# Sociodemographic Factors and Screening CT Colonography Use Among Medicare Beneficiaries

## Highlights

**Key finding:** In comparison with beneficiaries in communities with per capita income <$25,000 while controlling for race and ethnicity, those in communities with income ≥$100,000 were 5.7 times more likely to undergo screening CTC, a larger difference than observed for other CRC screening strategies (OR, 1.03-1.50) or for diagnostic CTC (OR, 2.00).

**Importance:** Lack of Medicare coverage may contribute to greater income-based differences in use of screening CTC than of other recommended screening strategies or of diagnostic CTC.

## ABSTRACT

**Background:** Approximately one-third of the eligible U.S. population have not undergone guideline-compliant colorectal cancer (CRC) screening. Guidelines recognize various screening strategies, to increase adherence. CMS provides coverage for all recommended screening tests except for CT colonography (CTC).

**Objective:** To compare CTC and other CRC screening tests in terms of associations of utilization with income, race and ethnicity, and urbanicity, in Medicare fee-for-service beneficiaries.

**Methods:** This retrospective study used CMS Research Identifiable Files from January 1, 2011, to December 31, 2020. These files contain claims information for 5% of Medicare fee-for-service beneficiaries. Data were extracted for individuals 45–85 years old, excluding those with high CRC risk. Multivariable logistic regression models were constructed to determine likelihood of undergoing CRC screening tests (as well as of undergoing diagnostic CTC, a CMS-covered test with similar physical access as screening CTC) as a function of income, race and ethnicity, and urbanicity, controlling for sex, age, Charlson comorbidity index, U.S. census region, screening year, and related conditions and procedures.

**Results:** For 12,273,363 beneficiary years (mean age, 70.5±8.2 years; 6,774,837 female, 5,498,526 male; 2,436,849 unique beneficiaries), there were 785,103 CRC screenings events, including 645 for screening CTC. Compared with individuals living in communities with per capita income <$25,000, individuals in communities with income ≥$100,000 had OR for undergoing screening CTC of 5.73, optical colonoscopy of 1.36, sigmoidoscopy of 1.03, guaiac fecal-occult blood test/fecal immunochemical test of 1.50, stool DNA of 1.43, and diagnostic

CTC of 2.00. Compared with non-Hispanic White individuals, OR for undergoing screening CTC was 1.00 for Hispanic individuals and 1.08 for non-Hispanic Black individuals. Compared with residents of metropolitan areas, OR for undergoing screening CTC was 0.51 for residents of micropolitan areas and 0.65 for residents of small or rural areas.

**Conclusion:** The association with income was substantially larger for screening CTC than for other CRC screening tests or for diagnostic CTC.

**Clinical Impact:** Medicare's non-coverage for screening CTC may contribute to lower adherence with screening guidelines for lower-income beneficiaries. Medicare coverage of CTC could reduce income-based disparities for individuals avoiding optical colonoscopy due to invasiveness, need for anesthesia, or complication risk.

# INTRODUCTION

Colorectal cancer (CRC) is the second leading cause of cancer deaths in the United States, with 52,550 projected deaths in 2023 [1]. The recommended CRC screening strategies from the U.S. Preventive Services Task Force, American College of Gastroenterology, and American Cancer Society include optical colonoscopy (OC) every 10 years, CT colonography (CTC) every 5 years, and sigmoidoscopy every 5 years, as well as stool-based tests: guaiac fecal occult blood test (gFOBT) every year, fecal immunochemical test (FIT) every year, and stool DNA (sDNA) every 3 years [2-5]. The provision of these various options for CRC screening is intended to increase compliance with the screening guidelines. All of these CRC screening strategies are covered by Medicare except for CTC [6-9].

Among these screening strategies, OC offers the highest detection sensitivity and is the only one to allow for lesion biopsy or resection [4, 5]. Although OC is the gold standard for CRC screening, it is also the most invasive and requires anesthesia. Individuals may be reluctant to undergo OC because of the test's invasiveness, need for anesthesia, or risk of complications [3, 4], thereby hindering compliance with CRC screening guidelines [3]. Accordingly, other screening strategies—sigmoidoscopy, gFOBT or FIT (hereafter, gFOBT/FIT), sDNA, and CTC—are beneficial to the degree that they expand the share of the eligible population who is screened [10-15]. For example, gFOBT/FIT or sDNA may expand the percentage of individuals who undergo guideline-concordant CRC screening among those who are unwilling to undergo the bowel preparation associated with OC, sigmoidoscopy, or CTC. Similarly, sigmoidoscopy or CTC may be preferred by individuals who wish to avoid anesthesia and prefer a less invasive test. However, these other initial screening tests require follow-up testing by OC if the test detects findings that are suspicious for CRC. In this regard, a CRC screening test's effectiveness

is a balance among sensitivity and specificity, patient compliance, and access or availability to the given strategy [16].

Among the U.S. adult population eligible for CRC screening, survey data indicate that approximately a third (31.2%) have not undergone guideline-compliant screening. This percentage varies by race and ethnicity (29.0% [White] to 43.9% [Hispanic]), education (24.4% [college] to 47.0% [less than high school completion]), annual household income (23.9% [≥$75,000] to 42.0% [<$15,000]), and insurance (28.8% [insured] to 59.9% [not insured]) [17]. Provision of insurance coverage for CTC may increase compliance with CRC screening guidelines [18, 19]. Studies have found screening CTC to be a cost-effective alternative to OC if it costs less or yields better adherence to screening guidelines [20-26]. In fact, one study found CTC to cost 22% less than OC due to reduced use of pathology services and the lack of a need for anesthesia [26].

The objective of this study was to compare CTC and other CRC screening tests in terms of associations of utilization with income, race and ethnicity, and urbanicity, in Medicare fee-for-service beneficiaries.

## METHODS

*Patient Sample and Data*

This retrospective study was deemed exempt from institution review broad oversight by the Advarra institutional review board. We evaluated the utilization of various CRC screening strategies using annual Research Identifiable Files obtained from CMS for all years from 2011 to 2020. Each file contains all individual-level Medicare fee-for-service claims from January 1 to December 31 of the given year for a nationally representative 5% sample of Medicare fee-for-

service beneficiaries. The data extracted from the files were initially restricted to the following inclusion criteria: beneficiaries with age 45–85 years; residing in the 50 U.S. states or the District of Columbia; with race and ethnicity of Hispanic, non-Hispanic Black, or non-Hispanic White; and who had Medicare fee-for-services coverage for the entire year (unless the individual turned 65 years old in the given year, in which case the individual was unlikely to be enrolled in Medicare for the entire year). Race and ethnicity were reported in the files as a single combined variable that was derived using information from the Social Security Administration and modified by a name-based Research Triangle Institute algorithm to identify additional Asian and Hispanic beneficiaries. The three previously noted race and ethnicity categories were reported in the database as Hispanic, Black (or African American), and non-Hispanic White, respectively. These race and ethnicity categories were selected for the present analysis because they reflected the most common race and ethnicity categories in the database and were qualitatively assessed as providing a sufficient sample size of individuals who underwent CTC in each group for purposes of the analysis. Individuals younger than age 65 years were included because approximately 14% of beneficiaries are younger than this age threshold [27]. In addition, beneficiaries at high risk for CRC or who had unknown sex or urbanicity were excluded. Individuals deemed high risk included those with ulcerative colitis, Crohn's disease, other hamartoses and phakomatoses, family history of colonic polyps, Lynch syndrome, multiple endocrine neoplasia syndrome, or colorectal or anal cancer; or who had undergone prior high-risk screening colonoscopy (Table S1). As individuals may have been Medicare fee-for-service beneficiaries for multiple years between 2011 and 2020 and may have undergone CRC screening in any given year, the sample was constructed in terms of beneficiary years whereby CRC screening for a beneficiary was evaluated for each year in which the beneficiary was represented in the data sets.

*CRC Screening Tests*

Guidelines for CRC screening include OC (Healthcare Common Procedure Coding System [HCPCS]: G0121), sigmoidoscopy (HCPCS: G0104), gFOBT/FIT (CPT or HCPCS: 82270, G0328, 82274), sDNA (CPT or HCPCS: 81528, G0464), and CTC (CPT or HCPCS: 74263, 0066T). These screening strategies vary in sensitivity, invasiveness, need for anesthesia, bowel preparation, and time off from work. OC, sigmoidoscopy, and CTC all require bowel preparation; only OC requires anesthesia, but it is the most sensitive [2, 5, 16]. Stool-based strategies—gFOBT/FIT and sDNA—do not require bowel preparation but are less sensitive than the other strategies including OC. This study modeled differences based on income, race and ethnicity, and urbanicity in the proportion of beneficiaries who underwent screening CTC relative to the other CRC screening tests. Because CMS provides coverage for OC, gFOBT/FIT, and sDNA but not for screening CTC, utilization differences for CTC relative to the other CRC screening strategies may be associated with the test's lack of Medicare coverage. Unlike screening CTC, diagnostic CTC (CPT or HCPCS: 74261, 74262, 0067T) is covered by Medicare. Diagnostic CTC requires the same equipment and training for technologists and radiologists as is required for screening CTC; diagnostic CTC and screening CTC are thus expected to have similar geographic or facility-level access. Given possible similarities in patient preference and access to screening CTC and diagnostic CTC, use of diagnostic CTC was evaluated as a counterfactual analysis. This analysis was intended to control for potential differences between screening CTC and the other screening tests in terms of patient preference and physical access and thereby better to isolate the impact of lack of Medicare coverage on screening CTC use.

