Assessing racial/ethnic disparities in colorectal cancer postoperative care

Janeth Sanchez

A dissertation

submitted in partial fulfillment of

the requirements for the degree of

Doctor of Philosophy

University of Washington

2019

Reading Committee:

Engelberta Thompson, Chair

Veena Shankaran

Joseph Unger

Program Authorized to Offer Degree:

Health Services – Public Health

University of Washington

Abstract

Assessing racial/ethnic disparities in colorectal cancer postoperative care

Janeth Sanchez

Chair of Supervisory Committee:
Engelberta Thompson, Professor Emeritus
Department of Health Services, School of Public Health

Surveillance after surgically resected colorectal cancer (CRC) is a vital clinical process that allows for the early detection of recurrence, especially among 40% of CRC survivors who are likely to develop recurrence after definitive surgical resection for primary CRC [1, 2]. If detected early, the recurrent disease may be responsive to potentially effective cancer treatment [1-3]. National guidelines recommend routine surveillance with colonoscopy, carcinoembryonic antigen (CEA) tests, and computed tomography (CT) scans for patients diagnosed with CRC stages II and III [4, 5]. Unfortunately, surveillance procedures are underutilized among CRC patients and racial/ethnic minorities are about 30% less likely to receive recommended surveillance procedures compared to non-Hispanic Whites [6-12].

This research expands on previous studies and assesses the association between key sociodemographic and economic factors that measure access to care and receipt of colonoscopy (Aim 1) and receipt of CEA tests and CT scans (Aim 2) across racial/ethnic groups. This research also describes the characteristics of CRC patients with recurrence and their surveillance behaviors (Aim 3). These are retrospective population-based cohort studies using the National Cancer Institutes' Surveillance, Epidemiology and End Results (SEER) – Medicare linked data collected from 2009 to 2014. Medicare beneficiaries who received surgical resection for CRC adenocarcinoma diagnosed with documented pathologically staged II and III single CRC as their first cancer between the ages of 66 and 85 were included in these studies. Statistical analyses include multivariate and multilevel logistic regression models.

Receipt of initial surveillance procedures remain low, especially for colonoscopies (57.5%) and CT scans (58.2%). In our study, 12.2% of patients had recurrent disease after 18-months following surgical resection and only 43.7% of these patients had received a colonoscopy, CEA tests, and a CT scan as recommended by national clinical guidelines. Disparities in receipt of surveillance colonoscopy exist among Blacks and NHW patients. There were no significant racial/ethnic differences in receipt of CEA tests or a CT scan. In addition to patient characteristics (predisposing factors) and clinical (need) factors, socioeconomic measures of access to care (enabling factors) are significantly associated with receipt of surveillance procedures. In addition to clinical factors, Black neighborhood density was significantly associated with recurrence. Results suggest inequitable access to surveillance procedures within and between racial/ethnic groups.

Findings from this research may help guide future public health and clinical interventions focused on improving the timely receipt of surveillance procedures among older adults who are likely to have limited access to recommended CRC care. In addition, characterizing patients diagnosed with recurrent or metastatic disease and assessing their surveillance behaviors is a first step for developing effective surveillance promotion interventions and improving cancer treatments for these patients.

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

ACKNOWLEDGEMENTS

I wish to express my utmost appreciation to Beti Thompson for her continued mentorship and guidance over 14 years and for giving me the confidence to improve my skills as a cancer health disparities researcher. I would also like to acknowledge Mary O'Connell and Graciela Unguez, my lifelong mentors, for giving me support and encouragement to overcome barriers and challenges.

My sincerest gratitude to my committee Veena Shankaran, Joe Unger and Margaret Madeleine for their mentorship and support throughout the dissertation phase of my graduate studies and for pushing me to develop focused and meaningful cancer research.

Thank you to the support from the Department of Health Services at the University of Washington faculty and staff for their leadership and dedication to students, particularly Susan Yates for her never-ending administrative assistance and Dave Grembowski for being a wonderful and supportive Program Director; the AHRQ T32 training fellowship, the Bio-behavioral Cancer Prevention and Control T32 Training Program, the Grayston-Day Fellowship, and Graduate Opportunities and Minority Achievement Program (GO-MAP) for the financial support and the opportunity to conduct cancer research.

My sincerest gratitude to my amazing friends and Seattle support system for their constant encouragement over 4 years – Thompson Studies Wonder Women: Kathy, Norma, Marilyn, and Sara; Noah and Shoko, Rebecca and Baloo, Vanessa and Eva, Bridget, Brando and Baby K, Gip, Courtney, and Anand.

Most importantly, I wish to thank my family for their unconditional love and unwavering support: God, Mom, Dad, Jenny, Hezel – my five pillars and rocks throughout my life; Bailey for making each Seattle day brighter with her companionship; James and Kimo for their patience and care/love packages; and Castañon family for their love and support from a far.

DEDICATION

This dissertation is dedicated to my beloved parents, Maria R. and Jesus J. Sanchez, who throughout my lifetime have been my source of inspiration and have etched in my heart a template of hard work, love, and compassion.

CHAPTER 1. Introduction

1.1 Background

Developments in colorectal cancer (CRC) screening, staging, and treatment have significantly improved survival over the last two decades from approximately 60% to 65% for both men and women [3, 13, 14]. Despite this progress, CRC continues to be a leading cause of cancer related deaths in the U.S. and striking racial/ethnic disparities in survival exist [13, 15, 16]. Much of the progress in survival is confined to non-Hispanic White (NHW) CRC patients, with Blacks and those residing in underserved areas (e.g., low income and rural) experiencing a 10% overall lower 5-year survival [3, 13, 15, 17-19]. One potential reason for the disparity in survival in CRC patients may be due to lower rates of receipt of appropriate cancer care such as surveillance after definitive surgical resection for CRC [6, 20-22].

CRC surveillance before symptoms arise is valuable in assisting clinicians in identifying secondary cancers and recurrence early when cancer treatment is possible [16, 23-25]. Approximately 40% of CRC patients who receive surgical resection following an initial diagnosis will experience recurrence and 60% to 80% of these recurrences will occur within the first 36 months post diagnosis [1, 2]. CRC patients with recurrence continue to have persistently poor health outcomes including lower overall survival [5, 16]. Therefore, the American Society of Clinical Oncology (ASCO) and the National Comprehensive Cancer Network (NCCN) strongly recommend CRC surveillance for individuals diagnosed with CRC stages II and III [4]. After definitive surgical resection, national clinical guidelines recommend one colonoscopy within 1-year, a minimum of one CEA test every 6-months for five years and, as of 2005, a yearly CT scan for 3 years following surgical resection for patients diagnosed with CRC stages II and III [4, 26, 27]. As a CRC postoperative surveillance procedure, colonoscopy is considered the ‘gold standard’ procedure for individuals at-risk for local CRC recurrence due to its high sensitivity and specificity (95% and 100%, respectively) in identifying potentially cancerous colorectal polyps and tumors [23, 24]. The CEA test is a test for detecting the CEA protein, a clinical tumor marker; over 80% of patients with distant metastases have elevated CEA levels [5, 26-29]. The CT scan is a non-invasive imaging procedure used in detecting metastatic recurrence, especially for patients who are at high-risk of recurrence based on clinical characteristics of the primary CRC (e.g., high-risk stage II and

stage III) [5, 26-29]. Receiving the colonoscopy, CEA tests, and CT scans at recommended intervals may improve overall survival by up to 33% [26, 30, 31].

Despite its clinical benefits, research indicates that receipt of CRC surveillance procedures falls short from the recommended guidelines and only about 40% of all CRC survivors receive timely surveillance [6-12, 32-36]. For example, approximately 55% and 75% of eligible CRC patients receive initial colonoscopy and CEA tests, respectively, within 12- to 18- months after surgery [6] [6]. Significantly less research has assessed receipt of surveillance CT scans, primarily due to variations in national clinical surveillance guidelines over the last two decades. Nonetheless, the limited studies suggest that rates of receipt of a CT scan within 12-months after surgical resection remain low, varying from 33% to 60% [6, 34-36]. Lower rates of receipt of surveillance procedures are observed among CRC patients who are racial/ethnic minorities, older, diagnosed with comorbidities, and who do not receive adjuvant treatment [6-12, 35, 36]. Racial/ethnic minority CRC survivors are 30% to 40% less likely to receive surveillance procedures compared to NHWs [6-12]. Among the elderly, Black and Hispanic CRC patients are approximately 10% less likely to receive surveillance colonoscopy within the first 24-months following surgical resection compared to NHW patients [6, 7, 33, 37]. Similarly, the proportion of CRC patients who receive CEA testing is about 5% lower for Blacks compared to NHWs [6, 20-22, 34]. Significant gaps in knowledge exist regarding racial/ethnic differences in receipt of CT scans, however, Hu et al (2011) found that the proportion of patients who receive CT scans at recommended intervals was about 2% lower for Blacks compared to NHWs [34]. Identifying the factors that contribute to lower receipt of surveillance among racial/ethnic minorities can assist researchers in developing targeted interventions to promote utilization of surveillance procedures for the early detection of recurrence and improve CRC-related outcomes.

There are likely multiple underlying factors contributing to racial/ethnic disparities in the timely receipt of CRC surveillance procedures. While research suggests that patient characteristics (e.g., age race/ethnicity) and clinical factors (e.g., stage, presence of comorbidities) influence receipt of surveillance, studies evaluating the association between patient- and neighborhood-level socioeconomic factors that measure access to care and receipt of surveillance are limited [6, 7]. There is also a lack of evidence on the effect of socioeconomic factors across racial/ethnic groups, especially from studies

focusing on the older adult Medicare population, a population with a 32% higher risk of death compared to older adults with private insurance [6, 7]. Medicare provides health care coverage for over 95% of the older adult American population and is the primary mechanism through which cancer care is covered for these beneficiaries. Failure to assess the effect of key factors that affect a patient's ability to access surveillance procedures may have macroeconomic implications and negatively impact efficiency of national CRC prevention programs [6-8, 32-34, 38].

Moreover, with over 50,000 CRC-related deaths expected to occur during 2019, improving the rates of early detection of recurrence and survival is a key public health priority [15]. Cancer recurrences detectable by surveillance procedures are more likely to be diagnosed at earlier stages of disease when they are most treatable, thus, lower rates of receipt of surveillance among CRC patients represents a critical missed opportunity for improving survivorship [39, 40]. Research assessing factors associated with recurrence after surgically resected CRC primarily focuses on clinically relevant factors, such as cancer stage, number of lymph node resections, histological grade, microsatellite instability and receipt of adjuvant therapy [16, 41-43]. However, other patient characteristics (e.g., age, gender, race/ethnicity) and attributes of the neighborhoods (e.g., minority composition, median household income) where CRC patients live may vary based on recurrence status. Population-based estimates of recurrence after definitive surgical resection provide an indicator of the potential effectiveness of cancer treatments and other efforts to reduce the burden of CRC. Unfortunately, data on the patient and neighborhood characteristics of patients with recurrence and their surveillance behaviors is sparse. Given the low rates of CRC surveillance utilization, this information can inform and promote cohesive and efficient cancer surveillance for the early detection of cancer progression [42, 44].

To address these limitations and gaps in the literature, this research uses the Surveillance Epidemiology and End Results-Medicare linked data to assess the association between key sociodemographic and economic patient- and neighborhood-level factors that measure access to care and receipt of colonoscopy (Aim 1) and receipt of CEA tests and CT scans (Aim 2) across racial/ethnic groups. The proposed research also describes the characteristics of CRC patients with recurrence and their surveillance behaviors (Aim 3). Results from these studies may assist researchers in identifying

potential drivers of surveillance utilization among vulnerable older adults and minority populations and define strategies to eliminate the unequal burden of CRC among racial/ethnic minorities in the U.S.

1.2 Specific Aims

Aim 1: Assess the association between patient- and neighborhood-level factors and receipt of surveillance colonoscopy among Medicare beneficiaries with surgically resected colorectal cancer. Using health care claims, receipt of initial surveillance colonoscopy is based on having received one colonoscopy over an 18-month period following surgical resection.

Hypothesis 1.0: Receipt of colonoscopy is lower than 60%, with the proportion of Hispanics and Blacks who receive a colonoscopy being lower than that of NHWs.

Hypothesis 1.1: Beneficiaries who are minority, older age, male, single status, with an earlier CRC stage, less comorbidities, and no adjuvant CRC therapy (i.e., chemotherapy and/or radiation therapy) have lower odds of receipt of colonoscopy.

Hypothesis 1.2: Beneficiaries living in neighborhoods characterized by a higher proportion of minority composition, lower educational attainment, lower household income, and geographically located in rural or u.rban areas and in the Midwest or South have lower odds of receipt of a colonoscopy

Hypothesis 1.3: In addition to predisposing and need factors, enabling factors are significantly associated with lower receipt of colonoscopy among minority CRC patients.

Aim 2: Assess the association between patient- and neighborhood-level factors and receipt of the minimum recommended carcinoembryonic antigen (CEA) test and computed tomography (CT) scans among Medicare beneficiaries with surgically resected colorectal cancer. The minimum recommended surveillance CEA test and CT scans is defined as receipt of at least two CEA test and/or one CT scan within an 18-month period following definitive surgical resection for CRC.

Hypothesis 2.0: Receipt of CEA tests and CT scans will be lower than 72% and 60%, respectively, among beneficiaries with the proportion of Hispanics and Blacks who receive these surveillance tests being lower than the proportion of NHWs.

Hypothesis 2.1: Beneficiaries who are minority, older age, male, single status, with an earlier CRC stage, less comorbidities, and no adjuvant CRC therapy have lower odds of receipt of a CEA tests and a CT scan.

Hypothesis 2.2: Beneficiaries living in neighborhoods characterized by a higher proportion of minority composition, lower educational attainment, lower household income, and geographically

located in rural or urban areas in the Midwest or South have lower odds of receipt of CEA tests and a CT scan.

Hypothesis 2.3: In addition to predisposing and need factors, enabling factors are significantly associated with lower odds of receipt of CEA test and a CT scan among racial/ethnic minority CRC patients.

Aim 3: Identify the patient and neighborhood characteristics of Medicare beneficiaries with surgically resected colorectal cancer who experience recurrence. Using health care claims, recurrence is operationalized as having claims for secondary surgical procedures, chemotherapy, radiation, and other claims that are indicative of liver, lung, and other metastases after 18-months following surgical resection [45].

Hypothesis 3.0: The proportion of patients who experience recurrence is less than 20%.

Hypothesis 3.1: Patients who are younger, with a more advanced disease stage (i.e., high-risk stage II and stage III vs stage II), those who receive adjuvant treatment, and with more comorbidities will have higher odds of recurrence.

Hypothesis 3.2: Neighborhood-level factors will not be associated with recurrence status.

Sub-Aim 3.a.: Assess the surveillance behaviors of Medicare beneficiaries with recurrence. Receipt of initial surveillance procedures is defined as receiving one colonoscopy, two carcinoembryonic antigen (CEA) tests, and/or one computed tomography (CT) scan from 6- to 18-months following surgical resection for CRC.

Hypothesis 3.a.0: The proportion of patients who receive surveillance procedures will be greater among those who experience recurrence.

