	0.94	0.77	1.14	0.82	0.64	1.04	1.15	0.88	1.52	0.97	0.78	1.22
% Non-white	Low	Reference											
	Low-Med	0.95	0.81	1.11	0.93	0.75	1.15	1.07	0.86	1.34	0.97	0.81	1.16
	Med-Hi	1.01	0.85	1.20	1.16	0.91	1.47	0.93	0.75	1.16	0.99	0.81	1.21
	High	1.16	0.94	1.43	1.23	0.93	1.62	1.27	1.00	1.60	1.12	0.87	1.43

AA=African-American; HS=High School.

[a]Adjusted per 10,000 population living in the county.

Table 4

Predicted probabilities of receiving CRC testing by distance to nearest endoscopy facility, calculated for a typical individual in a sample, stratified by insurance type.

Distance	Predicted probability			
	Total	Medicare only	Medicaid only	Dual
0–5 Miles	0.620	0.731	0.587	0.567
>5–10 Miles	0.614	0.713	0.569	0.578
>10–15 Miles	0.617	0.730	0.569	0.574
>15–20 Miles	0.602	0.728	0.531	0.572
>20–25 Miles	0.650	0.782	0.617	0.574
25+ Miles	0.561	0.654	0.506	0.517
% Point difference between categories: 0–5 miles and 25+ miles	*6.0%*	*7.6%*	*8.1%*	*5.1%*

*Modal sample for total cohort includes individuals with the following characteristics: female, white, Medicare only beneficiary, turned 50 years of age in 2003, and resident of a county where: population-adjusted *generalist* count is above median, population-adjusted endoscopic *procedural rate* is 1–200 in a given year, and county is in the lowest quartile of (1) high school education, (2) percentage poverty, (3) uninsurance rate, (4) unemployment rate, and (5) percentage non-white.