*Covariates*

The three covariates of interest were community income, race and ethnicity, and urbanicity. Community income was defined as the per capita annual income of the beneficiary's zip code, as reported by the Internal Revenue Service (classified as $0–24999, $25000–49999, $50000-74999, $75000-99999, or ≥$100000). As previously noted, beneficiary race and ethnicity was categorized as Hispanic, non-Hispanic Black, and non-Hispanic White. Urbanicity was categorized based on zip code using Rural-Urban Commuting Area codes (classified as metropolitan area [population ≥50000]; micropolitan area [population 10000–49999]; or small and/or rural area [population <10000]).

Other covariates included sex, age group (40–49, 50-64, 65–75, 76-85 years), Charlson comorbidity index (CCI: 0, 1, 2, ≥3, unknown), U.S. census region, screening year, and indicator variables for the presence of related conditions and procedures. Age groups were constructed to reflect both details of screening guidelines and differences in reasons for Medicare eligibility for individuals <65 years versus those ≥65 years. The related conditions and procedures included enteritis and colitis, diverticular disease, intestinal disorders, benign neoplasm of colorectum or anus, extracolonic cancer, diarrhea, hernia, colonic perforation, or prior colorectal surgery (Table S2). The presence of related conditions and procedures for a given beneficiary year reflected information in the file for the given year as well as for preceding years in which the individual was a Medicare fee-for-service beneficiary and thus included in the earlier file. The analysis controlled for these related conditions and procedures because these conditions and procedures may be associated with the choice of screening test as well as with CRC risk and thereby serve as confounding factors.

*Statistical Analysis*

Data were summarized using counts and percentages. The CRC screening rates per 100,000 beneficiary years were computed for each screening test stratified by year and in terms of the full study period; for sDNA, this determination of utilization began in 2014, the year of FDA approval. Frequencies of individuals who underwent any CRC screening test versus who did not undergo CRC screening, as well as of individuals screened by CTC versus by other screening tests, were compared within subgroups defined by the covariates using t tests and chi-square tests. We used a multivariable logistic regression model to compute the ORs for the likelihood of an individual to undergo screening CTC as a function of income, race and ethnicity, urbanicity, and other covariates (sex, age group, CCI, U.S. census region, screening year, and related conditions and procedures). Similarly, we used multivariable logistic regression models to separately compute the ORs for the likelihood of an individual to undergo CRC screening through OC, gFOBT/FIT, or sDNA. A parallel multivariable logistic regression model was used to compute the likelihood of an individual to undergo diagnostic CTC. Models for race and ethnicity used the race and ethnicity category with the highest frequency in the study sample as the reference category. The ORs for income, race and ethnicity, and urbanicity in the screening CTC model were compared to the analogous ORs from the other models to assess for differences. In this way, for example, the statistical association of race and ethnicity with screening was isolated from the associations of income, urbanicity, and other covariates with screening, as the latter factors may be associated with both screening use as well as with race and ethnicity. $P<.05$ was indicative of a statistically significant difference. Statistical analyses were conducted with SAS 9.4 (SAS Institute).

## RESULTS

*Beneficiary Characteristics*

Over the study period, 13,704,700 beneficiary years (representing 2,584,382 unique beneficiaries) met the initial inclusion criteria. After exclusions for presence of a condition indicative of high risk for CRC (147,360 beneficiaries) and missing sex or urbanicity (173 beneficiaries), the final sample comprised 12,273,363 beneficiary years representing 2,436,849 unique beneficiaries. Figure 1 shows the flow of beneficiary selection.

Table 1 summarizes characteristics of the final study sample, in terms of beneficiary years. A total of 55.2% (6,774,837) were female, and 44.8% (5,498,526) were male. The mean age was 70.5 ± 8.2 (SD) years. A total of 6.3% (773,609) were Hispanic, 9.8% (1,205,758) were non-Hispanic Black, and 83.9% (10,293,997) were non-Hispanic White. The mean CCI (when known) was 1.5 ± 2.1. The mean community income (when known) was $42,270± 33,954. A total of 75.4% (9,251,936) lived in metropolitan areas.

At the beneficiary year level, there were 785,103 beneficiary years with at least one CRC screening event (109,208 for OC, 1002 for sigmoidoscopy, 611,565 for gFOBT/FIT, 75,415 for sDNA, and 645 for screening CTC) and 3432 events for diagnostic CTC. Figure 2 shows the CRC screening rates per 100,000 beneficiary years, stratified by year. When calculated across the full study period, the screening rate per 100,000 beneficiary years, from highest to lowest, was 4983 (95% CI: 4971, 4995) for gFOBT/FIT, 890 (95% CI: 885, 895) for OC, 614 (95% CI: 610, 619) for sDNA, 8 (95% CI: 8, 9) for sigmoidoscopy, and 5 (95% CI: 5, 6) for screening CTC; utilization per 100,000 beneficiary years was 28 (95% CI: 27, 29) for diagnostic CTC.

Table 1 also compares beneficiary characteristics between those who underwent any CRC screening test to those who did not undergo CRC screening, as well as between those screened by CTC versus those screened by other strategies. Those with, versus without, CRC screening included a higher proportion of female individuals (61.7% vs 54.8%, p<.001); older individuals (mean age: 71.1 vs 70.5 years, p<.001); non-Hispanic White individuals (85.8% vs 83.7%, p<.001); those living in metropolitan areas (81.3% vs 75.0%, p<.001); those with higher annual community income (mean: $47,136 vs $41,936, p<.001); and those with a related condition or procedure (e.g., diverticular disease:14.0% vs 10.0%, p<.001; prior colorectal surgery: 12.7% vs 6.2%, p<.001). Among those who underwent CRC screening, those who underwent CTC screening versus those who underwent any other screening test included a higher proportion of female individuals (67.6% vs 61.7%, p=.004), older individuals (mean age: 71.7 vs 71.1, p=.03); those with higher CCI score (mean: 2.0 vs 1.5, p<.001); those living in metropolitan areas (87.6% vs 81.3%, p<.001); those living in higher-income communities (mean: $64,301 vs $47,122, p<.001); and those with a related condition or procedure (e.g., diverticular disease: 32.1% vs 13.9%, p<.001; prior colorectal surgery: 32.2% vs 12.7%, p<.001).

*Income*

Table 2 and Figure 3 show the ORs for undergoing various CRC screening tests with respect to community income. Relative to individuals living in communities with per capita income of <$25,000, individuals living in communities with per capita income of $100,000 or more demonstrated no significant difference in the likelihood of undergoing sigmoidoscopy (OR, 1.03; 95% CI: 0.72, 1.47), but were 36% more likely (OR, 1.36, 95% CI: 1.31, 1.40) to undergo OC, 50% more likely (OR, 1.50, 95% CI: 1.48, 1.52) to undergo gFOBT/FIT, and 43% more likely

(OR, 1.43, 95% CI: 1.37, 1.49) to undergo sDNA. Compared with those living in communities with per capita income of <$25,000, receipt of screening CTC was 84% more likely (OR, 1.84, 95% CI: 1.35, 2.52) for those living in communities with per capita income of $25,000-49,999; 134% more likely (OR, 2.34, 95% CI: 1.63, 3.34) for $50,000-74,999; 226% more likely (OR, 3.26, 95% CI: 2.13, 5.00) for $75,000-99,999; and 473% more likely (OR, 5.73, 95% CI: 3.94, 8.35) for ≥$100,000.

In the counterfactual analysis, income was a weaker determinant of use of diagnostic CTC than of screening CTC, in terms of lower ORs at each income level and a resulting less pronounced pattern of increasing ORs across income levels (Fig. 3). Specifically, compared to those in communities with per capita income of <$25,000, receipt of diagnostic CTC was 36% more likely (OR, 1.36; 95% CI: 1.21, 1.52) for those in communities with per capita income of $25,000-49,999; 57% more likely (OR, 1.57; 95% CI: 1.37, 1.80) for $50,000-74,999; 62% more likely (OR, 1.62; 95% CI: 1.34, 1.96) for $75,000-99,999; and 100% more likely (OR, 2.00; 95% CI: 1.69, 2.37) for ≥$100,000.