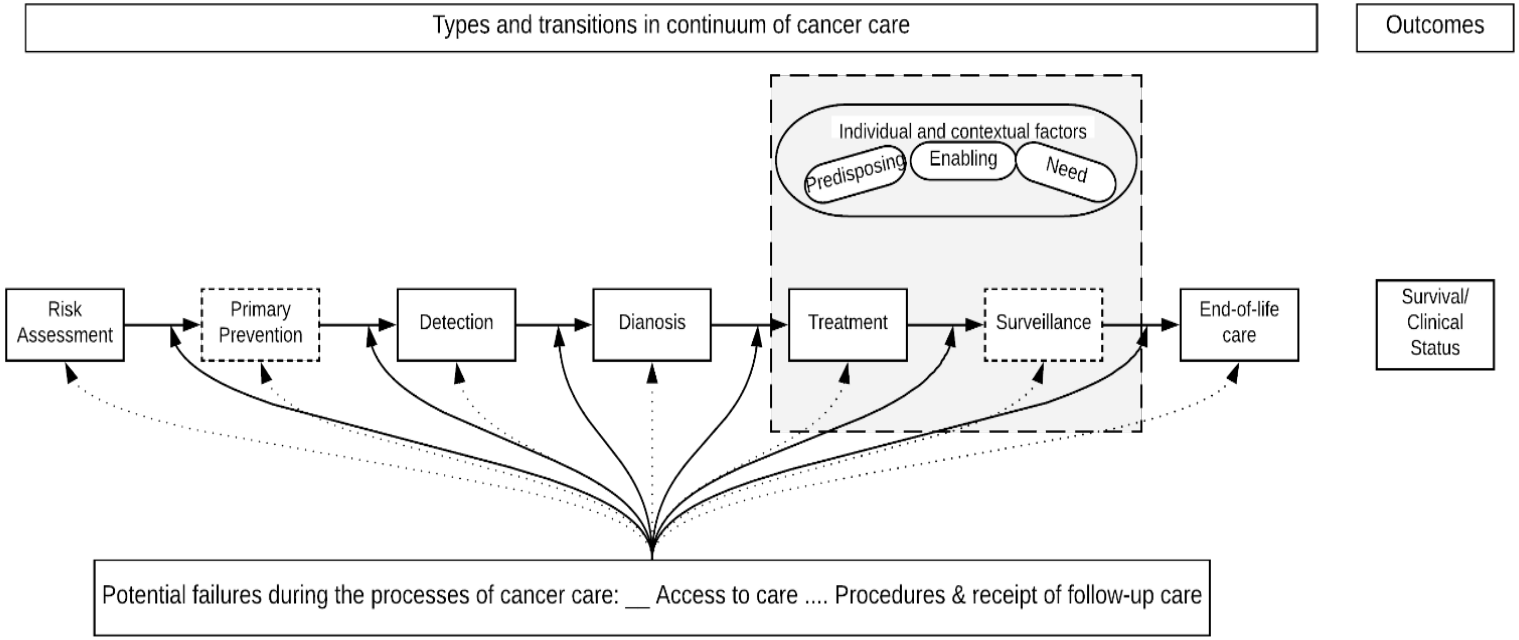
1.3 Theoretical Framework and Conceptual Model

Improving access to and the quality of CRC care for racial/ethnic minorities and underserved populations is important for reducing disparities in CRC-related outcomes. Translating effective and equitable cancer care into better outcomes for CRC survivors, however, requires a systematic understanding of the factors that play a critical role in receipt of all types of cancer care, including postoperative CRC surveillance. To gain insight into the context within which receipt of CRC surveillance occurs, consideration of relevant theoretical concepts is instrumental.

The explanatory model guiding the proposed research is adapted from Zapka's (2003) Quality in the Continuum of Cancer Care (QCCC) Framework and Andersen's (1978, 1995, 2007) Behavioral Model of Health Services Use. Combining these two models provides a better understanding of patient- and neighborhood-level factors associated with racial/ethnic disparities in receipt of surveillance and the surveillance behaviors of patients with recurrence.

QCCC Framework. The QCCC Framework provides a pragmatic approach to understanding CRC development and progression, as well as the relationship between processes of cancer care and health outcomes (Figure 1) [46]. The processes of cancer care along the continuum include the types of care delivered (e.g., diagnosis, treatment), interactions needed to go from one type of care to another (i.e., transitions, indicated by dotted boxes), health care encounters or actions within each type or transition in care (i.e., steps), and the interactions that link steps of care through the transfer of information between patients, providers, and health systems (i.e., interfaces) [47]. The steps and interfaces are not depicted in Figure 1 for simplification purposes.

Figure 1.1 Quality in the cancer continuum of care



Cancer care across the continuum encompasses several unique types of care and transitions, beginning with risk assessments and primary prevention through screening for both symptomatic and asymptomatic individuals, followed by diagnosis of illness, cancer treatment, surveillance and end-of-life care. Although the continuum is depicted as linear processes, moving along the cancer continuum is often non-sequential, with some patients moving back and forth between states. For example, not all CRC polyps detected and removed through early detection screening require cancer treatment (e.g., surgery, chemotherapy). If the polyp removed is diagnosed as pre-malignant or non-cancerous, the individual may go back to receiving screening at recommended intervals. Similarly, not all CRC patients will experience recurrence, and not all patients who experience recurrence will receive secondary treatment.

Within the processes of cancer care, multi-level (e.g., patient-, neighborhood-, health system- and policy-level) factors may pose challenges for patients, health providers and health systems that lead to failures throughout the cancer continuum. Along the continuum, failures in the following may occur: 1) access to cancer care, 2) cancer care procedures and procedure outcomes, and 3) receipt of follow-up care [46]. Based on published research, we know that receipt of CRC surveillance improves overall survival through the early detection of resectable asymptomatic recurrences and reduction in time to diagnosis of recurrence [21, 31, 48-50]. Failure to receive timely surveillance among racial/ethnic minorities may be, in part, driven by multilevel and multi-dimensional factors that affect access to care, such as individual patient characteristics and neighborhood-level social factors, and could be contributing to persistent racial/ethnic disparities in survival [46]. By examining the multidimensional factors that are associated with receipt of CRC-related care and outcomes, proposed models can provide further insight into the possible mechanisms contributing to racial/ethnic disparities in CRC-related outcomes.

Behavioral Model of Health Services Use. Andersen's Behavioral Model of Health Services Use posits that an individual's utilization of health care services, such as CRC surveillance, are functions of three dimensions of factors: 1) Predisposing, 2) Enabling and 3) Need factors. Each of the three PEN factors has two-levels, encompassing patient- and neighborhood-level PEN factors (Figure 2). **Predisposing factors** are socio-cultural factors that exist before the presence of disease and influence surveillance procedure utilization [51-53]. These include demographic characteristics (e.g., race, age,

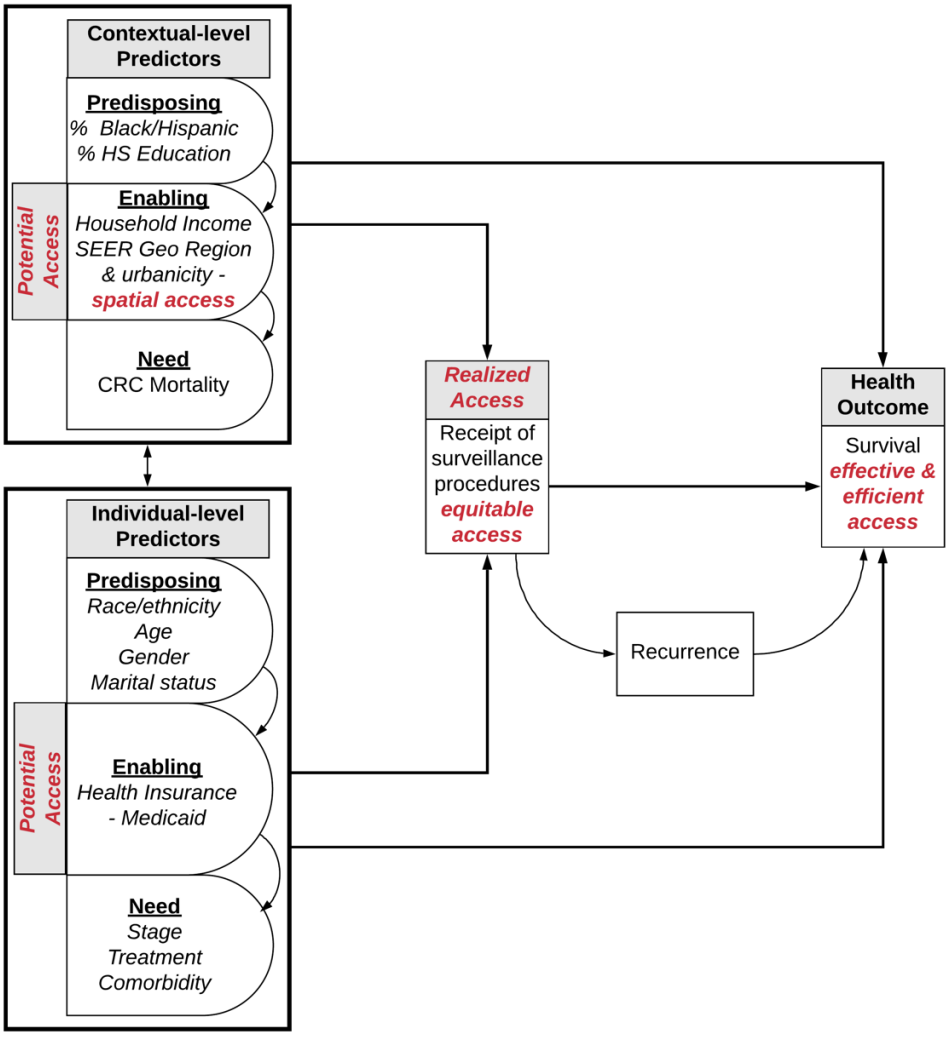
gender), social structures, and health beliefs. Social structures include factors associated with social networks such as marital status, as well as social culture and interactions (e.g., ethnicity), while health beliefs are composed of health care-related attitudes, values, and knowledge. Neighborhood-level predisposing factors include the demographic or social composition of one's neighborhood or community [51, 53]. **Enabling factors** facilitate a patient's ability to access surveillance, such as income, health insurance, and having a regular source of care. At the neighborhood-level, enabling factors include median household income, distance to health care facilities, number of health care facilities and health care personnel, as well as neighborhood level poverty and area deprivation. **Need factors** are potential measures of illness severity and are considered the most immediate factors that lead to receipt of surveillance [7, 20, 51, 54]. Need factors include *perceived need*, an individual's own health awareness and perception, and *evaluated need*. *Evaluated need* factors represent clinical diagnoses and health care professional opinions about an individual's health status. Genetic factors and psychological characteristics may be considered need factors as these may call for acute care or more frequent use of health care services. Although receipt of surveillance is driven by a patient's need for surveillance, the association between fundamental patient- and neighborhood-level PEN factors and racial/ethnic disparities in receipt of surveillance among Medicare beneficiaries is understudied [6, 7]. The factors influencing racial/ethnic disparities in receipt of surveillance over time may extend beyond patient-level characteristics. Social environment, such as place of residence, neighborhood composition, income, poverty, and area deprivation, may serve as key factors affecting whether a patient receives timely and appropriate surveillance. The proposed research hypothesizes that after adjusting for patient- and neighborhood-level predisposing and need factors, patient- and neighborhood-level enabling factors are significantly associated with receipt of surveillance procedures across all racial/ethnic groups, including Blacks and Hispanics.

Andersen's framework also integrates the concept of access to care in relation to health care utilization [51, 55]. The Anderson framework posits that better access to health care leads to greater utilization of health care services, which in turn improves health outcomes [51]. Accordingly, better access to CRC surveillance will lead to higher rates of receipt of surveillance procedures, thus, lead to the early detection of recurrence and improved survival. The conceptualization of access to cancer care is

fundamental to understanding and identifying the factors associated with receipt of surveillance among racial/ethnic minorities that could lead to differences in survival since multi-dimensional facilitators and barriers to access to care may vary by race/ethnicity.

Access to CRC Surveillance. As defined by the US Institute of Medicine, *access* to care is the timely utilization and receipt of health care services to achieve the best possible outcome [51, 56, 57]. More specifically, access is composed of several dimensions which describe possible and actual entry into the health care system and the process of receipt of cancer care [55].

Figure 1.2 Factors associated with receipt of CRC surveillance and outcomes



Dimensions of access. Dimensions of access to care include *potential, realized*, *spatial*, *effective*, *efficient* and *equitable* [51, 58]. *Potential access* implies entry into the health care system and is indicated as the presence of enabling factors and their association with receipt of cancer care [51, 59]. Inadequacy in enabling factors, such as lower household income, indicate potential barriers to receipt of surveillance and later diagnosis of recurrence, and consequently lower survival. The second dimension of access is *realized access*, also known as health care utilization. Receipt of surveillance procedure is a measure of *realized access* as it is an objective outcome measure of health care services utilization [51]. *Realized access* may be used to monitor and evaluate health policies and surveillance guidelines among minority and underserved populations [56]. The third dimension is *spatial access* to surveillance and is defined by geographic-related factors, such as distance to health care facilities where surveillance can be received (e.g., rural vs urban settings) [58, 59]. In addition, spatial patterns of access to surveillance are geographic measures of the relative availability and/or use of surveillance procedures among specific populations over time. The fourth dimension is *equitable access* to cancer care and is defined by the factors associated with differences in receipt of surveillance procedures across racial/ethnic groups. For example, access to surveillance is equitable across racial/ethnic groups if the difference in the timely receipt of surveillance is mostly explained by predisposing factors and need factors, while *inequitable access* to surveillance is observed when enabling factors are significantly associated with receipt of surveillance [56]. Assessing *equitable access* to surveillance can ensure that receipt of surveillance is determined by need and assist researchers in identifying the potential modifiable social characteristics affecting receipt of surveillance. Another dimension is *effective access* to surveillance, which occurs when receipt of surveillance improves health outcomes. The sixth dimension of access is *efficient access* and is accomplished when more intensive surveillance (e.g., greater number of surveillance procedures received) lead to higher rates of survival among CRC patients. *Efficiency* in access can assist publicly-funded programs in minimizing the costs of improving survival of CRC patients. Overall, the conceptualization of the dimensions of access provide a useful framework to better understand the mechanisms through which racial/ethnic differences in receipt of CRC surveillance and CRC outcomes arise. The italicized text in **Figure 2,** represent the variables that will be measured in this research.

The proposed model (Figure 2) exemplifies the effects of important patient- and neighborhood-level PEN factors on receipt of CRC surveillance and how racial/ethnic differences may exist in the association between receipt of surveillance and CRC outcomes, such as recurrence. The latter being moderated by several patient-level factors, including a more advanced stage, which may themselves be influenced by a patient's social and built environment. In this way, we can better inform clinical practices, assess patient prognosis, and formulate appropriate CRC surveillance guidelines for older adults with non-metastatic CRC.

CHAPTER 2. Patient and neighborhood factors associated with receipt of surveillance colonoscopy among Medicare beneficiaries with surgically resected colorectal cancer.

Introduction

Colorectal cancer (CRC) is the third most commonly diagnosed cancer in the United States (US). Of the 135,000 newly diagnosed CRC cases each year, 70% to 80% will undergo definitive surgical resection as part of their cancer treatment [1, 15, 60]. Following surgery, however, up to 40% of CRC patients will experience cancer recurrence and metachronous (second primary) CRC within 3 years after diagnosis [2, 60-62]. Thus, identification of recurrent or secondary cancers when potentially curative treatment is still possible is a critical aspect of CRC surveillance and an important predictor of survival in this population [16, 23-25, 63]. National surveillance guidelines strongly recommend a colonoscopy at 1-year and subsequently at 3- to 5-years after definitive surgical resection for patients diagnosed with stages II and III CRC [4, 26, 27]. Postoperative colonoscopy surveillance improves overall survival in CRC patients by detecting synchronous colorectal tumors that may have been missed during the preoperative workup, local and anastomotic recurrences, and metachronous CRCs [1, 2, 25, 27].

Despite its benefits, surveillance colonoscopy utilization is low, with approximately 50% of eligible CRC patients receiving a colonoscopy at the recommended time intervals [6, 33, 36, 64]. Older patients, patients with more comorbidities, and patients who do not receive adjuvant treatment chemotherapy are less likely to receive surveillance colonoscopy [6, 7, 35, 36]. More alarming are the persistent racial/ethnic disparities in receipt of CRC-related care that extend beyond early detection and treatment [6, 7, 32, 34, 37]. For example, elderly Black and Hispanic CRC patients were approximately 10% less likely to receive surveillance colonoscopy within the first 2 years following surgical resection compared to non-Hispanic White (NHW) patients (NHWs) [6, 7, 33, 37]. In one study, Black CRC patients were 9% less likely to receive subsequent endoscopic surveillance compared to NHWs after controlling for patient-level sociodemographic and clinical characteristics, [32].