*Race and Ethnicity*

Table 2 and Figure 4 show the ORs for undergoing various CRC screening tests with respect to race and ethnicity. The models used non-Hispanic White individuals as the reference group because this group represented the largest proportion of the patient sample. Relative to non-Hispanic White individuals, Hispanic individuals demonstrated no significant difference in the likelihood of undergoing OC (OR, 1.00, 95% CI: 0.97, 1.02), sigmoidoscopy (OR, 1.20, 95% CI: 0.93, 1.54), or screening CTC (OR, 0.68, 95% CI: 0.46, 1.00); were more likely to undergo

gFOBT/FIT (OR, 1.05, 95% CI: 1.04, 1.06); and were less likely to undergo sDNA (OR, 0.50, 95% CI: 0.48, 0.52). In the counterfactual analysis, the likelihood of undergoing diagnostic CTC was significantly lower for Hispanic individuals than for non-Hispanic White individuals (OR, 0.66, 95% CI: 0.56, 0.79); however, the OR for this comparison was qualitatively similar to the OR for the analogous comparison for screening CTC.

Relative to non-Hispanic White individuals, non-Hispanic Black individuals demonstrated no significance difference in the likelihood of undergoing screening CTC (OR, 1.08, 95% CI: 0.80, 1.46); were more likely to undergo OC (OR, 1.17, 95% CI: 1.15, 1.19), or sigmoidoscopy (OR, 1.26, 95 %CI: 1.03, 1.55); and were less likely to undergo gFOBT/FIT (OR, 0.82, 95% CI: 0.81, 0.83) or sDNA (OR, 0.49, 95% CI: 0.47, 0.50). In the counterfactual analysis, the likelihood of undergoing diagnostic CTC was not significantly different between non-Hispanic Black individuals and non-Hispanic White individuals (OR, 0.91, 95% CI: 0.79, 1.03).

*Urbanicity*

Table 2 and Figure 5 show the ORs for undergoing various CRC screening tests with respect to urbanicity. Relative to residents of metropolitan areas, residents of micropolitan areas demonstrated no significant difference in the likelihood of undergoing OC (OR, 1.01, 95% CI: 0.99, 1.03) or sigmoidoscopy (OR, 1.05, 95% CI: 0.87, 1.27); were more likely to undergo sDNA (OR, 1.03, 95% CI: 1.01, 1.05); and were less likely to undergo gFOBT/FIT (OR, 0.76, 95% CI: 0.75, 0.76) or screening CTC (OR, 0.51, 95% CI: 0.36, 0.71). In the counterfactual analysis, the likelihood of undergoing diagnostic CTC was significantly lower for residents of

micropolitan areas than for residents of metropolitan areas (OR, 0.67, 95% CI: 0.59, 0.76); this difference was qualitatively similar to the analogous results for screening CTC. Relative to residents of metropolitan areas, residents of small or rural areas demonstrated no significant difference in the likelihood of undergoing sigmoidoscopy (OR, 1.00, 95% CI: 0.82, 1.22); and were less likely to undergo OC (OR, 0.92, 95% CI: 0.90, 0.94), gFOBT/FIT (OR, 0.62, 95% CI: 0.61, 0.62), sDNA (OR, 0.88, 95% CI: 0.86, 0.91), or screening CTC (OR, 0.65, 95% CI: 0.47, 0.90). In the counterfactual analysis, the likelihood of undergoing diagnostic CTC was significantly lower for residents of small or rural areas than for residents of metropolitan areas (OR, 0.68, 95% CI: 0.60, 0.78); this difference was qualitatively similar to the analogous results for screening CTC.

## DISCUSSION

This study compared screening CTC to Medicare-covered CRC screening strategies in terms of differences in utilization related to income, race and ethnicity, and urbanicity, among Medicare fee-for-service beneficiaries. Substantial differences were observed in CTC use related to income. Individuals living in communities with per capita income of $100,000 or more were 473% more likely to undergo screening CTC compared to those living in communities with per capita income of less than $25,000. Although higher income was also associated with a greater likelihood of screening by OC, gFOBT/FIT, and sDNA, these associations were weaker (36%, 50%, and 43%, respectively) in comparison with the association of income with likelihood of undergoing screening CTC.

While Medicare does not provide coverage for screening CTC, it does so for diagnostic CTC. Screening CTC and diagnostic CTC may be subject to similar patient preferences and access. Hence, diagnostic CTC was applied in this study as a counterfactual comparison to screening CTC use. Individuals living in communities with per capita income of $100,000 or more were 100% more likely to undergo diagnostic CTC than those living in communities with per capita income of less than $25,000, indicating a weaker association of income with diagnostic CTC use than with screening CTC use.

The present study's observed relationship between income and screening CTC use is opposite from the relationship reported by a study that analyzed Medicare data from 2007 and 2008 [28]. In that earlier study, individuals in the highest-income group were 11% less likely to use screening CTC than individuals in the lowest-income group, adjusting for patient characteristics and clinical indications. However, the data from that study preceded the announcement by CMS in March 2009 that indicated definitively that CMS would not cover screening CTC. Given the ambiguity over coverage at the time of the prior data, we speculate that higher-income individuals may have had greater awareness of Medicare's potential non-coverage of screening CTC.

This study found no statistical differences in screening CTC use for Hispanic individuals and non-Hispanic Black individuals in comparison with non-Hispanic White individuals. The literature has yielded mixed results in terms of associations of race and ethnicity with CTC use. The previously noted study using 2007-2008 Medicare data found lower screening CTC use among racial and ethnic minority groups [28]. However, studies using the National Health Interview Survey (which surveyed individuals with all insurance types including no insurance) found higher screening CTC use among racial and ethnic minority groups [15, 29]. Given the

increased likelihood of individuals belonging to racial and ethnic minority groups to live in low-income communities, differences in income may have contributed to associations of CTC use with race and ethnicity in unadjusted analyses in earlier works [7, 28].

Although race and ethnicity were not significantly associated with screening CTC use, they were associated with use of other CRC screening tests. For example, sDNA use was substantially lower for Hispanic individuals (OR, 0.50) and non-Hispanic Black individuals (OR, 0.49) in comparison with non-Hispanic White individuals. These findings are consistent with studies showing racial and ethnic preferences in the choice of CRC screening strategy, with racial and ethnic minority groups having a higher preference for gFOBT, FIT, or sDNA [30, 31]. Earlier work indicates that, across all racial and ethnic groups, test accuracy is generally the most important attribute to patients [31, 32], but among those patients who prefer gFOBT, convenience is the most important attribute [33]. Further, data from the 2018 Behavioral Risk Factor Surveillance System survey found racial and ethnic differences in the percent of the U.S. adult population eligible for CRC screening who were not adherent with screening guidelines: 43.9% for Hispanic individuals versus 29.0% for White individuals [17]. These differences were not specific to a particular CRC screening strategy but were representative of compliance overall.

We found differences in screening CTC use associated with urbanicity. Relative to residents of metropolitan areas, residents of small or rural areas were significantly less likely to undergo screening CTC (OR, 0.65); residents of small or rural areas showed a less pronounced decrease in likelihood of undergoing OC (OR, 0.92) and no difference in likelihood of undergoing sigmoidoscopy (OR, 1.00). An earlier study likewise found substantially lower screening CTC use for rural than urban residents [34]. However, in the counterfactual analysis, associations with urbanicity appeared similar for screening CTC use and diagnostic CTC use.

Drivers of the difference in screening CTC use between urban and rural areas may include limited awareness of CTC [35] and geographic proximity in urban areas to a facility that performs CTC.

The Affordable Care Act mandates that private health insurance plans cover all screening strategies recommended by the U.S. Preventive Services Task Force with a grade of A or B, which includes screening CTC [36]. This mandate does not apply to Medicare, and CMS does not cover CTC as it does all other guideline-recommended screening strategies [6-9]. This difference in Medicare coverage for screening CTC compared with other guideline-recommended screening strategies may impact the use of screening CTC among Medicare beneficiaries. Indeed, the present study's observation of substantial differences between screening CTC and other CRC screening tests in terms of associations with income is consistent with Medicare coverage differences and associated differences in individuals' out-of-pocket costs.

This study had limitations. First, the present data almost certainly do not reflect all screening CTC services received by Medicare fee-for-service beneficiaries, as lack of Medicare coverage discourages submitting claims. Any such underreporting would impact the conclusions if the underreporting were not randomly distributed across groups. Second, this study is based on Medicare fee-for-service beneficiaries; the findings may not be generalizable to populations insured by Medicare Advantage, commercial insurance (which provides coverage for screening CTC), or without insurance. Third, we cannot directly model the impact of lack of Medicare coverage on screening CTC use since reasons not captured by this study's covariates may have impacted the differences that were observed across the CRC screening strategies. For this reason, we also assessed the associations of income, race and ethnicity, and urbanicity with diagnostic

CTC use because, outside of Medicare coverage, the drivers of diagnostic CTC utilization may be similar to those of screening CTC utilization. Finally, some diagnostic CTC claims may have been associated with incomplete OCs. The presence of such instances would limit the inference of similar patient preferences for screening CTC and diagnostic CTC.

In conclusion, residing in a higher-income community was associated with higher odds of undergoing screening for most CRC screening strategies. The association with income was substantially larger for screening CTC than for other screening strategies as well as substantially larger for screening CTC than for diagnostic CTC, possibly related to lack of Medicare coverage for screening CTC. Screening CTC use did not show statistically significant associations with race and ethnicity. Screening CTC use was lower for individuals residing in non-metropolitan areas, although such associations were not substantially different from associations observed for other screening tests or for diagnostic CTC. Associations of lower income with minority race and ethnicity categories and of non-metropolitan residence may have contributed to aggregate or unadjusted associations of screening CTC use with race and ethnicity or with urbanicity. The inverse relationship between screening CTC use and income contrasts with the findings of prior research performed before Medicare clarified that it would not cover screening CTC. The findings indicate that lower income groups may prefer the less-invasive and accurate screening approach of CTC, absent a cost barrier. Thus, Medicare's coverage determination may result in differences in screening adherence for lower-income beneficiaries.

## References

1. Siegel RL, Miller KD, Wagle NS, Jemal A. Cancer Statistics, 2023. *CA Cancer J Clin*. 2023;73(1):17-48. doi:10.3322/caac.2176

2. Davidson KW, Barry MJ, Mangione CM, et al. Screening for Colorectal Cancer: US Preventive Services Task Force Recommendation Statement. *JAMA - J Am Med Assoc*. 2021;325(19):1965-1977. doi:10.1001/jama.2021.6238

3. Wolf AMD, Fontham ETH, Church TR, et al. Colorectal Cancer Screening for Average-Risk Adults : 2018 Guideline Update From the American Cancer Society. *CA Cancer J Clin*. 2018;68(4):250-281. doi:10.3322/caac.21457

4. Shaukat A, Kahi CJ, Burke CA, Rabeneck L, Sauer BG, Rex DK. ACG Clinical Guidelines : Colorectal Cancer Screening 2021. *Am J Gastroenterol*. 2021;116(3):458-479.

5. Bibbins-Domingo K, Grossman DC, Curry SJ, et al. Screening for Colorectal Cancer: US Preventive Services Task Force Recommendation Statement. *JAMA - J Am Med Assoc*. 2016;315(23):2564-2575. doi:10.1001/jama.2016.5989

6. Dachman AH, Yee J. The challenges of Ct colonography reimbursement. *J Am Coll Radiol*. 2013;10(12):937-942. doi:10.1016/j.jacr.2013.09.014

7. Moreno CC, Yee J, Dachman AH, Duszak R, Goldman L, Horný M. Use of Screening CT Colonography by Age and Race: A Study of Potential Access Barriers Related to Medicare Noncoverage Based on Data From the ACR's National CT Colonography Registry. *J Am Coll Radiol*. 2021;18(1):19-26. doi:10.1016/j.jacr.2020.09.043

8. Yee J, Keysor KJ, Kim DH. The Time Has Arrived for National Reimbursement of Screening CT Colonography. *Am J Roentgenol*. 2013;201(1):73-79. doi:10.2214/AJR.13.10656

9. Yee J, McGlothlin A, Keysor KJ. Screening CT Colonography Reimbursement: Triumphs and Navigating a Path Forward. *Abdom Radiol*. 2017;42(1):86-89. doi:10.1007/s00261-016-0974-6

10. Kriza C, Emmert M, Wahlster P, Niederländer C, Kolominsky-Rabas P. An International Review of the Main Cost-effectiveness Drivers of Virtual Colonography versus Conventional Colonoscopy for Colorectal Cancer Screening: Is the Tide Changing Due to Adherence? *Eur J Radiol*. 2013;82(11):e629-e636. doi:10.1016/j.ejrad.2013.07.019

11. de Haan MC, Pickhardt PJ, Stoker J. CT Colonography: Accuracy, Acceptance, Safety and Position in Organised Population Screening. *Gut*. 2015;64(2):342-350. doi:10.1136/gutjnl-2014-308696

12. Knechtges PM, McFarland BG, Keysor KJ, Duszak R, Barish MA, Carlos RC. National and Local Trends in CT Colonography Reimbursement: Past, Present, and Future. *J Am Coll Radiol*. 2007;4(11):776-799. doi:10.1016/j.jacr.2007.07.014

13. Moawad FJ, Maydonovitch CL, Cullen PA, Barlow DS, Jenson DW, Cash BD. CT Colonography May Improve Colorectal Cancer Screening Compliance. *Am J Roentgenol*. 2010;195(5):1118-1123. doi:10.2214/AJR.10.4921

14. Sali L, Regge D. CT Colonography for Population Screening of Colorectal Cancer: Hints from European Trials. *Br J Radiol*. 2016;89(1068). doi:10.1259/bjr.20160517

15. Hong YR, Xie Z, Turner K, Datta S, Bishnoi R, Shah C. Utilization Pattern of Computed Tomographic Colonography in the United States: Analysis of the U.S. National Health Interview Survey. *Cancer Prev Res*. 2021;14(1):113-122. doi:10.1158/1940-6207.CAPR-20-0175

16. Ahlquist DA. Stool-Based Tests Vs Screening Colonoscopy for the Detection of Colorectal Cancer. *Gastroenterol Hepatol*. 2019;15(8):437-440.

17. Joseph DA, King JB, Dowling NF, Thomas CC, Richardson LC. Vital Signs: Colorectal Cancer Screening Test Use — United States, 2018. *Morb Mortal Wkly Rep*. 2020;69(10):253-259.

18. Harris R. Speaking for the Evidence: Colonoscopy vs Computed Tomographic Colonography. *J Natl Cancer Inst*. 2010;102(16):1212-1214. doi:10.1093/jnci/djq286

19. Pickhardt PJ, Kim DH, Hassan C. Re: Cost-Effectiveness of Computed Tomographic Colonography Screening for Colorectal Cancer in the Medicare Population. *J Natl Cancer Inst*. 2010;102(21):1676. doi:10.1093/jnci/djq381

20. Knudsen AB, Lansdorp-Vogelaar I, Rutter CM, et al. Cost-Effectiveness of Computed Tomographic Colonography Screening for Colorectal Cancer in the Medicare Population. *J Natl Cancer Inst*. 2010;102(16):1238-1252. doi:10.1093/jnci/djq242

21. Abdolahi H, Asiabar A, Azami-Aghdash S, Pournaghi-Azar F, Rezapour A. Cost-effectiveness of colorectal cancer screening and treatment methods: Mapping of systematic reviews. *Asia-Pacific J Oncol Nurs*. 2018;5(1):57-67. doi:10.4103/apjon.apjon_50_17

22. Pyenson B, Pickhardt PJ, Sawhney TG, Berrios M. Medicare Cost of Colorectal Cancer Screening: CT Colonography vs. Optical Colonoscopy. *Abdom Imaging*. 2015;40(8):2966-2976. doi:10.1007/s00261-015-0538-1

23. van der Meulen MP, Lansdorp-Vogelaar I, Goede SL, et al. Cost-Effectiveness of Colonoscopy Versus CT-Colonography Screening for Colorectal Cancer with Observed Attendance and Costs. *Radiology*. 2018;287(3):901-911. doi:10.1148/radiol.2017162359.Cost-effectiveness

24. Hassan C, Pickhardt PJ. Cost-effectiveness of CT Colonography. *Radiol Clin North Am*. 2013;51(1):89-97. doi:10.1016/j.rcl.2012.09.006.Cost-effectiveness

25. Duszak R, Kim DH, Pickhardt PJ. Expanding Utilization and Regional Coverage of Diagnostic CT Colonography: Early Medicare Claims Experience. *J Am Coll Radiol*. 2011;8(4):235-241. doi:10.1016/j.jacr.2010.08.028

26. Sawhney TG, Pyenson BS, Rotter D, Berrios M, Yee J. Computed Tomography Colonography less Costly than Colonoscopy for Colorectal Cancer Screening of Commercially Insured Patients. *Am Heal Drug Benefits*. 2018;11(7):353-361.

27. Tarazi W, Welch WP, Nguyen N, et al. Medicare Beneficiary Enrollment Trends and Demographic Characteristics.; 2022. https://aspe.hhs.gov/sites/default/files/documents/f81aafbba0b331c71c6e8bc66512e25d/medicare-beneficiary-enrollment-ib.pdf

28. Zafar HM, Yang J, Harhay M, Lev-Toaff A, Armstrong K. Predictors of CT Colonography Utilization among Asymptomatic Medicare Beneficiaries. *J Gen Intern Med*. 2013;28(9):1208-1214. doi:10.1007/s11606-013-2414-4

29. O'Connor B, Boakye-Ansa NK, Brown CA, et al. Predictors of CT Colonography Use: Results From the 2019 National Health Interview Cross-Sectional Survey. *J Am Coll Radiol*. 2022;19(7):874-880. doi:10.1016/j.jacr.2022.03.018

30. Inadomi JM, Vijan S, Janz NK, et al. Adherence to Colorectal Cancer Screening. *Arch Intern Med*. 2012;172(7):575-582. doi:10.1001/archinternmed.2012.332

31. Lee SJ, Leary MCO, Umble KE, Wheeler SB. Eliciting Vulnerable Patients' Preferences Regarding Colorectal Cancer Screening: A Systematic Review. *Patient Prefer Adherence*. 2018;12:2267-2282.