Although a growing body of literature demonstrating racial/ethnic disparities in cancer treatment and surveillance, few studies have evaluated the extent to which patient- and neighborhood-level factors contribute to observed racial/ethnic disparities in cancer surveillance [36, 46]. Racial/ethnic differences in

receipt of appropriate surveillance with colonoscopy may be driven, in part, by the dynamic interdependence of multiple levels of influence including the characteristics of patients and the neighborhoods in which they reside. For example, racial/ethnic minorities tend to reside in neighborhoods characterized by socioeconomic disadvantage which may reduce access to health care and the likelihood that a cancer patient may receive a recommended surveillance procedure [65-68]. Socioeconomically disadvantaged cancer patients (e.g., patients from low socioeconomic status and/or from resource deprived neighborhoods) exhibit lower cancer survival [65, 69, 70]. In studies of Medicare beneficiaries, an older adult population with nearly universal access to health care through the Medicare program, failure to assess the effect of neighborhood-level factors that impact a survivor's ability to obtain surveillance colonoscopy at the recommended intervals may lead to missed opportunities for improving health care utilization and outcomes among minority and underserved older adult CRC survivors [6-8, 32-34].

Andersen's Behavioral Model of Health Services Use posits that an individual's utilization of health care services, such as receipt of surveillance procedures, are functions of three dimensions of influences called PEN factors: 1) Predisposing (i.e., predisposition to use services), 2) Enabling (i.e., ability to access health services) and 3) Need (i.e., severity of illness) [53, 56]. Each of the three PEN factors has two-levels encompassing patient- and neighborhood-level factors. For example, at the patient-level, Predisposing factors include age and gender, Enabling factors include insurance coverage and income, while Need factors include stage at diagnosis and presence of comorbidities. As a potential indicator of illness severity, receipt of adjuvant therapy (e.g., chemotherapy and/or radiation) is also considered a Need factor and may influence utilization of surveillance procedures. At the neighborhood-level, Predisposing factors include minority composition and educational attainment, while Enabling factors include median household income, and the geographical region where patients reside (e.g., rurality, SEER registry).

Although patient-level Need factors are considered the most proximal factors driving utilization of health services, enabling factors may influence cancer care utilization through socioeconomic resources at the patient- and neighborhood-level that facilitate or hinder access to care. Inadequacy in Enabling factors, such as lack of health insurance, being low income or residing in neighborhoods with lower

household income, indicate potential barriers to receipt of surveillance procedures, lead to inequitable access to cancer surveillance, and consequently contribute to poor CRC outcomes among minority populations [71]. Based on this conceptual framework, the aim of this research study is to assess the association between patient- and neighborhood-level factors and receipt of surveillance colonoscopy among Medicare beneficiaries from different racial/ethnic groups. The extent of neighborhood variability in receipt of surveillance colonoscopy in the US is largely understudied. Assessing the overall variation in receipt of surveillance colonoscopy determined by neighborhoods is important for measuring potential effects of factors beyond the patient-level and for identifying appropriate levels of analysis [72, 73], which may aid researchers in developing targeted interventions to improve receipt of postoperative surveillance colonoscopy among medically underserved populations [6, 36, 37].

Methods

Study design and data source

This retrospective cohort study used the National Cancer Institute's Surveillance, Epidemiology and End Results (SEER) – Medicare linked data (2009 to 2014). The linked SEER – Medicare data is a large population-based source of detailed health information about Medicare beneficiaries diagnosed with cancer [74]. The Medicare Provider Analysis and Review (MedPAR), Carrier, and Outpatient files were used to identify receipt of surveillance colonoscopy among CRC patients, while the SEER Patient Entitlement and Diagnosis Summary File (PEDSF) was used to identify cancer outcomes. Additional files used in this study included the Durable Medical Equipment (DME) and Part D Event (PDE) files to ascertain receipt of CRC-related adjuvant treatment.

Study Population

We identified Medicare beneficiaries between the ages of 66 and 85 who were enrolled in Medicare Part A and B fee-for-service 12-months prior to CRC diagnosis (Figure 1). Patients who are $\leq$65 years of age and $\geq$ 86 years of age were excluded since beneficiaries younger than 66 years may have incomplete Medicare data on comorbidities and patients older than 85 are not likely candidates for routine surveillance by colonoscopy. Patients with documentation for pathologically staged CRC (stages II and III) as their first and only cancer and who received surgical resection for primary CRC adenocarcinoma were included in this study. Patients with high-risk stage II were identified using factors

available in the SEER data and include the number of lymph nodes examined (≤12 or >12 lymph nodes), tumor T stage (T0-T4) and disease grade based on tumor cell differentiation (well, moderately, poor or undifferentiated). In our cohort, 97% of the patients had less than 12 lymph nodes examined, therefore, we defined high-risk stage II as patients with high grade tumors (poorly differentiated or undifferentiated) and T4 stage. Beneficiaries were identified as having received definitive surgical resection for first primary CRC if they had a Medicare claim based on CPT and ICD-9 diagnosis and procedure codes for resection, a colectomy, less than colectomy, or surgical excision with pathology specimen (Supplemental Table 1). The index surgery date is defined as surgical resection less than or equal to 120 days from diagnosis. If surgery was not identified via Medicare data, the definitive surgery was ascertained from surgical codes in SEER (See Supplemental Table 1) [35, 45, 75].

Patients enrolled in a health maintenance organization (HMO) during the study period were excluded from the study, as we may not be able to fully capture surveillance claims (Figure 2.1). Patients with an unknown month of diagnosis, had a CRC diagnosis based on autopsy or death certificate, or died during the study period were also excluded.

Outcome: Receipt of surveillance colonoscopy

Based on recommended guidelines from the American Society of Clinical Oncology (ASCO) and the National Comprehensive Cancer Network (NCCN), receipt of initial surveillance colonoscopy is operationalized as having received at least one colonoscopy in an 18-month period following definitive surgery (Figure 2.2). The 18-month period was chosen as a clinically appropriate timeframe since it is likely that scheduling and receiving a colonoscopy may take several months [10, 32]. Surveillance colonoscopies received up to 6-months following surgery were excluded to ensure that perioperative-related procedures are not included, and because the likelihood of true, post-surgical surveillance colonoscopy in this time frame is low [4, 8, 32].

Patient- and neighborhood-level factors

*Predisposing factors***.** Predisposing factors are socio-cultural factors that exist before the presence of disease and may influence receipt of surveillance procedures [51, 53]. Patient-level P*redisposing* factors include race/ethnicity, age, gender, and marital status (Table 1). In this study, race/ethnicity has three racial/ethnic classifications (non-Hispanic White (NHW), Black, and Hispanic).

Other racial/ethnic groups, such as American Indian/Alaska Native and Asian/Pacific Islander were excluded due to limitations in sample sizes. Age was identified at time of CRC diagnosis and assessed continuously in years, gender was categorized as a male or female, and marital status was categorized as single (never married), married, or other (i.e., separated/ divorced/ widowed).

At the neighborhood-level, census tracts were used as a proxy measure for neighborhoods. Census tract tabulation areas are small geographic units with relatively similar characteristics containing an average of 4,000 residents. *Predisposing* neighborhood-level factors include the percent minority neighborhood composition measured by the percentage of the population who are Black or Hispanic, and educational attainment which is measured as the percentage of residents over the age of 25 that had less than high school education [76].

Enabling factors. Enabling factors facilitate a patient's ability to access surveillance colonoscopy and are measures of equitable access to health services [51]. At the patient-level, dual Medicare-Medicaid coverage is an *Enabling* factor defined as being covered through a state-buy in program and categorized as a binary - not having dual coverage or having dual coverage. At the neighborhood-level, *Enabling* factors include median household income, urbanization as a measure of the population size of the geographical area where a patient resides based on degree of urbanization and is categorized as metro, urban, and rural, and SEER registry, which is the geographic region in which the beneficiary resides and is categorized as Northeast, Midwest, South, and West. As measures of spatial access, both urbanization and geographic region are factors that assess the relative geographic availability or use of surveillance colonoscopy among specific populations.

Need factors. Patient-level *Need* factors include staging at time of diagnosis, receipt of adjuvant treatment, and the presence of comorbidity. Stage is categorized as being diagnosed with stage II, high-risk stage II, or stage III CRC. Receipt of adjuvant treatment is based on having claims for chemotherapy and/or radiation using CPT, ICD-9 and Revenue Center codes within 120 days from index surgery (See Supplemental Table 1) [45, 77]. Comorbidity, measured by the Charlson comorbidity index (CCI), is a summary measure that combines 19 medical chronic conditions associated with increased mortality and are weighted from 1 to 6 based on disease severity. Presence of comorbidity was established if the Medicare beneficiary had chronic conditions present 12-months before diagnosis. Comorbidity is

categorized as having 0, 1, 2, or 3+ comorbidities [7, 78].

Statistical Analyses

Significant differences in the distribution of patient characteristics across race/ethnicity categories were assessed using the Pearson Chi-square test and based on two-sided p-values less than 0.05. Bivariate analyses were performed to assess the independent association between each patient- and neighborhood-level PEN factor and receipt of surveillance colonoscopy. We calculated the variance inflation factor (VIF) to identify potential multicollinearity between patient and neighborhood-level PEN factors (mean VIF = 1.30). We used multivariate logistic regression to assess the effect of PEN factors on receipt of surveillance colonoscopy stratified by racial/ethnic group.

For the multivariate logistic regression models, we generated indicators for race/ethnicity, specified two ways – one indicator for Blacks and one for Hispanics, both with NHWs as reference. We fit a null model with only the outcome and an empty (unadjusted) model that only included outcome and race/ethnicity indicators without patient or neighborhood-level PEN factors. We subsequently fit five multivariate logistic regression models by adding blocks of patient- and neighborhood-level PEN factors to the empty model. The first model (Model 1) included patient-level Predisposing factors (age, gender, marital status). Patient-level Need factors (stage, receipt of adjuvant treatment, comorbidity) were added in the second model (Model 2). We subsequently added Medicaid coverage status as a patient-level Enabling factor in the third model (Model 3). The fourth model included neighborhood-level Predisposing factors (% Black composition, % Hispanic composition, and % of neighborhood population with less than high school education) (Model 4). The full model contained all patient characteristics, clinical factors and neighborhood characteristics, including median household income, urbanization and SEER registry (Model 5).

The final model included a time variable modeled linearly to account for changes in the relationship between the year a beneficiary was diagnosed with CRC and receipt of surveillance colonoscopy. The 2-way interaction terms between race/ethnicity and PEN factors were added one at a time to the final model to assess whether the relationship between receipt of surveillance colonoscopy and racial/ethnic composition differed between PEN factors. An interaction term with p-value < 0.05 suggested that the association between receipt of surveillance colonoscopy and PEN factor is

significantly different across levels of the factor. All analyses were conducted in STATA 15.1 software (STATACorp, 2019).

Secondary analyses. We further explored the variance in receipt of surveillance colonoscopy that is explained by the clustering structure. We fit an empty multilevel logistic regression model with a clustered structure at the neighborhood level (i.e., census tract) and with no patient or neighborhood-level factors to quantify this variance. A second multilevel model was fit with all PEN factors to assess random effects (varying intercept and varying slope) using a likelihood-ratio tests. Since 50.3% of the neighborhoods had only one patient, we conducted sensitivity analyses to assess differences in characteristics between neighborhoods with only one patient and those with more than one patient.

Missing Data. In this study, missingness of patient- and neighborhood-level factors was less than 5%, except for marital status and neighborhood % Black composition which had a missingness of ~8% and 13%, respectively. Based on a Chi-square test, there was strong evidence suggesting that missingness for each PEN factor was not associated with receipt of surveillance colonoscopy across racial/ethnic categories ($p>.05$) (data not shown). Sensitivity analyses were conducted to assess how missing data for these two factors affected inferences about receipt of surveillance colonoscopy by racial/ethnic groups. We concluded that the missing data was not biasing the analyses as estimates from the complete case data and the sensitivity analysis were identified to be similar [79].

Results

Characteristics of the study population

The final study cohort included 6,602 Medicare beneficiaries diagnosed with stage II or III CRC between 2010 and 2013. The cohort had a mean age of 75 years and was predominantly NHW (86.0%), female (54.4%), married (56.3%), and not covered by Medicaid (82.3%; Table 1.2). Clinically, 41.8% of the patients were stage II, 15.6% were high-risk stage II, and 42.6% were stage III. Approximately 35% received adjuvant chemotherapy within 120 days after surgical resection and 63% of the beneficiaries had at least one comorbid condition at time of diagnosis. Many of the CRC patients lived in neighborhoods characterized by a low minority composition and less than a high school education, and with median household incomes between $30K to $50K.

Significant differences across racial/ethnic groups were observed for all patient- and neighborhood-level PEN factors (Table 1.2). NHW and Hispanic beneficiaries had a larger proportion of married patients compared to Blacks (58.0% and 57.0% vs 37.7%). Compared to NHWs, racial/ethnic minorities were more likely to be covered by Medicaid, with at least two comorbid conditions and have residence in neighborhoods characterized by a higher percent minority composition and lower household income ($0 to $30K). Hispanic patients were more likely to receive radiation therapy as part of adjuvant treatment in addition to surgical resection and resided in neighborhoods characterized by a higher proportion of the population with less than high school education compared to NHWs and Blacks. Blacks were more likely to live in the southern United States whereas Hispanics were more likely to live in the West.

Receipt of surveillance colonoscopy

Overall, 57.5% of the CRC patients had received a surveillance colonoscopy within 18-months post-surgical resection. The proportion of Blacks who received surveillance colonoscopy was lower compared to NHWs and Hispanics (47.3% vs 58.9% and 52.4%, respectively; $p < .001$). In the unadjusted model, both Blacks and Hispanics had significantly lower odds of receipt of surveillance colonoscopy compared to NHWs (Figure 2.3). The difference in odds between minority patients and NHW patients decreased as PEN factors were added, but only the difference between Blacks and NHWs remained significant after addition of the patient-level enabling factor (Blacks: OR = .696, 95% Confidence Interval (CI) = 0.57 to 0.85, $p < .001$; Hispanics: OR = 0.843, 95% CI = 0.68 to 1.12, $p > 0.05$). After adjusting for all patient- and neighborhood-level PEN factors, Blacks had 29.6% lower odds of receiving surveillance colonoscopy compared to NHWs ($p = .002$). Hispanics had 12.9% lower odds of receiving surveillance colonoscopy compared to NHWs, however, this difference was not statistically significant ($p > .05$).

Factors associated with surveillance colonoscopy

In bivariate analyses, younger age, married status, and receipt of chemotherapy were independently associated with higher odds of receipt of surveillance colonoscopy across all racial/ethnic groups (Table 1.3). Factors that varied by racial/ethnic categories included having Medicaid coverage and the presence of comorbidities, which were independently associated with lower odds of receipt of

surveillance colonoscopy among NHWs and Blacks. Among NHWs, neighborhood median household income (MHI) of $90K+ and urbanization (e.g., residing in an urban neighborhood) were independently associated with higher odds of receipt of surveillance colonoscopy (Table 1.3).

Predisposing Factors. Multivariate analyses indicate that increased age is associated with a slight decrease in the odds of receiving surveillance colonoscopy among NHWs, but not among Blacks or Hispanics (Table 1.4). NHW colorectal cancer patients who are single had significantly lower odds of receipt of surveillance colonoscopy compared to NHW patients whose marital status was 'married' or 'other'. Among NHWs and Blacks, females had higher odds of surveillance colonoscopy compared to males from similar racial/ethnic backgrounds. Among Hispanics, females had 17% lower odds of receiving surveillance colonoscopy compared to Hispanic males. However, only the differences across gender were statistically significant for NHWs. Neighborhood predisposing characteristics were not significantly associated with receipt of surveillance colonoscopy across all three racial/ethnic groups.