32. Hawley ST, Volk RJ, Krishnamurthy P, Jibaja-weiss M, Vernon SW, Kneuper S. Preferences for Colorectal Cancer Screening Among Racially/Ethnically Diverse Primary Care Patients. *Med Care*. 2008;46(9):10-16.

33. Wolf RL, Basch CE, Brouse CH, Shmukler C, Shea S. Patient Preferences and Adherence to Colorectal Cancer Screening in an Urban Population. *Am J Public Health*. 2006;96(5):809-811. doi:10.2105/AJPH.2004.049684

34. Moreno CC, Duszak R, Yee J, Horny M. Geographic Dispersion and Rural Versus Urban Utilization of CT Colonography in the United States. *J Am Coll Radiol*. 2020;17(4):475-483. doi:10.1016/j.jacr.2019.10.002

35. Narayan AK, Lopez DB, Kambadakone AR, Gervais DA. Nationwide, Longitudinal Trends in CT Colonography Utilization: Cross-Sectional Survey Results From the 2010 and 2015 National Health Interview Survey. *J Am Coll Radiol*. 2019;16(8):1052-1057. doi:10.1016/j.jacr.2018.12.039

36. Chen S, Moreno CC, Duszak R, Horný M. U.S. Preventive Services Task Force Update and Computed Tomography for Colorectal Cancer Screening Among Privately Insured Population. *Am J Prev Med*. 2021;61(1):128-132. doi:10.1016/j.amepre.2021.01.033

**Table 1:** Patient Characteristics, Calculated for Beneficiary Years and Stratified by Colorectal Cancer Screening Status

| Variable | Entire Sample | Those Without CRC Screening | Those With CRC Screening | Those With Screening, Not by CTC | Those With Screening by CTC | p[a] |
|---|---|---|---|---|---|---|
| Sex | | | | | | .004 |
| Female | 55.2 (6,774,837) | 54.8 | 61.7 | 61.7 | 67.6 | |
| Male | 44.8 (5,498,526) | 45.2 | 38.3 | 38.3 | 32.4 | |
| Age (y), mean ± SD | 70.5 ± 8.2 | 70.5 ± 8.2 | 71.1 ± 7.0 | 71.1 ± 7.0 | 71.7 ± 6.9 | .03 |
| Age group (y) | | | | | | .05 |
| 40-49 | 2.2 (268,169) | 2.3 | 0.6 | 0.6 | 0.2 | |
| 50-64 | 11.8 (1,443,520) | 12.0 | 8.9 | 8.9 | 8.2 | |
| 65-75 | 58.3 (7,160,951) | 57.9 | 64.8 | 64.8 | 61.7 | |
| 76-85 | 27.7 (3,400,723) | 27.8 | 25.7 | 25.7 | 29.9 | |
| Race and ethnicity | | | | | | .09 |
| Hispanic | 6.3 (773,608) | 6.3 | 6.2 | 6.2 | 4.2 | |
| Non-Hispanic Black | 9.8 (1,205,758) | 9.9 | 8.0 | 8.0 | 7.6 | |
| Non-Hispanic White | 83.9 (10,293,997) | 83.7 | 85.8 | 85.8 | 88.2 | |
| CCI group | | | | | | .002 |
| 0 | 42.2 (5,175,538) | 42.3 | 40.6 | 40.6 | 33.2 | |
| 1 | 18.7 (2,298,831) | 18.6 | 20.9 | 20.9 | 21.1 | |
| 2 | 11.7 (1,439,738) | 11.6 | 13.0 | 13.0 | 15.0 | |
| ≥3 | 21.1 (2,591,494) | 21.1 | 21.2 | 21.2 | 27.3 | |
| Unknown | 6.3 (767,762) | 6.4 | 4.3 | 4.3 | 3.4 | |
| CCI[b], mean ± SD | 1.5 ± 2.1 | 1.5 ± 2.1 | 1.5 ± 2.0 | 1.5 ± 2.0 | 2.0 (±.4 | <.001 |
| Urbanicity | | | | | | <.001 |
| Metropolitan area | 75.4 (9,251,936) | 75.0 | 81.3 | 81.3 | 87.6 | |
| Micropolitan area | 12.7 (1,554,842) | 12.8 | 10.6 | 10.6 | 5.9 | |
| Small or rural area | 11.9 (1,466,585) | 12.2 | 8.2 | 8.2 | 6.5 | |
| Income group | | | | | | 0.001 |

| | | | | | | |
|---|---|---|---|---|---|---|
| <$25,000 | 18.1 (2,218,380) | 18.2 | 15.8 | 15.8 | 7.3 | |
| $25,000-49,999 | 59.2 (7,264,823) | 59.4 | 55.9 | 55.9 | 51.6 | |
| $50,000-74,999 | 12.6 (1,546,465) | 12.4 | 15.5 | 15.5 | 16.7 | |
| $75,000-99,999 | 3.4 (421,611) | 3.4 | 4.6 | 4.6 | 6.8 | |
| ≥$100,000 | 3.8 (466,787) | 3.7 | 5.7 | 5.7 | 13.6 | |
| Unknown | 2.9 (355,297) | 2.9 | 2.6 | 2.6 | 3.9 | |
| Income[b], mean ± SD | $42,270 ± 33,954 | $41,936 ± 33,366 | $47,136 ± 41,286 | $47,122 ± 41,263 | $64,301 ± 60,561 | <.001 |
| U.S. census region | | | | | | <.001 |
| Midwest | 23.1 (2,834,659) | 23.4 | 18.2 | 18.2 | 19.5 | |
| Northeast | 17.6 (2,164,279) | 17.6 | 17.8 | 17.8 | 20.3 | |
| South | 40.8 (5,012,187) | 40.5 | 45.1 | 45.1 | 29.0 | |
| West | 18.4 (2,262,238) | 18.4 | 19.0 | 19.0 | 31.2 | |
| Related conditions and procedures | | | | | | |
| Enteritis or colitis | 4.9 (604,024) | 4.9 | 5.6 | 5.6 | 7.3 | .07 |
| Diverticular disease | 10.2 (1,256,582) | 10.0 | 14.0 | 13.9 | 32.1 | <.001 |
| Disorders of the intestine | 6.3 (774,380) | 6.2 | 8.4 | 8.4 | 11.9 | .002 |
| Benign colonic neoplasm | 7.9 (970,168) | 7.8 | 10.0 | 10.0 | 20.5 | <.001 |
| Extra-colonic cancer | 24.3 (2,984,549) | 24.0 | 29.4 | 29.4 | 36.0 | <.001 |
| Diarrhea | 8.4 (1,028,507) | 8.2 | 10.4 | 10.4 | 16.9 | <.001 |
| Hernia | 4.2 (514,282) | 4.2 | 4.5 | 4.5 | 7.8 | <.001 |
| Colonic perforation | 0.2 (21,637) | 0.2 | 0.2 | 0.2 | 0.9 | <.001 |
| Colorectal surgery | 6.6 (816,152) | 6.2 | 12.7 | 12.7 | 32.2 | <.001 |
| n (beneficiary years) | 12,273,363 | 11,488,260 | 785,103 | 784,458 | 645 | |
| n (beneficiaries) | 2,436,849 | 2,411,237 | 480,367 | 479,925 | 637 | |

Note: Unless otherwise indicated, data indicate percentage, with number of beneficiary years in parentheses. Because the unit of analysis was a beneficiary year, each beneficiary was counted for each separate year in which they were eligible and included in the study.

[a]For comparisons of each characteristic between individuals screened by CTC versus those screened by any other screening test. Differences in characteristics between individuals without versus with CRC screening were all statistically significant at $p<.001$.

[b]Among patients for whom value is known.

CTC = CT colonography; CRC = colorectal cancer; CCI = Charlson comorbidity index.

**Table 2:** Results of multivariable regression models for identifying associations of covariates with use of colorectal cancer screening tests

| Subgroup | Screening Colonoscopy | Screening Sigmoidoscopy | Screening gFOBT/FIT | Screening sDNA | Screening CTC | Diagnostic CTC |
|---|---|---|---|---|---|---|
| Income group (Ref: <$25,000) | | | | | | |
| $25,000-49,999 | 1.08 (1.06, 1.10) | 1.00 (0.84, 1.19) | 1.00 (1.00, 1.01) | 1.19 (1.17, 1.22) | 1.84 (1.35, 2.52) | 1.36 (1.21, 1.52) |
| $50,000-74,999 | 1.21 (1.19, 1.24) | 0.93 (0.72, 1.19) | 1.23 (1.21, 1.24) | 1.33 (1.30, 1.37) | 2.34 (1.63, 3.34) | 1.57 (1.37, 1.80) |
| $75,000-99,999 | 1.28 (1.24, 1.33) | 1.01 (0.70, 1.47) | 1.33 (1.31, 1.35) | 1.34 (1.28, 1.40) | 3.26 (2.13, 5.00) | 1.62 (1.34, 1.96) |
| ≥$100,000 | 1.36 (1.31, 1.40) | 1.03 (0.72, 1.47) | 1.50 (1.48, 1.52) | 1.43 (1.37, 1.49) | 5.73 (3.94, 8.35) | 2.00 (1.69, 2.37) |
| Race and ethnicity (Ref: Non-Hispanic White) | | | | | | |
| Hispanic | 1.00 (0.97, 1.02) | 1.20 (0.93, 1.54) | 1.05 (1.04, 1.06) | 0.50 (0.48, 0.52) | 0.68 (0.46, 1.00) | 0.66 (0.56, 0.79) |
| Non-Hispanic Black | 1.17 (1.15, 1.19) | 1.26 (1.03, 1.55) | 0.82 (0.81, 0.83) | 0.49 (0.47, 0.50) | 1.08 (0.80, 1.46) | 0.91 (0.79, 1.03) |
| Urbanicity (Ref: Metropolitan) | | | | | | |
| Micropolitan | 1.01 (0.99, 1.03) | 1.05 (0.87, 1.27) | 0.76 (0.75, 0.76) | 1.03 (1.01, 1.05) | 0.51 (0.36, 0.71) | 0.67 (0.59, 0.76) |
| Small or rural | 0.92 (0.90, 0.94) | 1.00 (0.82, 1.22) | 0.62 (0.61, 0.62) | 0.88 (0.86, 0.91) | 0.65 (0.47, 0.90) | 0.68 (0.60, 0.78) |

Data expressed as OR with 95% CI in parentheses.

gFOBT = guaiac fecal-occult blood test; FIT = fecal immunochemical test; sDNA = stool DNA; CTC = CT colonography; ref = reference.

## Figure Legends

**Figure 1.** Flow diagram of study selection process. Initial inclusion criteria comprised: age 48-85 years; residency in 50 U.S. states or District of Columbia; race and ethnicity of Hispanic, non-Hispanic Black, or non-Hispanic White; and Medicare fee-for-service coverage for entire year.

**Figure 2.** Colorectal cancer screening rates per 100,000 beneficiary years, by screening test. Diagnostic CT colonography rate per 100,000 beneficiary years is included as counterfactual comparison. Cologuard (sDNA) was approved by FDA in August 2014. Values are shown in logarithmic scale. Number of observations per screening method is 109,208 for OC, 1002 for sigmoidoscopy, 611,565 for FOBT/FIT, 75,415 for sDNA, 645 for screening CTC, and 3432 for diagnostic CTC. gFOBT = guaiac fecal-occult blood test; FIT = fecal immunochemical test; sDNA = stool DNA.

**Figure 3.** ORs for likelihood of undergoing CRC screening based on income, stratified by screening test. ORs for likelihood of undergoing diagnostic CT colonography included as counterfactual comparison. Reference group (OR=1) is per capita community income <$25,000. Error bars indicate 95% CIs. gFOBT = guaiac fecal-occult blood test; FIT = fecal immunochemical test; sDNA = stool DNA; CRC = colorectal cancer.

**Figure 4.** ORs for likelihood of undergoing CRC screening based on race and ethnicity, stratified by screening test. ORs for likelihood of undergoing diagnostic CT colonography included as counterfactual comparison. Reference group (OR=1) is non-Hispanic White. Error bars indicate 95% CIs. gFOBT = guaiac fecal-occult blood test; FIT = fecal immunochemical test; sDNA = stool DNA; CRC = colorectal cancer.

**Figure 5.** ORs for likelihood of undergoing CRC screening based on urbanicity, stratified by screening test. ORs for likelihood of undergoing diagnostic CT colonography included as counterfactual comparison. Reference group (OR=1) is metropolitan area. Error bars indicate 95% CIs. gFOBT = guaiac fecal-occult blood test; FIT = fecal immunochemical test; sDNA = stool DNA; CRC = colorectal cancer.

Figure 1

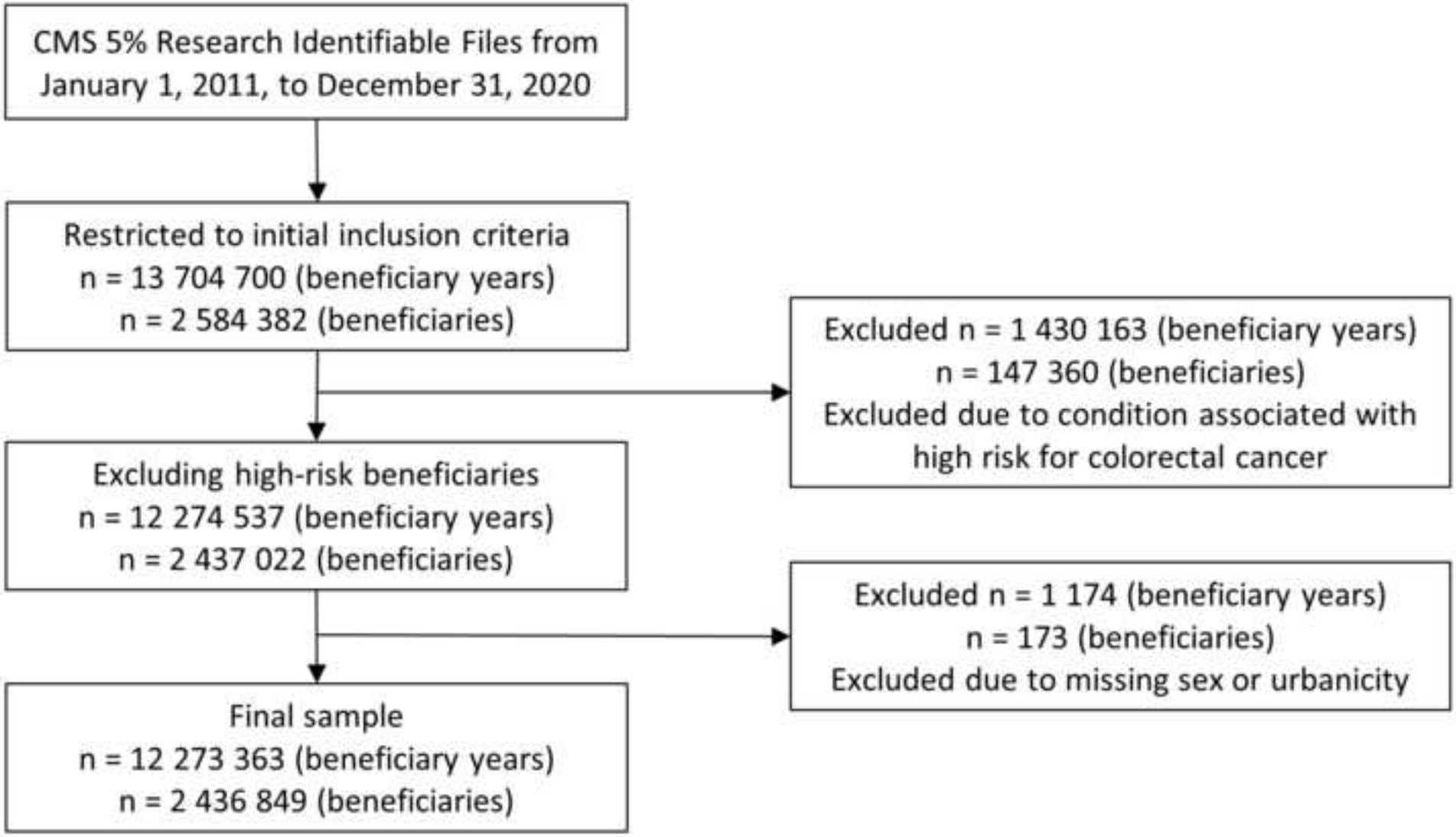
CMS 5% Research Identifiable Files from January 1, 2011, to December 31, 2020
Restricted to initial inclusion criteria
n = 13 704 700 (beneficiary years)
n = 2 584 382 (beneficiaries)
Excluded n = 1 430 163 (beneficiary years)
n = 147 360 (beneficiaries)
Excluded due to condition associated with high risk for colorectal cancer
Excluding high-risk beneficiaries
n = 12 274 537 (beneficiary years)
n = 2 437 022 (beneficiaries)
Excluded n = 1 174 (beneficiary years)
n = 173 (beneficiaries)
Excluded due to missing sex or urbanicity
Final sample
n = 12 273 363 (beneficiary years)
n = 2 436 849 (beneficiaries)