Enabling Factors. Among NHWs, those with dual Medicare-Medicaid coverage demonstrated significantly lower odds (35%) of receipt of surveillance colonoscopy compared to NHWs without dual coverage. Although not significant, Black and Hispanic CRC patients with dual coverage had higher odds (13% and 49%, respectively) of receipt of surveillance colonoscopy, compared to Blacks and Hispanics without dual coverage. Differences in receipt of surveillance colonoscopy by level of neighborhood enabling factors among all three racial/ethnic groups were not statistically significant except for Hispanics and MHI (Table 1.4). Hispanics residing in neighborhoods with MHIs of $90K+ had 69% lower odds of receipt of surveillance colonoscopy compared to Hispanics residing in neighborhoods with MHI between $0 - $30K ($p = 0.47$).

Need Factors. NHW and Black patients with high-risk stage II and stage III had lower odds of receipt of surveillance colonoscopy compared to NHW and Black patients, respectively, with stage II, but only the difference between stage III and stage II NHW patients was statistically significant (OR = 0.78, 95% CI = 0.67 to 0.90, $p = 0.001$). The reverse association was observed among Hispanics, but this association was not statistically significant. NHWs who received only chemotherapy as part of their adjuvant treatment had 92% higher odds of receipt of surveillance colonoscopy compared to NHWs who did not receive any chemotherapy or radiation, while those who received only radiation therapy had 36%

lower odds of receipt of surveillance colonoscopy. The odds of receiving surveillance colonoscopy significantly decreased with increased number of comorbidities among NHWs. The opposite was observed among Blacks, but this increase was not significant. There were no statistically significant differences in receipt of surveillance colonoscopy by level of adjuvant treatment and comorbidity among Hispanics.

Neighborhood variation in receipt of surveillance colonoscopy

Patients were distributed across 3,322 neighborhoods. The average number of patients per neighborhood was 2 with a range of 1 to 54 patients. There were no statistically significant differences in receipt of surveillance colonoscopy between neighborhoods with only one patient and neighborhoods with 2+ patients ($p>.05$). Less than .0001% of the variability in receipt of surveillance colonoscopy was explained by between-neighborhood differences. A likelihood ratio test confirmed that random-effect models did not offer a significant improvement over a logistic regression model with only fixed effects ($p>.05$).

Discussion

Colonoscopy is a key guideline-recommended component of CRC surveillance and enables the early detection of local cancer recurrence and synchronous/metachronous CRC lesions. We found that only about 58% of eligible patients in our cohort received initial colonoscopy within 18-months following surgery. Blacks have lower receipt of surveillance colonoscopy than NHWs after adjusting for patient and neighborhood-level PEN factors. Given the benefits of surveillance colonoscopy in improving early detection of local recurrence, disparity in receipt of surveillance colonoscopy may contribute to poorer CRC survival among Black CRC patients [18, 66, 80-82]. Although other studies have found that Hispanics are less likely to receive surveillance colonoscopy, we found no statistically significant difference in receipt of surveillance colonoscopy between Hispanics and NHWs. However, other studies included a larger sample of Hispanic CRC patients which may contribute to their observed significance (n= 1,064 vs n= 376) [83].

Predisposing factors

Patient predisposing factors influenced receipt of surveillance colonoscopy in NHWs, but not among Blacks and Hispanics. Among NHWs, receipt of surveillance colonoscopy was lower among

those who are older, male and single. The protective factor of being married on cancer outcomes has been previously established [66, 84]. Previous studies have shown that among older adult CRC patients, married status is significantly associated with higher survival among Whites and Hispanics compared to other racial/ethnic groups [84-86]. Among NHW patients, having a spouse or significant other may play an important role in receiving CRC follow-up care by facilitating transportation to health care facilities, thus, increasing the likelihood that a patient may keep medical appointments with primary care physicians and specialists, as well as provide social support and higher psychological well-being [34, 73, 84, 87]. This protective factor was not detected among Black and Hispanic CRC patients. Among minority populations, psychological mechanisms related to marital satisfaction (e.g., low marital quality and negative spousal behaviors) may be playing a role in the observed pattern. In addition, some studies have identified differential effects of marriage on health outcomes by gender, geographical and cultural factors, which may be more pronounced among minority CRC patients [66, 84].

Enabling factors

Insurance status also influenced receipt of surveillance colonoscopy differentially in NHWs compared to Blacks and Hispanics. The odds of receipt of surveillance colonoscopy was 35% lower among NHWs patients who were dual Medicare-Medicaid covered compared to NHWs without dual coverage. Medicaid coverage is a potential measure of socioeconomic position since those who are Medicare enrollees are low income or live in poverty [88 2016]. Research suggests that individuals who are uninsured, underinsured, or have public insurance (e.g., Medicare and/or Medicaid) are less likely to receive early detection CRC screening, and receive incomplete evaluation of symptoms, thus, placing them at higher risk of poorer health outcomes compared to patients with private insurance [89-93].

Conversely, as an important health insurance supplement for low income individuals, Medicaid coverage provides additional access to cancer care for many low-income patients with chronic conditions and mitigates the effects of social determinants on receipt of CRC cancer care across racial/ethnic groups [94]. We found a higher proportion of Blacks and Hispanics who had dual Medicare-Medicaid coverage compared to the proportion of NHWs (39.5% and 47.3%, respectively vs 17.7%). Although not significant, Black and Hispanic patients with dual coverage were more likely to receive surveillance colonoscopy compared to their racial/ethnic counterparts without dual coverage. The potential beneficial

effects of Medicare-Medicaid dual coverage are primarily facilitated through increasing access to care by providing financial coverage for health care services that enable the detection of cancer, including recurrence, at earlier stages [95]. Medicaid coverage is a patient-level enabling factor; these results suggest potential inequitable access to surveillance colonoscopy across and within racial/ethnic groups.

Need factors

Similar to other studies, NHWs diagnosed with stage II vs stage III, with no comorbidities and who received chemotherapy had significantly higher odds of receipt of surveillance colonoscopy. Differences by stage, type of adjuvant treatment, and number of comorbidities did not significantly vary among Blacks and Hispanics.

Neighborhood-level factors

Other studies have found that, in addition to clinical factors such as stage at diagnosis, neighborhood SES-related factors contribute to racial/ethnic disparities in receipt of postoperative care and survival, suggesting that neighborhood social determinants, support mechanisms and access to cancer care are significant factors [66, 83]. A key finding was that Hispanics residing in neighborhoods with median household incomes (MHI) of $90K+ had significantly lower odds of receipt of surveillance colonoscopy compared to Hispanics residing in neighborhoods with MHI of $0 to $30K. This highlights the complex interrelationship between race/ethnicity, neighborhood socioeconomic status (SES) and receipt of CRC care. MHI, a useful proxy measure for patient SES and social milieu, influences utilization of CRC-related health services through psychosocial mechanisms such as social norms, collective efficacy and social control [71, 96]. Our findings suggest that being Hispanic may amplify exposure to unequal social conditions that may perpetuate disparities in access to surveillance colonoscopy. It is also likely that older adult Hispanics residing in low income neighborhoods may benefit from greater access to health care safety net resources for low income and underserved populations [97-99]. In these neighborhoods, federal programs (e.g., Medicare and Medicaid) also tend to have higher reimbursement rates for health care services consequently increasing access to cancer care [53, 97-99]. Understanding these racial/ethnic patterns in neighborhood socioeconomic factors may assist us in better understanding the role of enabling factors in improving cancer outcomes among older adult minority populations.

Our study also found a lack of variation in receipt of surveillance colonoscopy between-neighborhoods indicating that neighborhoods, as defined by census tracts boundaries, do not appear to capture relevant context for understanding a patient's tendency to receiving their first surveillance colonoscopy within the recommended guidelines. It is unlikely that a lack of between neighborhood variation is driven by the small size of approximately 50% of the neighborhoods.

Limitations. This study has several limitations. Non-statistically significant differences in receipt of surveillance colonoscopy by levels of PEN factors across Blacks and Hispanics may be due to the small sample sizes of these two racial/ethnic groups. Future studies should include more years and a larger sample of minority patients to assess potential racial/ethnic disparities in CRC surveillance over time. Conversely, statistically significant but small differences between groups may not be meaningful. Also, we were unable to adjust for individual-level income, which likely confounds the relationship between race/ethnicity and receipt of surveillance colonoscopy. Further, it is difficult to differentiate between colonoscopies received as part of surveillance from diagnostic testing using claims data. However, among CRC survivors, 95% of the colonoscopies received within 36-months from surgery are for routine surveillance and not for diagnostic reasons [10]. Other factors, such as surgical complications, may potentially affect receipt of surveillance colonoscopy but such information is not available in the SEER-Medicare database. To minimize misclassification of receipt of surveillance colonoscopy we excluded colonoscopies received within 6 months after index surgery. The SEER-Medicare data does not include claims data for beneficiaries enrolled in HMOs, care received in other healthcare systems outside Medicare (i.e., Veterans Affairs Administration), or coverage provided by Medigap or Medicare Advantage. The results from this study are therefore limited to data from individuals with fee-for-service Medicare parts A and B, potentially leading to an underestimation of receipt of surveillance colonoscopy.

Despite these limitations, the SEER-Medicare database is a rich population-based database that contains information about a patient's characteristics and provides researchers with a unique opportunity to assess cancer care utilization and outcomes by racial/ethnic group. The estimates of receipt of surveillance colonoscopy and the associated factors among Medicare patients stratified by racial/ethnic groups provides valuable information for improving cancer surveillance among an older adult population who may be at high risk of death. This is timely information for the guidance of clinical practice among

older CRC survivors residing in underserved areas. Further, unlike screening for the early detection of CRC, assessing the association between patient- and neighborhood-level factors and receipt of surveillance colonoscopy highlights the lack of significant impact that neighborhood characteristics (at the census tract-level) and variability has. However, using census tracts as the unit measure of neighborhood attributes is only one way to consider neighborhood effects and fails to account for racial/ethnic cultural beliefs and perceptions about cancer care that may influence receipt of surveillance procedures. Further research should examine the effects of better measures of social determinants of health that embody neighborhood socioeconomic status, such as an area deprivation index, on receipt of surveillance procedures [100]. Other factors such as patient preferences for specific surveillance procedures, physician perceptions, as well as the cancer care coordination across health systems for older adults may play a significant role in whether Medicare CRC patients receive surveillance colonoscopy at the recommended times and should be examined further.

Tables and Figures

Table 1.1 Key PEN factors by level and dimension	
Patient-level	
Predisposing	Age Gender Marital status
Enabling	Medicare-Medicaid dual coverage
Need	Comorbidity Tumor stage Adjuvant Treatment
Neighborhood-level (Census Tract)	
Predisposing	% Hispanic composition % Black composition % Less than HS education
Enabling	Median household income Urbanization Geographic region (SEER registry)

Table 1.2 Descriptive Statistics by Race/Ethnicity									
	Overall Cohort (N = 6,602)		NHW (N = 5,678)		Black (N = 527)		Hispanic (N = 376)		p-value
	N	(%)	N	(%)	N	(%)	N	(%)	
Patient-level									
Predisposing									
Age (Mean)	75.0		75.2		73.6		74.4		
Gender									.001
Male	3,013	45.6%	2,604	45.6%	213	40.1%	200	52.9%	
Female	3,589	54.4%	3,101	54.4%	318	59.9%	178	47.1%	
Marital status									<.001
Single	648	10.3%	494	9.1%	106	21.8%	42	11.6%	
Married	3,540	56.3%	3,143	58.0%	183	37.7%	207	57.0%	
Other	2,102	33.4%	1,784	32.9%	197	40.5%	114	31.4%	
Enabling									
Medicaid coverage									<.001
None	5,434	82.3%	4,902	86.3%	319	60.5%	198	52.7%	
Any	1,169	17.7%	776	13.7%	208	39.5%	178	47.3%	
Need									
Stage									.009
II	2,759	41.8%	2,377	41.9%	220	41.8%	152	40.4%	
High-risk II	1,031	15.6%	918	16.2%	64	12.1%	44	11.7%	
III	2,812	42.6%	2,383	42.0%	243	46.1%	180	47.9%	
Adjuvant treatment									.006
None	4,287	65.0%	3,716	65.6%	336	63.8%	218	58.0%	
Chemotherapy	1,920	29.1%	1,636	28.8%	161	30.5%	120	31.9%	

Radiation	217	3.3%	175	3.1%	17	3.2%	24	6.4%	
Chemo + Rad	178	2.7%	151	2.7%	13	2.5%	14	3.7%	
Comorbidity									<.001
0	2,462	37.3%	2,171	38.2%	163	30.9%	122	32.4%	
1	1,807	27.4%	1,571	27.7%	125	23.7%	107	28.5%	
2	1,009	15.3%	848	14.9%	94	17.8%	60	16.0%	
3+	1,324	20.1%	1,088	19.2%	145	27.5%	87	23.1%	
Neighborhood-level (Census Tract)									
Predisposing									
% Black Composition									<.001
Lowest Quartile	5,043	87.9%	4,394	89.2%	345	74.7%	293	87.5%	
2nd Quartile	310	5.4%	256	5.2%	34	7.4%	19	5.7%	
3rd Quartile	171	3.0%	132	2.7%	25	5.4%	11	3.3%	
Highest Quartile	215	3.8%	144	2.9%	58	12.6%	12	3.6%	
% Hispanic Composition									<.001
Lowest Quartile	5,532	85.9%	4,834	87.2%	423	83.1%	257	70.2%	
2nd Quartile	529	8.2%	434	7.8%	49	9.6%	45	12.3%	
3rd Quartile	216	3.4%	161	2.9%	22	4.3%	33	9.0%	
Highest Quartile	160	2.5%	114	2.1%	15	3.0%	31	8.5%	
% < HS education									<.001
Lowest Quartile	5,897	89.8%	5,124	90.7%	455	86.7%	300	80.9%	
2nd Quartile	597	9.1%	473	8.4%	65	12.4%	56	15.1%	
3rd Quartile	71	1.1%	51	<1.0%	--	<1.0%	15	4.0%	
Enabling									
Median Household Income									<.001
0 – 30k	462	7.0%	354	6.3%	71	13.5%	35	9.4%	
30k – 60k	3,529	53.6%	3,040	53.7%	286	54.4%	192	51.5%	
60k – 90k	1,794	27.3%	1,556	27.5%	121	23.0%	110	29.5%	
90k+	798	12.1%	713	12.6%	48	9.1%	36	9.7%	
Urbanization									<.001
Metro	5,241	79.4%	4,431	78.0%	451	85.6%	341	90.7%	
Urban	1,178	17.4%	1,076	19.0%	67	12.7%	32	8.5%	
Rural	183	2.8%	171	3.0%	--	--	--	--	
Geographic region									<.001
Northeast	380	5.8%	338	6.0%	24	4.6%	14	3.7%	
Midwest	952	14.4%	873	15.4%	70	13.2%	--	--	
South	3,082	46.7%	2,601	45.8%	350	66.4%	124	33.0%	
West	2,188	33.1%	1,866	32.9%	83	15.8%	231	61.4%	

-- # of patients is less than 10

Table 1.3 Independent association between patient- and neighborhood-level factors and receipt of surveillance colonoscopy by race/ethnicity