Figure 2

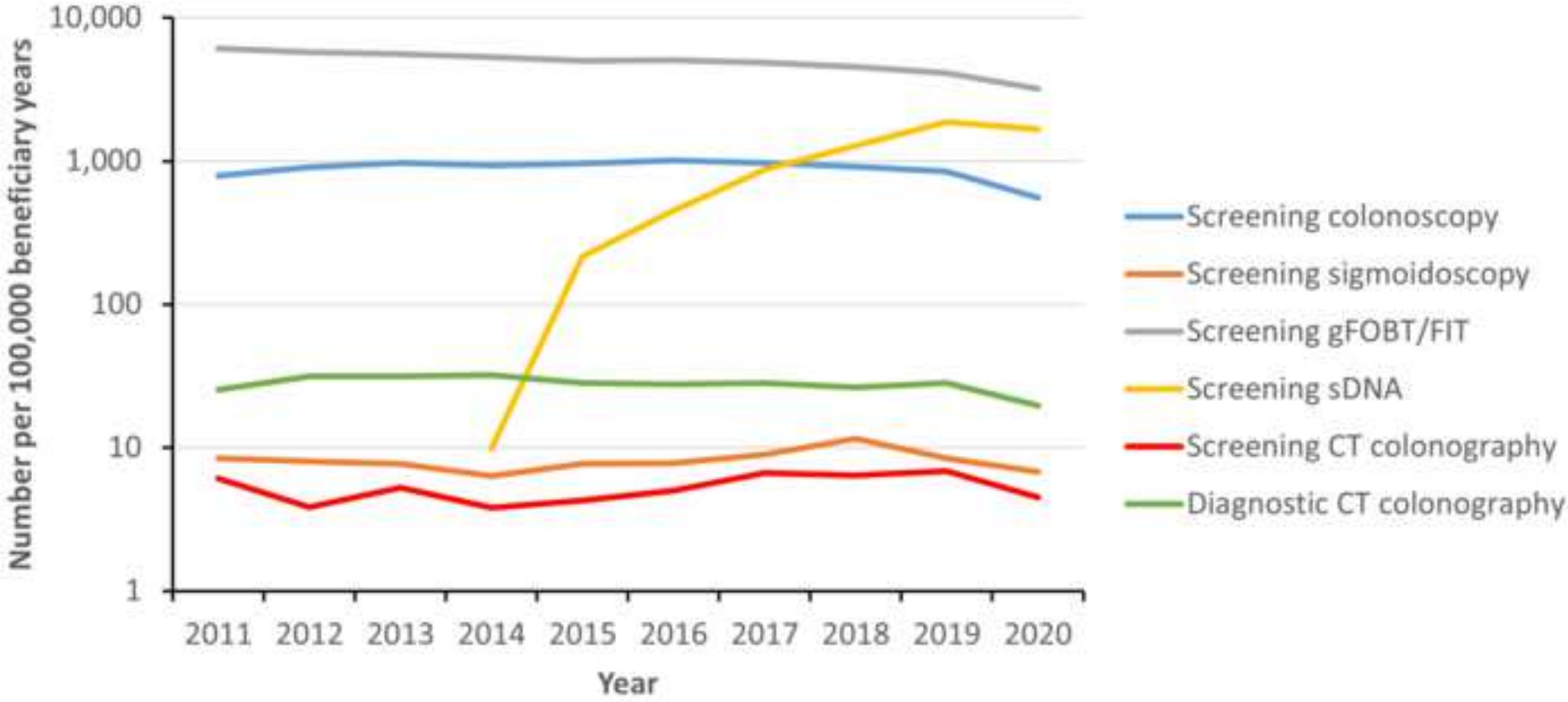
10,000
1,000
100
10
1
Number per 100,000 beneficiary years
2011
2012
2013
2014
2015
2016
2017
2018
2019
2020
Year
Screening colonoscopy
Screening sigmoidoscopy
Screening gFOBT/FIT
Screening sDNA
Screening CT colonography
Diagnostic CT colonography

Figure 3

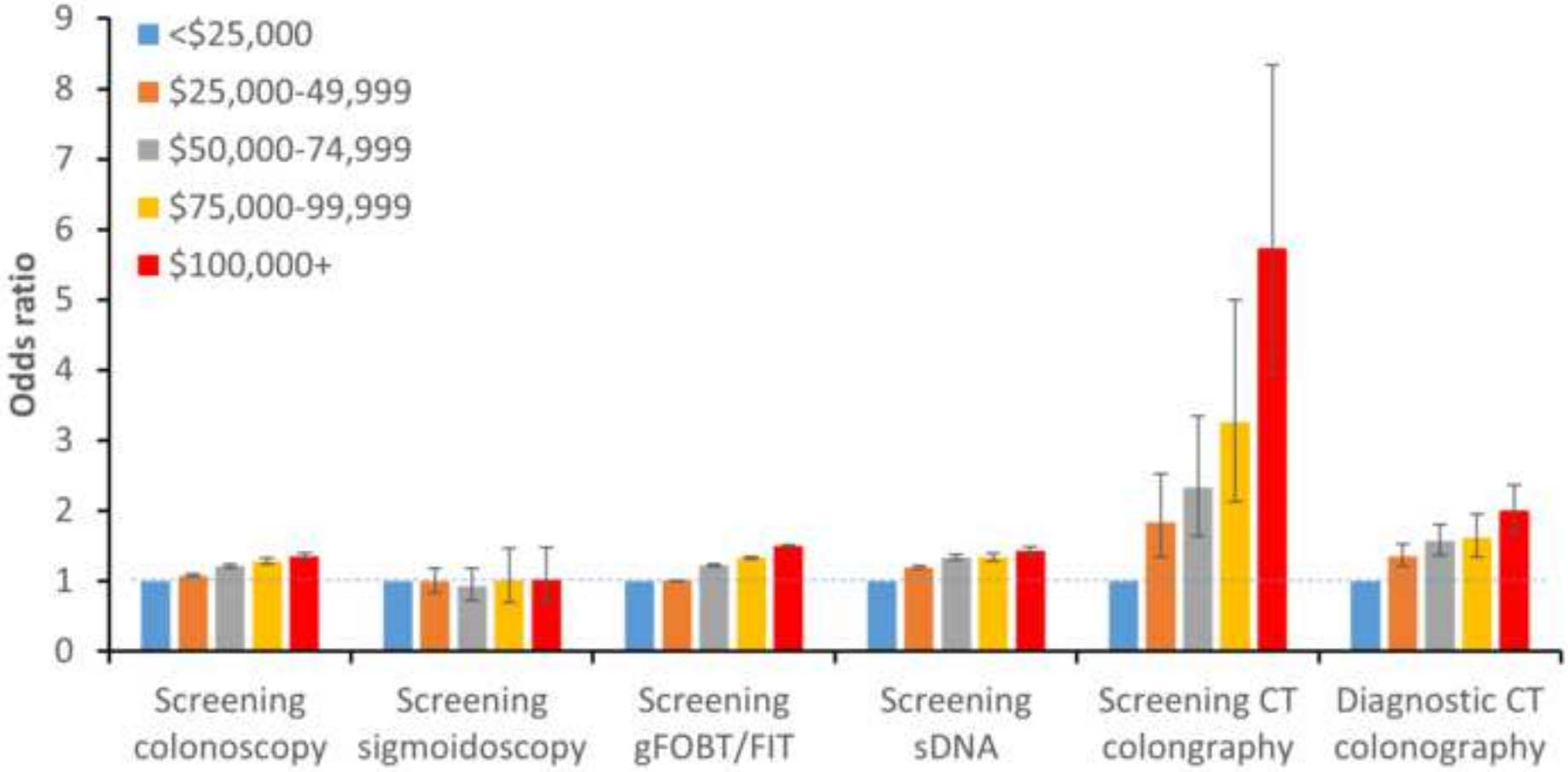
Odds ratio
9
8
7
6
5
4
3
2
1
0
<$25,000
$25,000-49,999
$50,000-74,999
$75,000-99,999
$100,000+
Screening colonoscopy
Screening sigmoidoscopy
Screening gFOBT/FIT
Screening sDNA
Screening CT colongraphy
Diagnostic CT colonography