	Adherent		NHW		Black		Hispanic	
	n	%	OR	95% CI	OR	95% CI	OR	95% CI
Patient-level								
Predisposing								
Age			**0.94**	**0.93–0.95**	**0.96**	**0.93–0.99**	**0.95**	**0.91–0.99**
Gender								
Male	1,724	45.4%	Ref.	–	Ref.	–	Ref.	–
Female	2,073	54.6%	1.00	0.90–1.11	1.21	0.86–1.73	1.10	0.73–1.65
Marital status								
Single	277	7.6%	Ref.	–	Ref.	–	Ref.	–
Married	2,262	62.4%	**2.22**	**1.83–2.69**	**2.39**	**1.46–3.94**	**2.15**	**1.09–4.24**
Other	1,088	30.0%	**1.38**	**1.13–1.69**	**1.64**	**1.00–2.67**	1.07	0.52–2.20
Enabling								
Medicaid coverage								
None	3,282	86.4%	Ref.	–	Ref.	–	Ref.	–
Any	515	13.6%	**.51**	**.44–.60**	**.55**	**.39–.79**	.83	.56–1.25
Need								
Stage								
II	1,564	41.2%	Ref.	–	Ref.	–	Ref.	–
High-risk II	576	15.2%	0.98	0.84–1.14	0.65	0.37–1.16	1.11	0.57–2.18
III	1,657	43.6%	1.09	0.97–1.22	1.07	0.74–1.54	1.49	0.96–2.30
Adjuvant treatment								
None	2,257	59.4%	Ref.	–	Ref.	–	Ref.	–
Chemotherapy	1,337	35.2%	**2.02**	**1.78–2.29**	**2.12**	**1.45–3.11**	**3.20**	**1.99–5.16**
Radiation	93	2.5%	**0.66**	**0.49–0.90**	0.76	0.28–2.11	0.94	0.40–2.22
Chemo + Rad	110	2.9%	**1.47**	**1.05–2.07**	1.21	0.39–3.65	1.76	0.59–5.25
Comorbidity								
0	1,565	41.2%	**Ref.**	**–**	Ref.	–	Ref.	–
1	1,085	28.6%	**0.85**	**0.75–0.98**	0.85	0.54–1.36	1.04	0.62–1.76
2	544	14.3%	**0.63**	**0.53–0.74**	0.97	0.59–1.62	1.27	0.68–2.39
3+	603	15.9%	**0.48**	**0.42–0.56**	**0.52**	**0.33–0.81**	0.60	0.34–1.04
Neighborhood-level								
Predisposing								
% Black Composition								
Lowest Quartile	2,893	88.1%	Ref.	–	Ref.	–	Ref.	–
2nd Quartile	175	5.3%	0.96	0.75–1.24	0.77	0.38–1.59	1.75	0.67–4.58
3rd Quartile	100	3.1%	1.15	0.81–1.65	1.02	0.46–2.30	0.85	0.25–2.85
Highest Quartile	116	3.5%	0.90	0.65–1.26	0.84	0.48–1.47	5.10	1.10–23.75
% Hispanic Composition								
Lowest Quartile	3,200	86.4%	Ref.	–	Ref.	–	Ref.	–
2nd Quartile	301	8.1%	0.97	0.79–1.18	1.09	0.60–1.97	0.99	0.52–1.86
3rd Quartile	116	3.1%	0.81	0.59–1.12	1.99	0.82–4.84	0.72	0.35–1.49
Highest Quartile	89	2.4%	0.95	0.65–1.39	1.30	0.46–3.65	0.81	0.38–1.71
% < HS education								

Lowest Quartile	3,409	90.2%	Ref.	–	Ref.	–	Ref.	–
2nd Quartile	334	8.8%	0.86	0.71–1.03	1.64	0.97–2.78	1.31	0.73–2.33
3rd Quartile	35	<1%	0.84	0.48–1.46	0.29	0.03–2.64	0.61	0.21–1.75
Enabling								
Median Household Income								
0 – 30k	243	6.4%	Ref.	–	Ref.	–	Ref.	–
30k – 60k	2,061	54.4%	1.24	0.99–1.55	1.53	0.90–2.60	0.78	0.37–1.63
60k – 90k	1,001	26.4%	1.15	0.91–1.45	1.21	0.67–2.19	0.49	0.23–1.08
90k+	483	12.8%	**1.44**	**1.11–1.87**	0.87	0.41–1.84	0.47	0.18–1.22
Urbanization								
Metropolitan	2,956	77.9%	Ref.	–	Ref.	–	Ref.	–
Urban	729	19.2%	**1.23**	**1.07–1.41**	1.26	0.75–2.10	0.91	0.44–1.87
Rural	112	3.0%	1.19	0.87–1.63	0.92	0.24–3.47	1.81	0.16–20.2
Geographic region								
Northeast	213	5.6%	Ref.	–	Ref.	–	Ref.	–
Midwest	577	15.2%	1.21	0.94–1.57	1.11	0.43–2.89	0.56	0.09–3.53
South	1,782	46.9%	1.03	0.82–1.30	1.85	0.79–4.34	1.15	0.37–3.52
West	1,225	32.3%	1.02	0.80–1.29	0.85	0.33–2.18	0.69	0.23–2.07

Table 1.4 Association between patient- and neighborhood-level PEN factors and receipt of surveillance colonoscopy by race/ethnicity (adjusted)

	NHW		Black		Hispanic	
	OR	95% CI	OR	95% CI	OR	95% CI
Patient-level						
Predisposing						
Age	**0.96**	**0.95 – 0.97**	1.01	0.97 – 1.05	1.00	0.96 – 1.05
Gender						
Male	Ref.	–	Ref.	–	Ref.	–
Female	**1.15**	**1.02 – 1.30**	1.20	0.78 – 1.86	0.83	0.51 – 1.35
Marital status						
Single	Ref.	–	Ref.	–	Ref.	–
Married	**1.98**	**1.63 – 2.40**	1.03	0.57 – 1.87	1.07	0.49 – 2.33
Other	**1.38**	**1.13 – 1.69**	1.06	0.59 – 1.91	0.81	0.35 – 1.85
Enabling						
Medicaid coverage						
None	Ref.	–	Ref.	–	Ref.	–
Any	**0.65**	**0.55 – 0.76**	1.13	0.73 – 1.78	1.49	0.91 – 2.44
Need						
Stage						
II	Ref.	–	Ref.	–	Ref.	–
High-risk II	0.89	0.76 – 1.06	0.66	0.33 – 1.35	1.08	0.51 – 2.30
III	**0.78**	**0.67 – 0.90**	0.75	0.47 – 1.18	1.42	0.84 – 2.39
Adjuvant treatment						
None	Ref.	–	Ref.	–	Ref.	–
Chemotherapy	**1.92**	**1.64 – 2.25**	0.89	0.55 – 1.42	1.39	0.80 – 2.41
Radiation therapy	**0.64**	**0.46 –0.89**	1.52	0.48 – 4.86	1.10	0.39 – 3.07
Chemo+Radiation	1.16	0.80 – 1.70	0.59	0.15 – 2.36	1.69	0.47 – 6.11
Comorbidity						
0	Ref.	–	Ref.	–	Ref.	–
1	0.90	0.78 – 1.04	1.11	0.63 – 1.96	1.03	0.56 – 1.91
2	**0.76**	**0.64 – 0.90**	1.26	0.67 – 2.37	2.07	1.00 – 4.30
3+	**0.62**	**0.53 – 0.73**	1.29	0.73 – 2.28	1.48	0.77 – 2.85
Neighborhood-level						
Predisposing						
% Black Composition						
Lowest Quartile	Ref.	–	Ref.	–	Ref.	–
2nd Quartile	0.97	0.75 – 1.27	0.78	0.33 – 1.82	2.04	0.67 – 6.19
3rd Quartile	1.23	0.85 – 1.78	1.01	0.36 – 2.81	0.87	0.22 – 3.42
Highest Quartile	1.23	0.85 – 1.77	0.69	0.32 – 1.49	3.05	0.57 – 16.14
% Hispanic Composition						
Lowest Quartile	Ref.	–	Ref.	–	Ref.	–
2nd Quartile	1.03	0.84 – 1.27	1.18	0.59 – 2.37	0.76	0.37 – 1.58
3rd Quartile	0.95	0.67 – 1.36	3.01	1.03 – 8.78	0.85	0.36 – 2.03
Highest Quartile	1.04	0.64 – 1.69	1.97	0.52 – 7.53	1.02	0.39 – 2.63
% < HS education						
Lowest Quartile	Ref.	–	Ref.	–	Ref.	–
2nd Quartile	1.02	0.79 – 1.31	1.57	0.83 – 2.97	1.93	0.97 – 3.83

3rd Quartile	1.15	0.58 – 2.28	0.95	0.97 – 11.48	0.98	0.23 – 4.13
Enabling						
Median Household Income						
0 – 30k	Ref.	–	Ref.	–	Ref.	–
30k – 60k	1.20	0.93 – 1.56	1.53	0.77 – 3.03	0.63	0.25 – 1.60
60k – 90k	1.07	0.81 – 1.42	1.54	0.72 – 3.30	0.44	0.17 – 1.17
90k+	1.28	0.94 – 1.75	0.97	0.39 – 2.42	**0.31**	**0.10 – 0.99**
Urbanization						
Metropolitan	Ref.	–	Ref.	–	Ref.	–
Urban	1.15	0.97 – 1.36	0.71	0.37 – 1.38	1.47	0.62 – 3.47
Rural	1.07	0.74 – 1.55	0.83	0.19 – 3.58	--	--
Geographic region						
Northeast	Ref.	–	Ref.	–	Ref.	–
Midwest	1.05	0.80 – 1.40	0.70	0.23 – 2.12	0.71	0.09 – 5.51
South	0.96	0.75 – 1.23	1.23	0.47 – 3.19	1.39	0.39 – 4.96
West	0.97	0.76 – 1.25	0.65	0.23 – 1.87	0.73	0.21 – 2.52

Figure 2.1 Study diagram for cohort selection

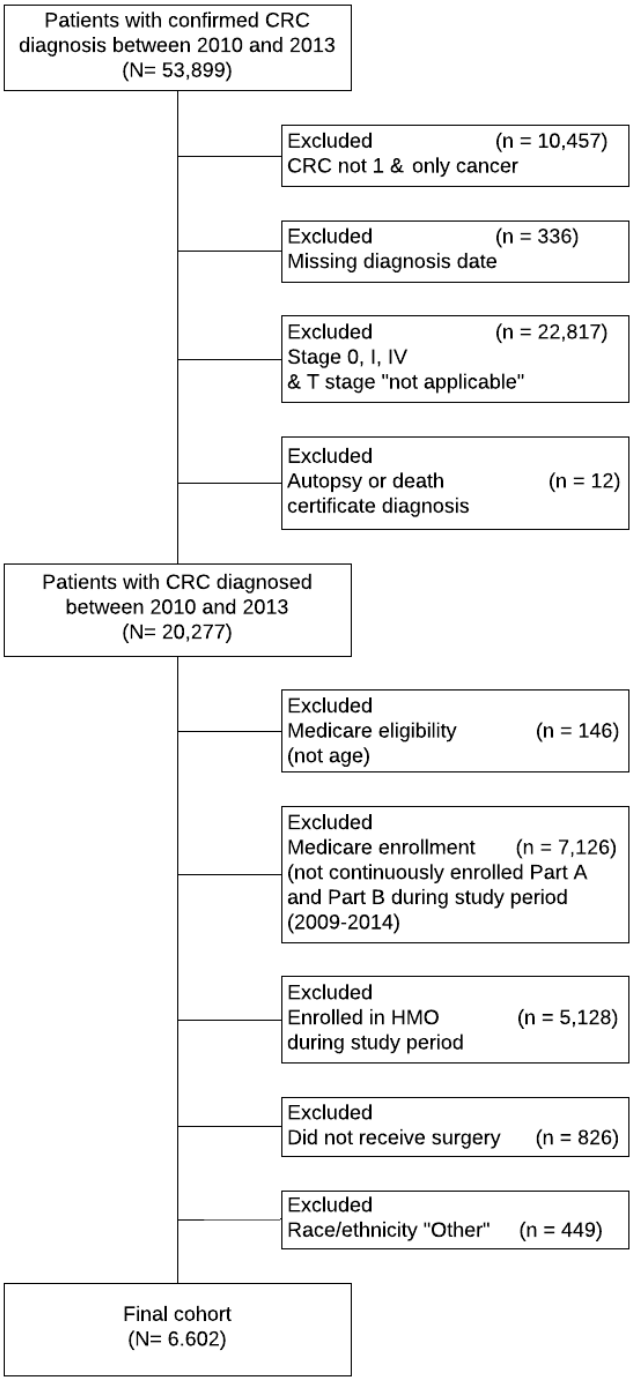


Figure 2.2 Period of observation used for identifying surveillance colonoscopy

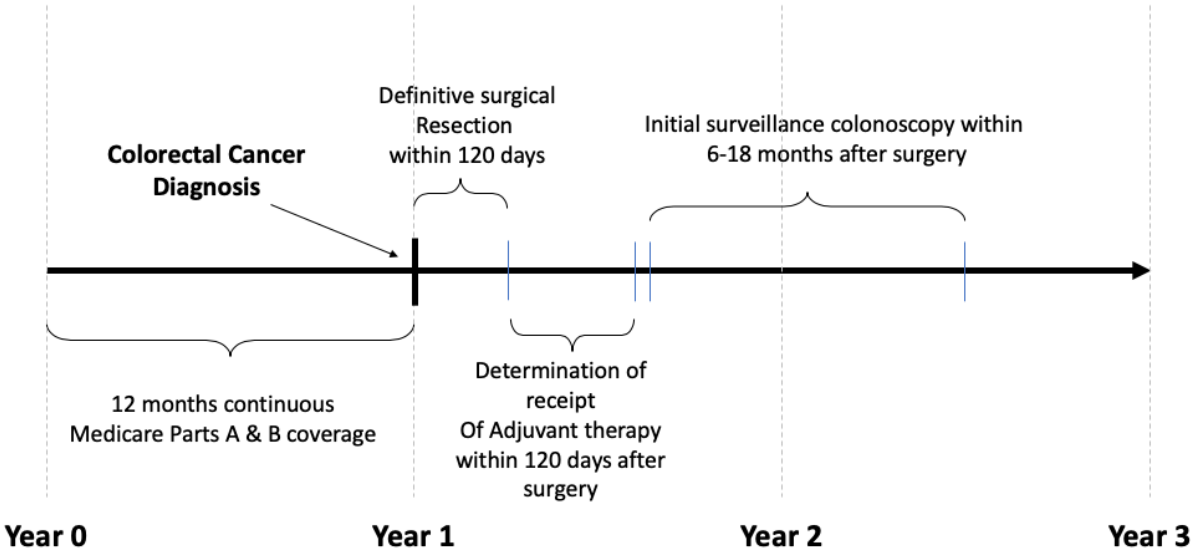
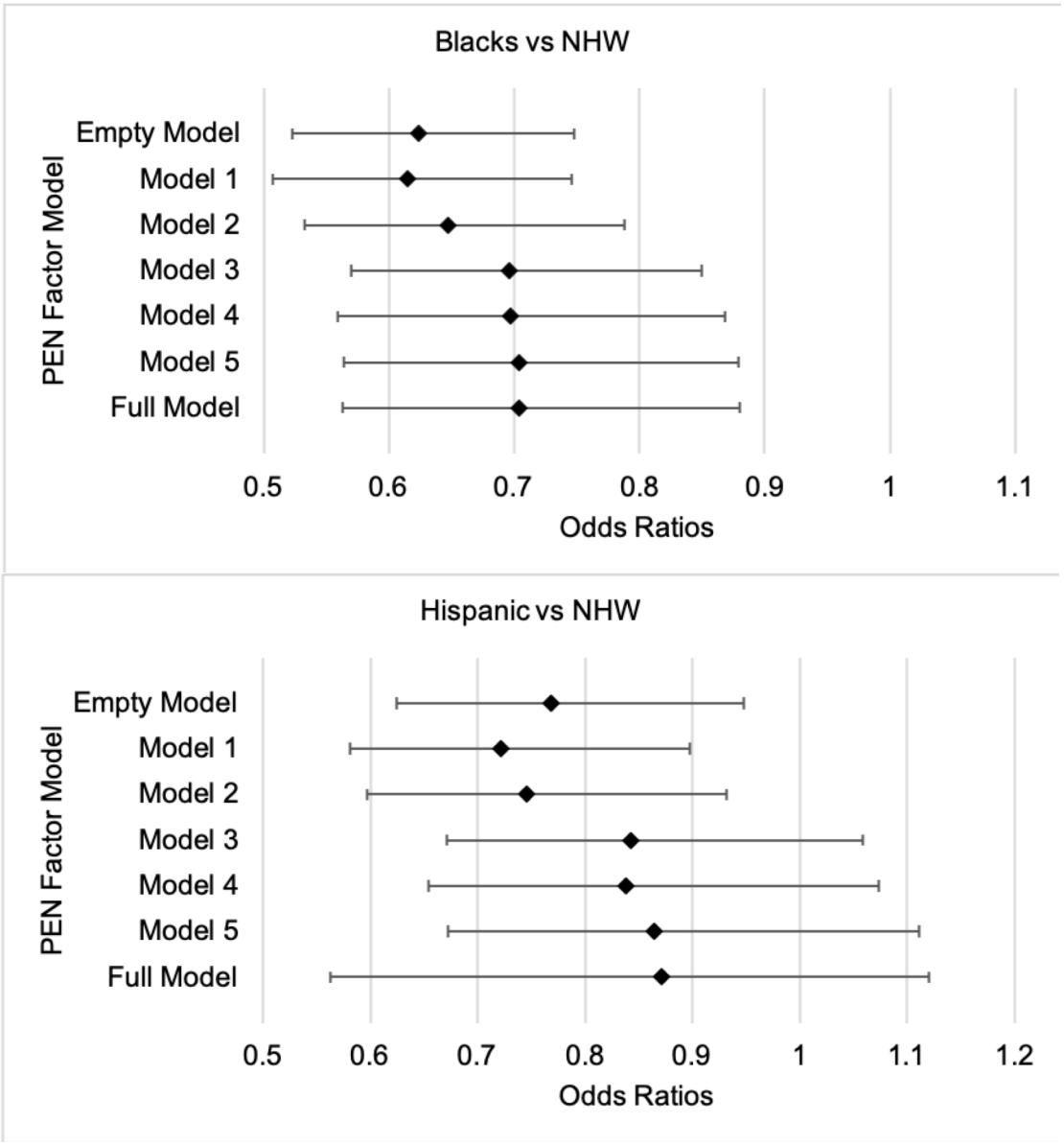


Figure 2.3 Receipt of surveillance colonoscopy by race ethnicity



* NHW odds ratio is 1

CHAPTER 3. Patient and neighborhood factors associated with receipt of surveillance CEA tests and CT scans among Medicare beneficiaries with surgically resected colorectal cancer

Introduction

Surgical resection continues to be a main treatment procedure for individuals diagnosed with stage I-III colorectal cancer (CRC) [1, 15]. Up to 40% to 50% of early stage CRC patients, however, will experience cancer recurrence within 3 years of surgery, with most metastatic recurrent disease occurring in the liver and lungs [4, 26, 27, 101, 102]. Effective cancer treatments for metastatic recurrence over the last decades have improved survival and today approximately 40% of CRC patients who receive liver and lung resections survive 5 years [28, 102-104]. However, treatments for metastatic recurrence are most effective when these are detected early in the asymptomatic phase through surveillance testing with carcinoembryonic antigen (CEA) levels and computer tomography (CT) imaging. [28].

The American Society of Clinical Oncology (ASCO) and the National Comprehensive Cancer Network (NCCN) recommend a minimum of one CEA test every 6-months for five years and, as of 2005, a yearly CT scan for 3 years following surgical resection for patients diagnosed with CRC stages II and III [4, 26, 27]. The FACS trial found that CEA tests alone or in combination with CT scans increases the proportion of CRC patients who can receive definitive treatment for recurrence, with two-thirds of recurrences in the study being detected with scheduled CEA tests and CT scans [4, 28]. Receipt of surveillance CEA test and CT scans before symptoms arise may help identify patients with distant recurrence who could be amenable to potentially curative metastatectomy [28, 63].

Receipt of surveillance CEA tests and CT scans have increased since 2000, but despite the clinical advantages, underutilization continues to be a challenge and many patients fail to meet the minimum recommended national guidelines [34-36]. Less than 75% and 60% of CRC patients receive at least one CEA test and one CT scan, respectively, within 12 to 18 months after surgical resection for primary CRC [34-36]. Racial/ethnic disparities in receipt of surveillance CEA tests also exist, such that the proportion of Black CRC patients who receive CEA testing is approximately 5% lower compared to non-Hispanic Whites (NHWs) [6, 20-22, 34]. Much less research has assessed racial/ethnic differences in receipt of CT scans, however, Hu et al (2011) found that the proportion of patients who receive CT scans at recommended intervals was lower among Blacks compared to NHWs (7.8% vs 9.2%,

respectively) [34, 35]. Identifying the factors that contribute to lower receipt of the recommended surveillance CEA tests and CT scans among minorities can assist researchers in developing targeted interventions to promote surveillance procedures for the early detection of metastatic recurrence and improve CRC-related outcomes.

The limited research suggests that patient-level factors may be associated with lower receipt of these surveillance procedures, such as older age, advanced cancer stage and having one or no comorbidities [35, 36]. However, the association between other patient- and contextual-level (e.g., neighborhood) factors and receipt of surveillance CEA tests and CT scans across racial/ethnic groups is understudied [6, 7, 37]. Among CRC patients, the racial/ethnic disparities in receipt of cancer care persist after adjusting for certain patient demographic (e.g., age and gender) and clinical factors [69]. The effect of patient socioeconomic status on receipt of CRC surveillance appear to be important as these factors contribute to disparities in receipt of other CRC-related care (i.e., screening and treatment, surveillance colonoscopy) [38, 105-107]. Older adult CRC patients who are low-income or either uninsured or underinsured, and less likely to receive the appropriate cancer care after surgical resection [38]. At the neighborhood-level, socioeconomic environment, such as residing in neighborhoods with low median household income, influences economic hardship and may act as a barrier to access of cancer care [38, 73, 85]. As key determinants of health, patient- and neighborhood-level socioeconomic factors may play a critical role in access to and receipt of surveillance CEA tests and CT scans among older adult CRC patients and should be further examined across racial/ethnic groups [5, 70, 73, 94].

To address these gaps in the literature, this study uses Andersen's Behavioral Model of Health Services Use to assess patient- and neighborhood-level factors associated with receipt of the minimum recommended surveillance CEA tests and CT scan [53, 56]. Andersen's model states that health services utilization is influenced by three types of factors called PEN factors and include: 1) Predisposing characteristics, socio-cultural factors that exist before the presence of disease (e.g., age, race, gender) and predispose patients to seeking and using health care services, 2) Enabling factors, socioeconomic resources that facilitate or hinder access to care (e.g., health insurance, income, geographic resources), and 3) Need factors such as health status and health conditions (e.g., staging, comorbidities, receipt of adjuvant treatment) that influence utilization of healthcare services [51 2007, 53]. Although receipt of

CRC surveillance procedures is primarily motivated by a patient's characteristics (predisposing factors) and need for surveillance, enabling patient- and neighborhood-level factors may contribute to potential inequitable access to surveillance CEA tests and CT scans [51, 53, 56, 108]. Inequitable access to receipt of surveillance procedures occurs when patients lacking access-enabling resources, such as being uninsured or underinsured, and being financially disadvantaged (e.g., being low income or residing in neighborhoods with lower median household incomes) have lower receipt of cancer care [51, 53, 56, 108]. Based on Andersen's model, improved access to surveillance procedures leads to greater utilization of these services, which in turn leads to better CRC-related outcomes [51].

Efforts focused on improving receipt of CRC surveillance procedures among minority populations must account for the patient- and neighborhood-level factors that influence receipt of cancer care, including neighborhood context. We use population-based data to assess the association between PEN factors and receipt of the minimum recommended surveillance CEA test and CT scan. This study also measures the between-neighborhood variation in receipt of these surveillance procedures to better understand how neighborhood social context impacts CRC surveillance. Findings from this study may help inform future clinical practice guidelines and assist in the development of interventions for promoting CRC surveillance.

Methods

Data source and study population. This retrospective cohort study uses the linked Surveillance, Epidemiology and End Results (SEER) – Medicare data (2009 to 2014). The SEER-Medicare data is a unique source of information from two large population-based databases and provides a longitudinal perspective that enables the assessment of disparities in the utilization of cancer-related procedures [74, 109, 110].

Medicare beneficiaries between the ages of 65 and 86 diagnosed with single first CRC stage II and III adenocarcinomas were included in this study. Beneficiaries were excluded if they were not enrolled in both Medicare Part A and B 12-months prior to CRC diagnosis, or if they were enrolled in a health maintenance organization during the study period. Medicare beneficiaries were also excluded if they were diagnosed during autopsy or death certificate or if the patient died during the study period as we are unable to ascertain surveillance-related behaviors for these patients.

Outcome: Receipt of minimum recommended surveillance CEA tests and CT scans. The primary study outcomes are: 1) receipt of at least two CEA tests and 2) one CT scan within an 18-month period following CRC surgical resection (Figure 3.1). Receipt of surveillance procedures is based on total number of each procedure received over an 18-month period identified from monthly Medicare claims using ICD-9 and CPT-4 codes (Supplemental Table 1) [8, 11, 34, 35]. Surveillance procedures received up to 6-months following surgery were excluded to ensure that perioperative procedures were not included. The index surgery date is defined as surgical resection (e.g., resection, a colectomy, less than colectomy, or surgical excision with pathology specimen) for first primary CRC stages II and III received within two months prior to cancer diagnosis through six months post cancer diagnosis based on Medicare claims (Supplemental Table 1) [35, 45, 75].

Patient- and neighborhood-level factors.

***Predisposing factors*.** Patient-level predisposing factors include race/ethnicity (non-Hispanic White, Black and Hispanic), age at time of diagnosis (continuous: 65 – 85 years), gender (male or female), and marital status (not married, married, other). At the neighborhood-level, predisposing factors include the percent Black and Hispanic neighborhood composition, and educational attainment measured as the percent of the population with less than high school education [53, 76]. Neighborhood-level factors are measured at the census-tract level and categorized in quartiles.

***Enabling* factors.** Enabling factors are socioeconomic resources that serve as facilitators in seeking and receiving health care services and measure equitable access to cancer care [51]. Patient-level enabling factors include Medicaid coverage, a proxy for patient-level income, defined as being covered through a state-buy in program. The neighborhood *enabling* factors include neighborhood median household income, urbanization (metropolitan, urban and rural) and SEER registry (Northeast, Midwest, South, and West). Median household income measures socioeconomic composition of the resident population and of the neighborhoods where patients reside, while urbanization and SEER-registry are considered enabling factors that measure the relative availability of surveillance procedures in the geographical area where a patient resides (spatial access) [51, 58, 59, 73].

***Need* factors.** Patient-level need factors include CRC staging at time of diagnosis (stage II, high-risk stage II, stage III), receipt of adjuvant treatment (none, chemotherapy, radiation, chemotherapy and

radiation) within 120 days from index surgery date (based on CPT, ICD-9 and Revenue Center codes, Supplemental Table 1) [45, 77], and presence of comorbidities. We defined high-risk stage II patients as patients with high grade tumors (poorly differentiated or undifferentiated) and T4 stage. Comorbidity was measured using the Charlson comorbidity index (CCI), a summary measure of 19 medical conditions associated with increased mortality present 1-year before surgical resection [78].

Statistical Analyses

Significant differences in demographic characteristics across race/ethnic group were compared using the Chi-square test. A two-sided p-value less than 0.05 was considered statistically significant. Bivariate analyses were performed to assess the independent association between patient- and neighborhood-level PEN factors and receipt of surveillance CEA tests and CT scans. The proportion of Medicare beneficiaries who adhere to the minimum recommended CEA tests and CT scans within 18-months post-surgery by race/ethnicity are also reported.

We used multivariate logistic regression to assess the effect of patient- and neighborhood-level PEN factors and receipt of the minimum recommended surveillance CEA tests and CT scans. For each surveillance procedure, we fit an empty (unadjusted) model with only the outcome and two race/ethnicity indicators. The race/ethnicity indicators were created for Blacks and Hispanics, with NHWs as the reference category. We fit five multivariate logistic regressions by successively adding blocks of PEN factors to the empty model: patient-level predisposing factors (Model 1), patient-level need factors (Model 2), patient-level enabling factors (Model 3), neighborhood-level predisposing factors (Model 4), and neighborhood-level enabling factors (Model 5).

In the final model, we included a linear time variable to control for changes in the relationship between the year when a patient was diagnosed and receipt of CEA tests and CT scan. We assessed whether the association between receipt of minimum recommended CEA tests and CT scan and patient race/ethnicity differed between PEN factors by adding two-way interactions between race/ethnicity indicators and each PEN factor.

Secondary analyses. We fit a multilevel logistic regression with a clustered structure at the neighborhood (census tract) level to identify the variance in receipt of surveillance procedures that is explained by the clustering structure. For each surveillance procedure, we fit an empty model with only

the outcome and race/ethnicity indicators. We subsequently fit multivariate models to identify the remaining variation in receipt of surveillance procedure independent of potential PEN factors that may cluster spatially or across levels of the factor. All analyses were conducted in STATA 15.1 software (STATACorp, 2019).

Results

Patient characteristics.

A total of 6,602 Medicare beneficiaries with CRC stages II and III with surgical resection were included. Patient characteristics and levels of PEN factors differed across racial/ethnic groups (Table 2.1). Blacks had a lower proportion of patients who were married compared to NHWs and Hispanics (37.7% vs 58.0% and 57.0%, respectively). Compared to NHWs, Blacks and Hispanics were more likely to be covered by Medicaid, diagnosed with stage III vs stage II, had at least one comorbid condition, and lived in neighborhoods with a higher minority composition, higher percentage of the population with less than a high school education, and with lower median household incomes.

Receipt of surveillance CEA tests and CT scan.

Surveillance CEA tests. About 78% of patients had received at least two CEA tests within 18 months following surgical resection. The proportion of Blacks who received the CEA tests was lower compared to NHWs and Hispanics (72.5% vs 78.6% and 79.0%, respectively). The associations between race/ethnicity and receipt of CEA tests differed based on covariate adjustment (Figure 3.2). In the unadjusted model (Model 1), Blacks had significantly lower odds of receipt of surveillance CEA tests compared to NHWs (OR = 0.72, 95% Confidence Interval (CI) = 0.56 to 0.88, P = .001). After adjusting for all patient- and neighborhood level PEN factors, Blacks had 15.7% and Hispanics had 3.5% lower odds of receipt of CEA tests, however, these differences were not statistically significant.

Predisposing factors. In multivariate analyses, NHW patients who were younger, and female had significantly higher odds of receipt of CEA tests (Table 2.3). Black female patients had 11% lower odds of receipt of CEA tests compared to Black males, while female Hispanics patients had 12% higher odds compared to Hispanic males, but these differences in receipt of CEA test by gender were not significant. Among NHWs, patients who were married had 56% higher odds of receipt of CEA tests compared to NHW patients who were single ($p < .001$). Minority patients who were married had lower odds of receipt

of CEA tests compared to minority patients who were single, but these differences were not significant. Differences by level of neighborhood predisposing characteristics were not significant across all three racial/ethnic groups, except for Blacks residing in neighborhoods with the second highest percentage of Hispanic composition, whose odds of receipt of CEA tests were 57% lower compared to Blacks residing in neighborhoods with the lowest percentage of Hispanic neighborhood composition.

Enabling factors. Among NHW patients, those who were dually covered with Medicare and Medicaid had 39% lower odds of receipt of CEA tests ($p < .001$) (Table 2.3). Black patients with Medicaid coverage had almost two times the odds of receiving CEA tests compared to Black patients without dual coverage (OR = 1.99, 95% CI = 1.20 to 3.31, $p < .01$). Among Hispanics, those with Medicaid coverage had 35% higher odds of receipt of surveillance CEA tests, however, this difference was not statistically significant. Differences in receipt of CEA tests by level of neighborhood enabling factors among all three racial/ethnic groups were not statistically significant.

Need factors. Among NHW patients, those with high-risk stage II and stage III had significantly higher odds of receipt of CEA tests compared to patients with CRC stage II (Table 2.3). Minority patients diagnosed with CRC stage III had 20% lower odds of receipt of CEA tests compared to minority patients diagnosed with stage II. Receipt of chemotherapy and/or radiation was also associated with higher odds of receipt of CEA tests among NHWs and Hispanics, but only the association among NHWs was significant. NHW patients with 3 or more comorbidities had 32% lower odds of receiving CEA tests compared to NHW patients without any comorbidities. Differences in receipt of CEA tests by level of Need factors among minorities were not statistically significant except for Blacks and presence of comorbidities. Black patients with two comorbidities had 67% lower odds of receipt of CEA tests compared to Black patients with no comorbidities ($p < .01$).