Figure 4

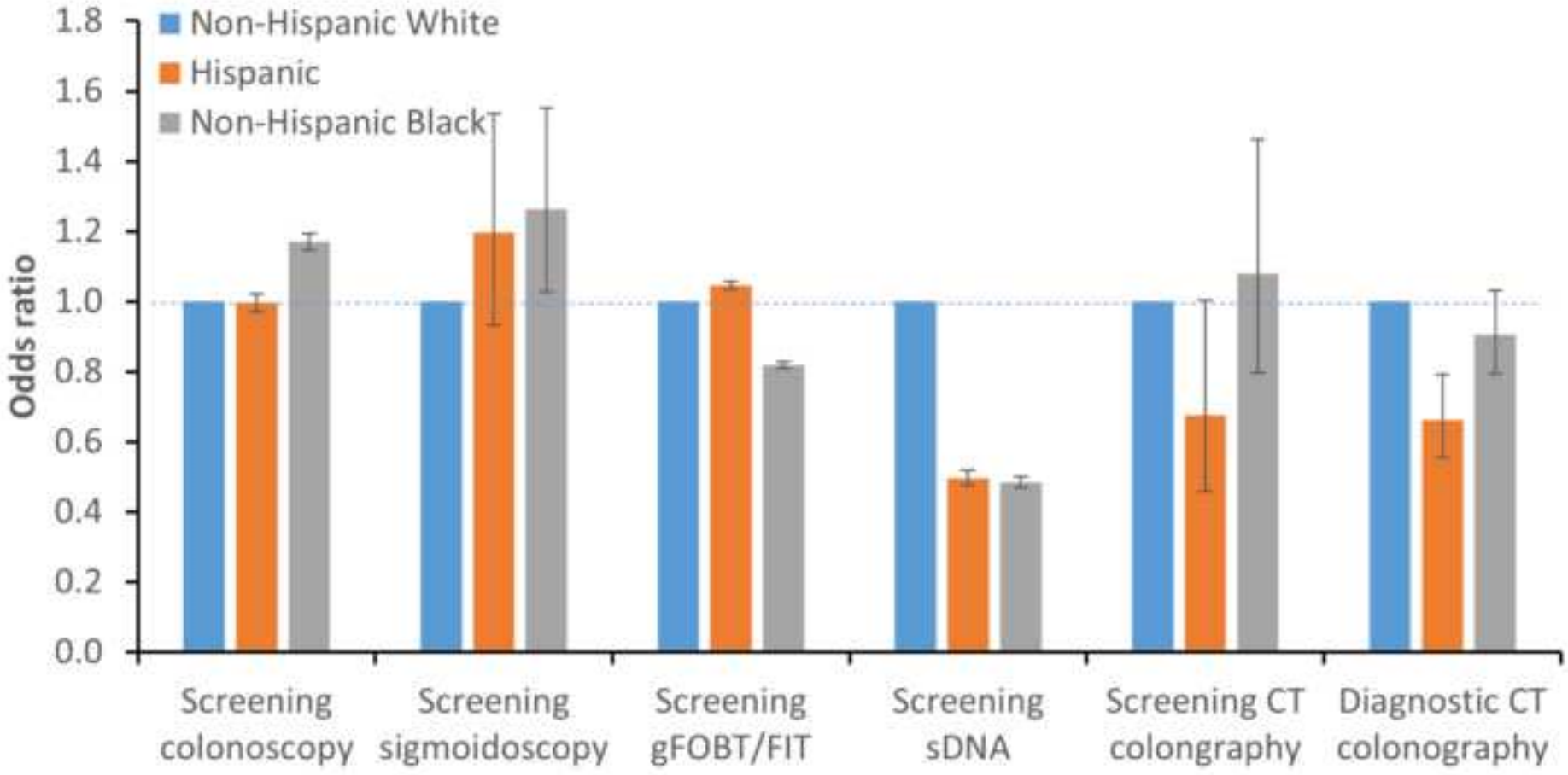
Non-Hispanic White
Hispanic
Non-Hispanic Black
Odds ratio
1.8
1.6
1.4
1.2
1.0
0.8
0.6
0.4
0.2
0.0
Screening colonoscopy
Screening sigmoidoscopy
Screening gFOBT/FIT
Screening sDNA
Screening CT colongraphy
Diagnostic CT colonography

Figure 5

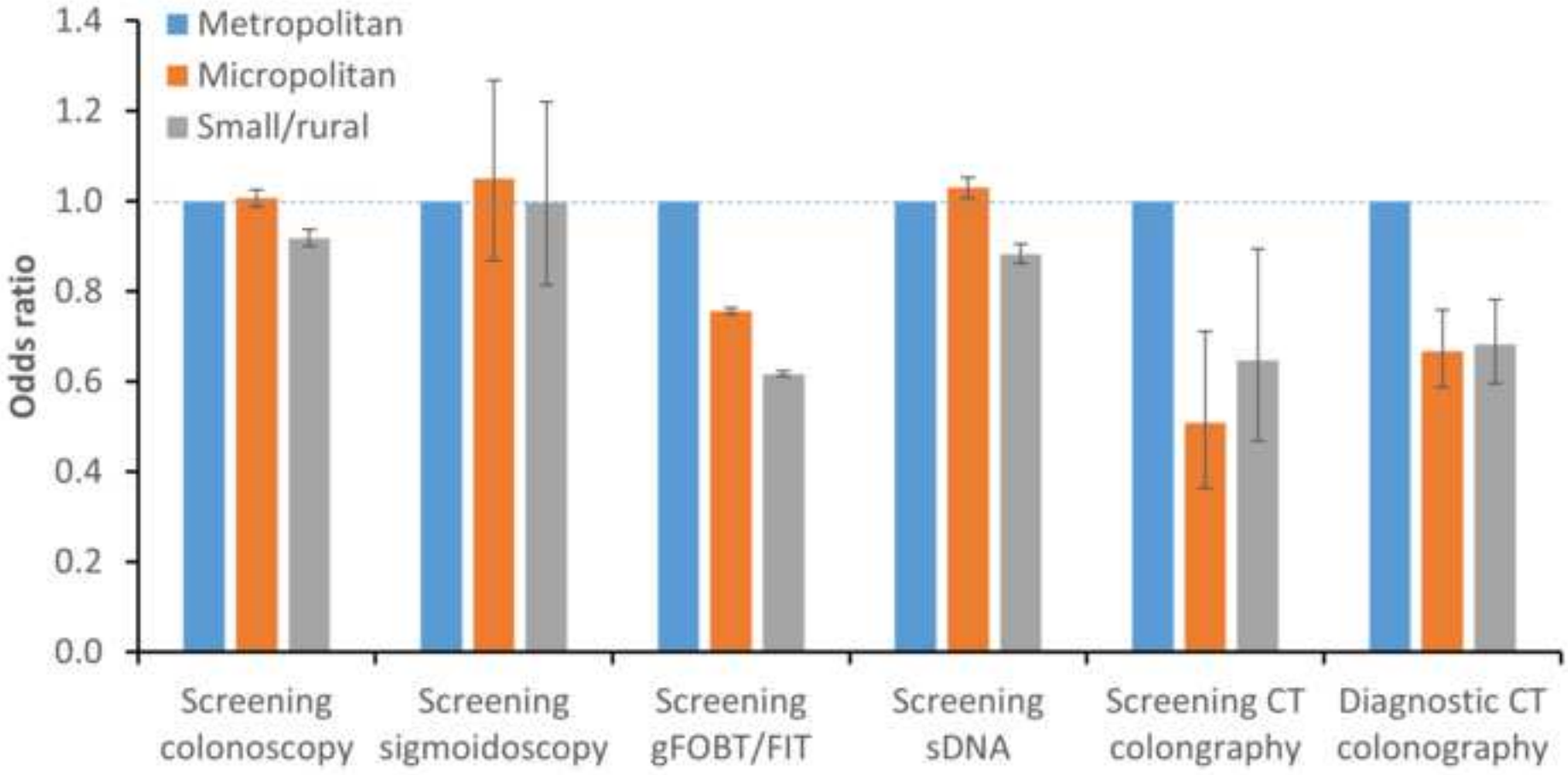
Metropolitan
Micropolitan
Small/rural
Odds ratio
1.4
1.2
1.0
0.8
0.6
0.4
0.2
0.0
Screening colonoscopy
Screening sigmoidoscopy
Screening gFOBT/FIT
Screening sDNA
Screening CT colongraphy
Diagnostic CT colonography

**Table S1:** Criteria for study exclusion due to being deemed at high risk for colorectal cancer

| **Condition or Procedure** | **ICD9 or ICD10 codes** |
|---|---|
| Ulcerative colitis | 556, K51 |
| Crohn disease or regional enteritis | 555, K50 |
| Other hamartoses, NEC; other phakomatoses, NEC (PTEN tumor syndrome, Cowden syndrome) | 759.6, Q85.8 |
| Family history of colonic polyps | V18.51, Z83.71 |
| Hereditary nonpolyposis colorectal cancer (Lynch syndrome) | V83.89, Z14.8 |
| Multiple endocrine neoplasia syndrome | 258.8, 258.01, 258.02, 258.03, V18.11, V84.81, E31.2, E31.8, Z83.41, Z15.81 |
| Colorectal or anal cancer | 152, 154, 230.4, 230.5, 230.6, 230.7, C17, C19-C21, D01.1, D01.2, D01.3, D01.4 |
| Prior high-risk screening colonoscopy | G0105, G0120[a] |

[a]HCPCS codes

HCPCS = Healthcare Common Procedure Coding System; NEC = neuroendocrine carcinoma; PTEN = phosphatase and tensin homolog

**Table S2:** Related conditions and procedures used as covariates

| Condition or Procedure | ICD9 or ICD10 codes |
|---|---|
| Other and unspecified noninfective gastroenteritis and colitis | 558, K52 |
| Diverticular disease of intestine | 562, K57 |
| Other disorders of intestine | 569, K62 |
| Benign colorectal or anal neoplasm | 211.3, 211.4, D12, K63.5 |
| Extracolonic cancer | 140-151, 155-209, 230.0-230.2, 230.8-230.9, 231-234, C00-C16, C22-C96, D00, D01.5-D01.9, D02-D09 |
| Diarrhea | 564.5, 787.91, K59.1, R19.7 |
| Hernia | 550, 551.2, 552.2, 553.2, 551.8, 552.8, 553.8, 551.9, 552.9, 553.9, K40, K43, K45, K46 |
| Colonic perforation | 569.83, K63.1 |
| Prior colorectal surgery | 44157, 44158, 44211, 44392, 45000-45999[a] |

[a]CPT codes