Surveillance CT scan. Overall, 58.2% of the patients had received at least one CT scan as recommended, of whom 90.3% had also received CEA tests. Blacks had a lower proportion of receipt of a CT scan compared to NHWs and Hispanics (54.8% vs 58.4% and 58.8%, respectively). In the unadjusted model (Model 1), Blacks had 13.6% lower odds and Hispanics had 2% higher odds of receipt of surveillance CT scan compared to NHWs (Figure 3.3). The difference in receipt of CT scan was marginally significant between Blacks and NHWs after adding patient-level predisposing, enabling and

need factors (OR = 0.82, 95% CI = 0.67 to 0.99, P = 0.05). After adjusting for all patient- and neighborhood-level PEN factors, Blacks and Hispanics had lower odds of receipt of CT scans (18.5% and 7.5%, respectively) compared to NHWs, but these differences were not statistically significant.

Predisposing factors. For receipt of CT scans, older age was significantly associated with lower odds of receipt of a CT scan, but only among NHWs (Table 2.3). Receipt of CT scans did not vary by gender across all racial/ethnic groups. Among NHW patients, married patients had 25% higher odds of receipt of a CT scan (p =.03) compared to single patients, while Blacks and Hispanics had lower odds (21% and 29%, respectively) compared to Blacks and Hispanics who were single (both p > .05). NHW patients who resided in neighborhoods with the third highest Black composition had 49% higher odds of receipt of surveillance CT scans compared to NHWs residing in neighborhoods with the lowest Black neighborhood composition.

Enabling factors. Although Blacks with dual coverage had 44% higher odds of receipt of a CT scan compared to non-dually covered Black patients, having Medicaid coverage was not significantly associated with receipt of CT scans across all three racial/ethnic categories. At the neighborhood-level, there were no significant differences by level of median household income and urbanization across all racial/ethnic categories. Geographically, NHWs who lived in the southern and western part of the U.S. had lower odds of receipt of CT scans compared to NHW patients living in the northern U.S (OR = .74, 95% CI = .57 to .95, p = .02; OR = .66, 95% CI = .51 to .85, p = .001).

Need factors. Similar to receipt of CEA tests, advanced stage and receipt of adjuvant treatment was associated with receipt of a CT scan among NHWs. In addition, Black patients who received chemotherapy and radiation had 82% lower odds of receipt of a surveillance CT scan (p = .02).

Neighborhood variation in receipt of surveillance CEA tests and CT scans. CRC patients were distributed across 3322 neighborhoods, with neighborhoods ranging from 1 to 54 patients. Empty multilevel models showed lack of significant between-neighborhood variability in receipt of surveillance procedures, with .01% and <.001% of the variance in receipt of CEA tests and CT scans, respectively, being explained by between-neighborhood differences (both p > .05).

Discussion

The clinical benefits of postoperative surveillance with CEA tests and CT scans for the early detection of metastatic recurrence among colorectal cancer (CRC) patients have been documented [28, 101, 111]. Although previous research indicates variable rates of receipt of CEA tests and CT scans [6, 34-36, 80], our study findings indicate high rates of receipt of initial CEA tests and relatively low rates of receipt of a CT scan within 18 months following surgical resection (78.1% and 58.1%, respectively). Higher rates in receipt of CEA tests compared to CT scans may be explained by the convenience and accessibility of CEA testing, [28]. In addition, there was a lack of clear evidence of the clinical benefits of CT scans in the early 2000s. Lower rates of receipt of CT imaging may be a result of delayed implementation of the 2005 updated national recommended guidelines for CRC surveillance.

Racial/ethnic differences in receipt of other surveillance procedures have been previously established [6, 7, 37, 107]. In this study, Black and Hispanic patients did not have significantly different rates of receipt of CEA tests and CT scans compared to NHW patients after adjusting for patient- and neighborhood-level PEN factors. The initial significant difference between Blacks and NHWs disappears after addition of neighborhood factors, suggesting that this racial/ethnic effect is partially mediated by neighborhood context.

Patient characteristics (i.e., age and marital status) were significantly associated with receipt of CEA tests and CT scans among NHWs, but not among minority patients. NHW patients who were younger and married had significantly higher odds of receipt of both surveillance procedures. Among NHW patients, higher odds of receipt of procedures among those who were married demonstrates that having a spouse provides a protective effect. Research suggests that being married may provide positive financial and psychosocial support for CRC patients who need to navigate complex multidisciplinary healthcare systems [66, 84]. Although not statically significant, the opposite effect was observed among Blacks and Hispanic patients.

Medicare-Medicaid dual coverage was significantly associated with 39% lower odds of receipt of CEA tests among NHW. The opposite effect was observed among Blacks, such that Blacks with dual coverage were twice as likely to receive CEA tests compared to Black patients without dual coverage. Previous studies indicate that patients with public health insurance coverage, such as Medicare and/or Medicaid, are more likely to be of lower socioeconomic status and have poor access to cancer care which

leads to delays in initiation of cancer treatment and surveillance [38, 66, 95, 112]. Low socioeconomic status and having limited socioeconomic resources independently influence receipt of preventive care through material deprivation which leads to transportation-related barriers and psychosocial mechanisms (e.g., social norms and collective efficacy) which contribute to fragmented patient-provider interactions [38, 73, 85]. These effects may be further amplified by the financial hardship experienced by CRC patients [113-116]. Lower Medicaid reimbursement rates and inconsistent acceptance of Medicaid across health care providers and systems may also lead to lower receipt of CEA tests among NHWs with Medicaid coverage [38, 94, 112]. Although racial/ethnic minorities are more likely to have Medicaid coverage than NHWs, Medicaid provides additional health care coverage (e.g., covers the Medicare Part B and prescription drugs) for disadvantaged patients whose incomes are below the poverty level and may act as an economic enabling facilitator to access and receipt of CEA tests among minority CRC patients, especially for Black CRC patients [94, 117, 118]. These findings underscore the complex relationships between race/ethnicity, health insurance coverage, and underlying access to and receipt of cancer surveillance procedures.

Advanced stage and receipt of adjuvant therapy was significantly associated with higher odds of receipt of CEA tests and CT scans, but only among NHWs. These patients may be more likely to receive CEA tests and CT scans because national guidelines are more explicit for stage III vs stage II and a more advanced stage may warrant careful surveillance for the early detection of metastatic disease.

Neighborhood social environment, the socioeconomic composition and social traits of the neighborhood are recognized as significant socioeconomic contexts that shape individual health [73, 119]. Research suggests that certain neighborhood attributes influence receipt of cancer-related care and outcomes through health behaviors and perceptions, psychosocial mechanisms and access to resources [73, 120]. In our study, NHW patients residing in the southern and western part of the U.S. had lower odds of receipt of a CT scan. Geographical differences in receipt of a CT scan may result, in part, from differences in the number of general primary care physicians and specialists in the region where a patient lives, as well as practice patterns, especially after 2005 when CT scans where added to the national guidelines. We found that receipt of CEA tests and a CT scan does not vary between-neighborhoods. However, it is possible that census tracts as geographical boundaries of neighborhoods

may fail to capture relevant socioeconomic context (e.g., cultural and behavioral aspects) of where patients reside that influences receipt of cancer care and outcomes among CRC patients.

This study has several limitations. Significant differences within and across racial/ethnic groups are modest and/or undetectable with our sample size of Blacks and Hispanic CRC patients. Future research should include larger samples of minority CRC patients to assess trends in receipt of CEA tests and CT scans before and after updates to national CRC surveillance guidelines in 2005. Findings are limited to Medicare beneficiaries who have claims for surveillance CEA tests and CT scans. Beneficiaries may receive care outside Medicare (e.g., Veterans Affairs) and thus lead to a potential underestimation of receipt of these two surveillance procedures. Similar to other studies that utilize SEER-Medicare data, it is difficult to differentiate between diagnostic testing from asymptomatic surveillance testing, especially among older adults who experience multiple comorbid conditions. The SEER-Medicare data also excludes individual income, patient – provider preferences and communication, and clinical practice patterns [121-123]. These factors have been associated with utilization of cancer care and prevention services and may also lead to lack of observed differences in receipt of surveillance across racial/ethnic groups [36, 123, 124]. Therefore, further research is needed to assess if these factors mediate the association between race/ethnicity and receipt of surveillance CEA tests and CT scans over time among CRC patients.

Careful monitoring and periodic surveillance with CEA tests and CT scans after surgical resection is important for the early detection of metastatic recurrence among CRC patients who have undergone CRC surgical resection. In addition to demographic and clinical factors that influence receipt of surveillance procedures, this study assessed neighborhood social determinants of health that embody socioeconomic status of the communities in which Medicare beneficiaries reside. Identifying how these factors vary across racial/ethnic groups can inform future policy and surveillance guidelines for older adults.

Tables and Figures

Table 2.1 Descriptive Statistics by Race/Ethnicity									
	Overall Cohort (N = 6,602)		NHW (N = 5,678)		Black (N = 527)		Hispanic (N = 376)		p-value
	N	(%)	N	(%)	N	(%)	N	(%)	
Patient-level									
Predisposing									
Age (Mean)	75.0		75.2		73.6		74.4		
Gender									.001
Male	3,013	45.6%	2,592	45.7%	212	40.2%	299	52.9%	
Female	3,589	54.4%	3,086	54.4%	315	59.8%	177	47.1%	
Marital status									<.001
Single	648	10.3%	494	9.1%	106	21.8%	42	11.6%	
Married	3,540	56.3%	3,143	58.0%	183	37.7%	207	57.0%	
Other	2,102	33.4%	1,784	32.9%	197	40.5%	114	31.4%	
Enabling									
Medicaid coverage									<.001
None	5,434	82.3%	4,902	86.3%	319	60.5%	198	52.7%	
Any	1,168	17.7%	776	13.7%	208	39.5%	178	47.3%	
Need									
Stage									.009
II	2,759	41.8%	2,377	41.9%	220	41.8%	152	40.4%	
High-risk II	1,031	15.6%	918	16.2%	64	12.1%	44	11.7%	
III	2,812	42.6%	2,383	42.0%	243	46.1%	180	47.9%	
Adjuvant treatment									.006
None	4,287	64.9%	3,716	65.6%	336	63.8%	218	58.0%	
Chemotherapy	1,920	29.1%	1,636	28.8%	161	30.6%	120	31.9%	
Radiation	217	3.3%	175	3.1%	17	3.2%	24	6.4%	
Chemo + Rad	178	2.7%	151	2.7%	13	2.5%	14	3.7%	
Comorbidity									<.001
0	2,462	37.3%	2,171	38.2%	163	30.9%	122	32.5%	
1	1,807	27.4%	1,571	27.7%	125	23.7%	107	28.5%	
2	1,009	15.3%	848	14.9%	94	17.8%	60	16.0%	
3+	1,324	20.1%	1,088	19.2%	145	27.5%	87	23.1%	
Neighborhood-level (Census Tract)									
Predisposing									
% Black Composition									<.001
Lowest Quartile	5,043	87.9%	4,394	89.2%	345	74.7%	293	87.5%	
2nd Quartile	310	5.4%	256	5.2%	34	7.4%	19	5.7%	
3rd Quartile	171	3.0%	132	2.7%	25	5.4%	11	3.3%	
Highest Quartile	215	3.8%	144	2.9%	58	12.6%	12	3.6%	
% Hispanic Composition									<.001
Lowest Quartile	5,532	85.9%	4,834	87.2%	423	83.1%	257	70.2%	
2nd Quartile	529	8.2%	434	7.8%	49	9.6%	45	12.3%	
3rd Quartile	216	3.4%	161	2.9%	22	4.3%	33	9.0%	
Highest Quartile	160	2.5%	114	2.1%	15	3.0%	31	8.5%	
% < HS education									<.001

Lowest Quartile	5,897	89.8%	5,124	90.7%	455	86.7%	300	80.9%	
2nd Quartile	597	9.1%	473	8.4%	65	12.4%	56	15.1%	
3rd Quartile	71	1.1%	51	<1.0%	–	–	15	4.0%	
Enabling									
Median Household Income									<.001
0 – 30k	462	7.0%	354	6.3%	71	13.5%	35	9.4%	
30k – 60k	3,529	53.6%	3,040	53.7%	286	54.4%	192	51.5%	
60k – 90k	1,794	27.3%	1,556	27.5%	121	23.0%	110	29.5%	
90k+	798	12.1%	713	12.6%	48	9.1%	36	9.7%	
Urbanization									<.001
Metro	5,241	79.4%	4,431	78.0%	451	85.6%	341	90.7%	
Urban	1,178	17.4%	1,076	19.0%	67	12.7%	32	8.5%	
Rural	183	2.8%	171	3.0%	–	–	–	–	
Geographic region									<.001
Northeast	380	5.8%	338	6.0%	24	4.6%	14	3.7%	
Midwest	952	14.4%	873	15.4%	70	13.3%	–	–	
South	3,082	46.7%	2,601	45.8%	350	66.4%	124	33.0%	
West	2,188	33.1%	1,866	32.9%	83	15.8%	231	61.4%	

– # of patients is less than 10

Table 2.2 Independent association between factors and receipt of minimum surveillance CEA tests and CT scan by Race/ethnicity

	CEA tests				CT scan			
	Adherent n (%)	NHW	Black OR (95% CI)	Hispanic	Adherent n (%)	NHW	Black OR (95% CI)	Hispanic
Patient-level								
Predisposing								
Age		**0.94 (0.93–0.95)**	**0.95 (0.92–0.99)**	**0.94 (0.89–0.98)**		**0.95 (0.95 – 0.96)**	0.97 (0.94 – 1.00)	**0.94 (0.90 – 0.98)**
Gender								
Male	2,326 (45.1)	Ref.	–	–	1,757 (45.7)	Ref.	–	–
Female	2,832 (54.9)	1.10 (0.97–1.25)	1.07 (0.72–1.58)	1.50 (0.90–2.48)	2,084 (54.3)	0.98 (0.88–1.09)	1.26 (0.89–1.79)	0.84 (0.55–1.26)
Marital status								
Single	463 (9.4)	Ref.	–	–	343 (9.4)	Ref.	–	–
Married	2,902 (58.9)	**1.89 (1.52–2.34)**	1.47 (0.87–2.48)	0.79 (0.33–1.90)	2,143 (58.4)	**1.38 (1.14–1.68)**	1.04 (0.64–1.68)	1.04 (0.52–2.06)
Other	1,565 (31.7)	1.17 (0.93–1.46)	1.37 (0.82–2.30)	0.56 (0.22–1.40)	1,183 (32.2)	1.15 (0.95–1.41)	1.38 (0.86–2.22)	0.57 (0.28–1.18)
Enabling								
Medicaid coverage								
None	4,352 (84.4)	Ref.	–	–	3,192 (83.1)	Ref.	–	–
Any	806 (15.6)	**0.49 (0.41–0.58)**	0.77 (0.52–1.13)	0.85 (0.51–1.39)	649 (16.9)	**0.85 (0.73–0.99)**	0.97 (0.68–1.37)	1.02 (0.67–1.53)
Need								
Stage								
II	1,912 (37.1)	Ref.	–	–	1,309 (34.1)	Ref.	–	–
High-risk II	796 (15.4)	**1.42 (1.19–1.70)**	1.77 (0.96–2.29)	**3.49 (1.29–9.43)**	608 (15.8)	**1.59 (1.36–1.86)**	1.53 (0.87–2.68)	1.72 (0.87–3.41)
III	2,450 (47.5)	**3.04 (2.62–3.54)**	**3.07 (2.00–4.72)**	**2.54 (1.49–4.33)**	1,924 (50.1)	**2.43 (2.16–2.74)**	**2.31 (1.59–3.37)**	**2.22 (1.42–3.47)**
Adjuvant treatment								
None	2,987 (57.9)	Ref.	–	–	2,098 (54.6)	Ref.	–	–
Chemo	1,824 (35.4)	**8.28 (6.53–10.49)**	**6.74 (3.67–12.4)**	**14.03 (5.07–40.4)**	1,455 (37.9)	**3.22 (2.83–3.67)**	**3.11 (2.06–4.67)**	**4.48 (2.68–7.51)**
Radiation	177 (3.4)	**1.95 (1.31–2.89)**	1.09 (0.39–3.01)	3.45 (1.00–11.98)	146 (3.8)	**2.37 (1.71–3.29)**	1.67 (0.62–4.49)	1.65 (0.70–3.89)
Chemo + Rad	170 (3.3)	**8.64 (4.03–18.5)**	7.11 (0.91–55.4)	–	142 (3.7)	**4.52 (2.99–6.85)**	1.36 (0.45–4.14)	**7.08 (1.54–32.45)**
Comorbidity								
0	2,016 (39.1)	Ref.	–	–	1,456 (37.9)	Ref.	–	–
1	1,443 (28.0)	0.87 (0.74–1.02)	0.80 (0.46–1.39)	1.15 (0.58–2.27)	1,089 (28.4)	1.07 (0.94–1.22)	1.03 (0.65–1.65)	0.77 (0.46–1.32)
2	772 (15.0)	**0.75 (0.62–0.91)**	**0.44 (0.25–0.78)**	1.03 (0.47–2.30)	561 (14.6)	0.87 (0.74–1.03)	0.78 (0.47–1.29)	0.94 (0.50–1.78)
3+	927 (18.0)	**0.51 (0.43–0.60)**	**0.59 (0.35–0.98)**	**0.52 (0.27–0.98)**	735 (19.1)	**0.85 (0.74–0.99)**	1.09 (0.69–1.71)	0.66 (0.37–1.15)
Neighborhood-level								
Predisposing								
% Black Composition (Quartiles)								
Lowest	3,967 (88.3)	Ref.	–	–	2.932 (87.4)	–	–	–
2nd	236 (5.3)	0.77 (0.58–1.03)	1.47 (0.62–3.48)	2.38 (0.53–10.58)	187 (5.6)	1.09 (0.84–1.41)	1.68 (0.81–3.51)	0.62 (0.24–1.56)
3rd	134 (3.0)	1.02 (0.66–1.57)	0.81 (0.34–1.93)	1.26 (0.26–5.98)	109 (3.3)	1.13 (0.79–1.61)	1.95 (0.82–4.64)	1.82 (0.47–7.03)
Highest	157 (3.5)	0.71 (0.49–1.03)	0.92 (0.50–1.69)	1.40 (0.30–6.55)	126 (3.8)	0.91 (0.65–1.27)	1.62 (0.91–2.87)	0.96 (0.30–3.09)

% Hispanic Composition (Quartiles)								
Lowest	4,335 (86.0)	Ref.	–	–	3,231 (86.4)	–	–	–
2nd	404 (8.0)	0.93 (0.74–1.18)	**0.47 (0.26–0.87)**	1.58 (0.67–3.73)	300 (8.0)	0.92 (0.76–1.13)	0.78 (0.43–1.40)	1.31 (0.68–2.54)
3rd	172 (3.4)	1.04 (0.71–1.54)	1.21 (0.44–3.36)	1.31 (0.52–3.33)	118 (3.2)	0.77 (0.56–1.05)	1.17 (0.49–2.79)	1.27 (0.60–2.69)
Highest	128 (2.5)	1.13 (0.70–1.80)	0.98 (0.30–3.14)	1.21 (0.47–3.11)	89 (2.4)	0.94 (0.64–1.36)	0.92 (0.33–2.59)	0.77 (0.37–1.63)
% < HS education (Quartile)								
Lowest	4,612 (89.9)	Ref.	–	–	3,466 (90.6)	Ref.	–	–
2nd	463 (9.0)	0.91 (0.73–1.14)	1.17 (0.64–2.14)	1.27 (0.61–2.66)	319 (8.3)	0.76 (0.63–0.92)	1.35 (0.79–2.30)	0.70 (0.39–1.24)
3rd	55 (1.1)	0.98 (0.50–1.92)	0.57 (0.09–3.48)	1.11 (0.30–4.04)	41 (1.1)	1.27 (0.71–2.27)	0.21 (0.02–1.90)	0.57 (0.20–1.61)
Enabling								
Median Household Income								
0 – 30k	346 (6.7)	Ref.	–	–	260 (6.8)	Ref.	–	–
30k – 60k	2,726 (53.0)	1.18 (0.92–1.52)	0.92 (0.51–1.66)	1.01 (0.41–2.50)	2,022 (52.8)	1.12 (0.89–1.39)	0.65 (0.38–1.10)	1.15 (0.56–2.38)
60k – 90k	1,424 (27.7)	**1.35 (1.03–1.77)**	1.02 (0.52–1.97)	0.95 (0.37–2.44)	1,064 (27.8)	1.16 (0.92–1.47)	0.93 (0.51– 1.70)	1.53 (0.71–3.32)
90k+	647 (12.6)	**1.54 (1.14–2.10)**	1.10 (0.47–2.54)	0.65 (0.22–1.96)	486 (12.7)	**1.32 (1.02–1.71)**	0.67 (0.31–1.40)	0.94 (0.37–2.40)
Urbanization								
Metro	4,088 (79.3)	Ref.	–	–	3,066 (79.8)	Ref.	–	–
Urban	932 (18.1)	1.01 (0.86–1.19)	1.84 (0.95–3.54)	1.16 (0.46–2.93)	666 (17.3)	0.92 (0.80–1.05)	0.78 (0.47–1.30)	1.20 (0.57–2.54)
Rural	138 (2.7)	0.89 (0.62–1.28)	0.50 (0.13–1.90)	0.54 (0.05–6.01)	109 (2.8)	0.99 (0.72–1.34)	1.61 (0.40–6.52)	–
Geographic region								
Northeast	300 (5.8)	Ref.	–	–	242 (6.3)	Ref.	–	–
Midwest	756 (14.7)	1.07 (0.78–1.47)	0.74 (0.27–2.03)	0.42 (0.07–2.67)	553 (14.4)	0.78 (0.60–1.01)	1.01 (0.39–2.59)	0.56 (0.09–3.57)
South	2,371 (46.0)	0.85 (0.64–1.12)	1.19 (0.48–2.96)	2.20 (0.68–7.16)	1,819 (47.4)	0.82 (0.65–1.04)	0.89 (0.38–2.06)	0.94 (0.31–2.88)
West	1,731 (33.6)	0.96 (0.72–1.28)	1.07 (0.39–2.93)	2.30 (0.73–7.20)	1,227 (31.9)	**0.70 (0.55–0.89)**	0.66 (0.26–1.67)	1.18 (0.39–3.50)

Table 2.3 Association between patient and neighborhood factors and receipt of minimum surveillance CEA tests and CT scan by race/ethnicity

	CEA tests			CT scan		
	NHW	Black OR (95% CI)	Hispanic	NHW	Black OR (95% CI)	Hispanic
Patient-level						
Predisposing						
Age	**0.96 (0.95–0.97)**	1.02 (0.97–1.06)	1.00 (0.94–1.05)	**0.97 (0.96 – 0.98)**	0.99 (0.96 – 1.03)	0.99 (0.95 – 1.03)
Gender						
Male	Ref.	–	–	Ref.	–	–
Female	**1.22 (1.05–1.42)**	0.89 (0.54–1.48)	1.12 (0.62–2.04)	1.06 (0.93–1.19)	1.25 (0.81–1.93)	0.78 (0.48–1.27)
Marital status						
Single	Ref.	–	–	Ref.	–	–
Married	**1.56 (1.24–1.97)**	0.62 (0.32–1.21)	0.39 (0.14–1.08)	**1.25 (1.03–1.52)**	0.79 (0.44–1.41)	0.71 (0.32–1.56)
Other	1.17 (0.92–1.48)	0.79 (0.41–1.50)	0.43 (0.15–1.23)	1.16 (0.94–1.42)	1.24 (0.70–2.21)	0.45 (0.20–1.04)
Enabling						
Medicaid coverage						
None	Ref.	–	–	Ref.	–	–
Any	**0.61 (0.51–0.73)**	**1.99 (1.20–3.31)**	1.35 (0.74–2.46)	1.00 (0.85–1.17)	1.44 (0.92–2.25)	1.03 (0.62–1.69)
Need						
Stage						
II	Ref.	–	–	Ref.	–	–
High-risk II	**1.30 (1.07–1.58)**	1.08 (0.50–2.34)	2.41 (0.84–6.97)	**1.42 (1.21–1.68)**	0.84 (0.43–1.65)	1.00 (0.47–2.12)
III	**1.61 (1.35–1.93)**	0.80 (0.46–1.37)	0.80 (0.43–1.51)	**1.56 (1.35–1.80)**	1.13 (0.72–1.79)	0.88 (0.52–1.47)
Adjuvant treatment						
None	Ref.	–	–	Ref.	–	–
Chemo	**5.60 (4.29–7.31)**	0.97 (0.43–2.19)	1.62 (0.55–4.81)	**2.49 (2.12–2.93)**	1.43 (0.86–2.41)	1.35 (0.76–2.43)
Radiation	**1.49 (1.00–2.21)**	0.56 (0.17–1.87)	1.71 (0.45–6.56)	**1.82 (1.31–2.53)**	1.29 (0.40–4.15)	0.72 (0.27–1.93)
Chemo + Rad	**8.05 (3.25–19.92)**	0.41 (0.04–4.19)	–	**3.12 (2.02–4.81)**	**0.18 (0.04–0.71)**	1.83 (0.36–9.25)
Comorbidity						
0	Ref.	–	–	Ref.	–	–
1	0.96 (0.79–1.15)	1.02 (0.51–2.06)	1.11 (0.50–2.47)	1.10 (0.95–1.27)	1.06 (0.60–1.88)	0.62 (0.33–1.17)
2	0.92 (0.74–1.15)	**0.33 (0.16–0.68)**	1.23 (0.49–3.10)	1.01 (0.85–1.21)	0.74 (0.39–1.39)	1.08 (0.51–2.28)
3+	**0.68 (0.56–0.82)**	1.08 (0.56–2.08)	1.07 (0.50–2.30)	1.05 (0.89–1.23)	1.21 (0.69–2.12)	0.71 (0.37–1.38)
Neighborhood-level						
Predisposing						
% Black Composition (Quartiles)						
Lowest	Ref.	–	–	–	–	–
2nd	0.74 (0.54–1.00)	1.89 (0.68–5.22)	3.32 (0.68–16.24)	1.09 (0.84–1.43)	1.31 (0.56–3.06)	0.60 (0.21–1.75)

3rd	1.09 (0.69–1.71)	0.89 (0.28–2.85)	2.58 (0.28–23.82)	**1.49 (1.03–2.17)**	1.99 (0.68–5.81)	2.01 (0.38–10.63)
Highest	0.84 (0.55–1.28)	1.25 (0.52–2.96)	1.00 (0.18–5.65)	1.08 (0.75–1.55)	1.85 (0.85–4.00)	0.63 (0.15–2.68)
% Hispanic Composition (Quartiles)						
Lowest	Ref.	–	–	–	–	–
2nd	0.86 (0.67–1.11)	**0.43 (0.20–0.93)**	1.76 (0.65–4.77)	1.02 (0.82–1.25)	0.82 (0.41–1.65)	1.32 (0.62–2.82)
3rd	0.97 (0.62–1.51)	0.57 (0.17–1.90)	0.99 (0.32–3.02)	1.11 (0.78–1.60)	1.33 (0.47–3.74)	1.01 (0.41–2.44)
Highest	1.06 (0.58–1.93)	1.69 (0.31–9.38)	1.29 (0.40–4.10)	1.07 (0.65–1.73)	1.76 (0.45–6.84)	0.80 (0.31–2.07)
% < HS education (Quartile)						
Lowest	Ref.	–	–	Ref.	–	–
2nd	1.04 (0.76–1.41)	0.78 (0.37–1.65)	1.37 (0.59–3.19)	0.70 (0.54–0.90)	1.91 (1.00–3.65)	0.78 (0.40–1.54)
3rd	1.38 (0.58–3.30)	–	1.58 (0.25–9.90)	1.07 (0.53–2.14)	0.48 (0.04–5.89)	0.52 (0.13–2.12)
Enabling						
Median Household Income						
0 – 30k	Ref.	–	–	Ref.	–	–
30k – 60k	1.07 (0.79–1.46)	0.99 (0.45–2.18)	1.43 (0.47–4.33)	1.10 (0.85–1.42)	0.63 (0.32–1.25)	1.33 (0.56–3.23)
60k – 90k	1.19 (0.85–1.66)	1.14 (0.47–2.77)	1.19 (0.38–3.79)	1.17 (0.88–1.55)	0.78 (0.36– 1.68)	1.90 (0.74–4.83)
90k+	1.20 (0.83–1.75)	1.09 (0.36–3.21)	0.72 (0.19–2.77)	1.18 (0.86–1.60)	0.53 (0.21–1.31)	1.28 (0.42–3.93)
Urbanization						
Metro	Ref.	–	–	Ref.	–	–
Urban	1.12 (0.91–1.38)	1.44 (0.60–3.48)	1.24 (0.44–3.46)	0.86 (0.73–1.02)	0.60 (0.31–1.16)	1.77 (0.75–4.20)
Rural	0.85 (0.54–1.34)	0.39 (0.08–1.95)	–	1.01 (0.70–1.47)	1.50 (0.33–6.87)	–
Geographic region						
Northeast	Ref.	–	–	Ref.	–	–
Midwest	0.94 (0.67–1.34)	0.53 (0.15–1.83)	0.56 (0.06–5.03)	0.77 (0.58–1.02)	1.23 (0.40–3.76)	0.86 (0.11–6.72)
South	0.78 (0.57–1.06)	1.14 (0.39–3.30)	3.66 (0.93–14.43)	**0.74 (0.57–0.95)**	0.92 (0.35–2.38)	1.12 (0.32–3.93)
West	0.97 (0.71–1.31)	1.20 (0.37–3.83)	3.53 (0.94–13.35)	**0.66 (0.51–0.85)**	0.86 (0.31–2.43)	1.42 (0.42–4.82)

Figures

Figure 3.1 Period of observation used for identifying surveillance CEA tests and CT scan

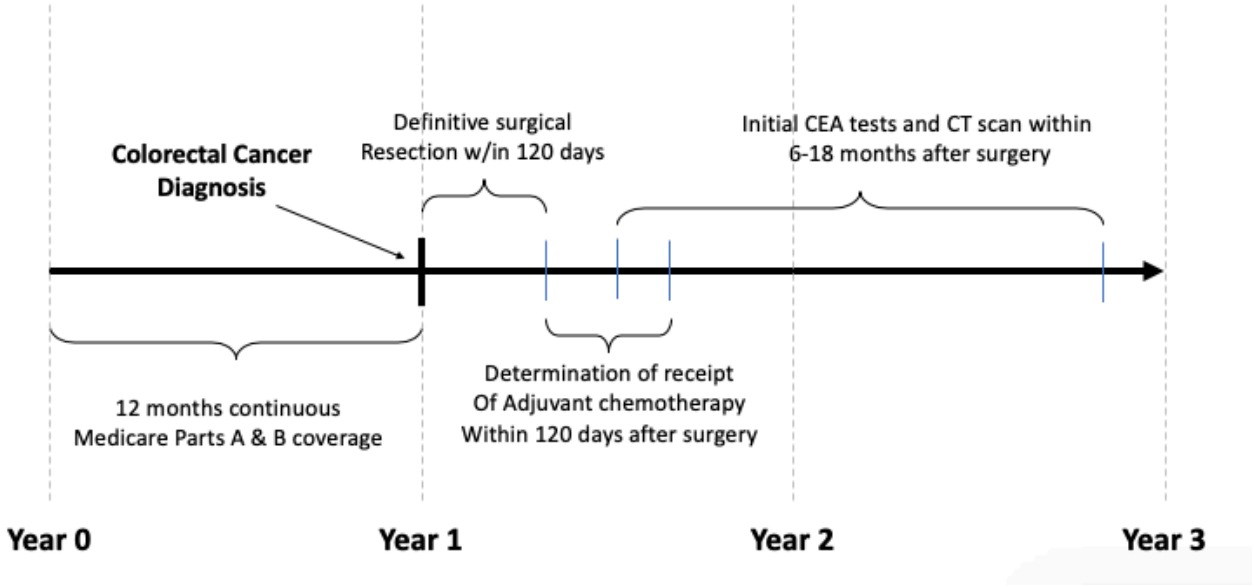
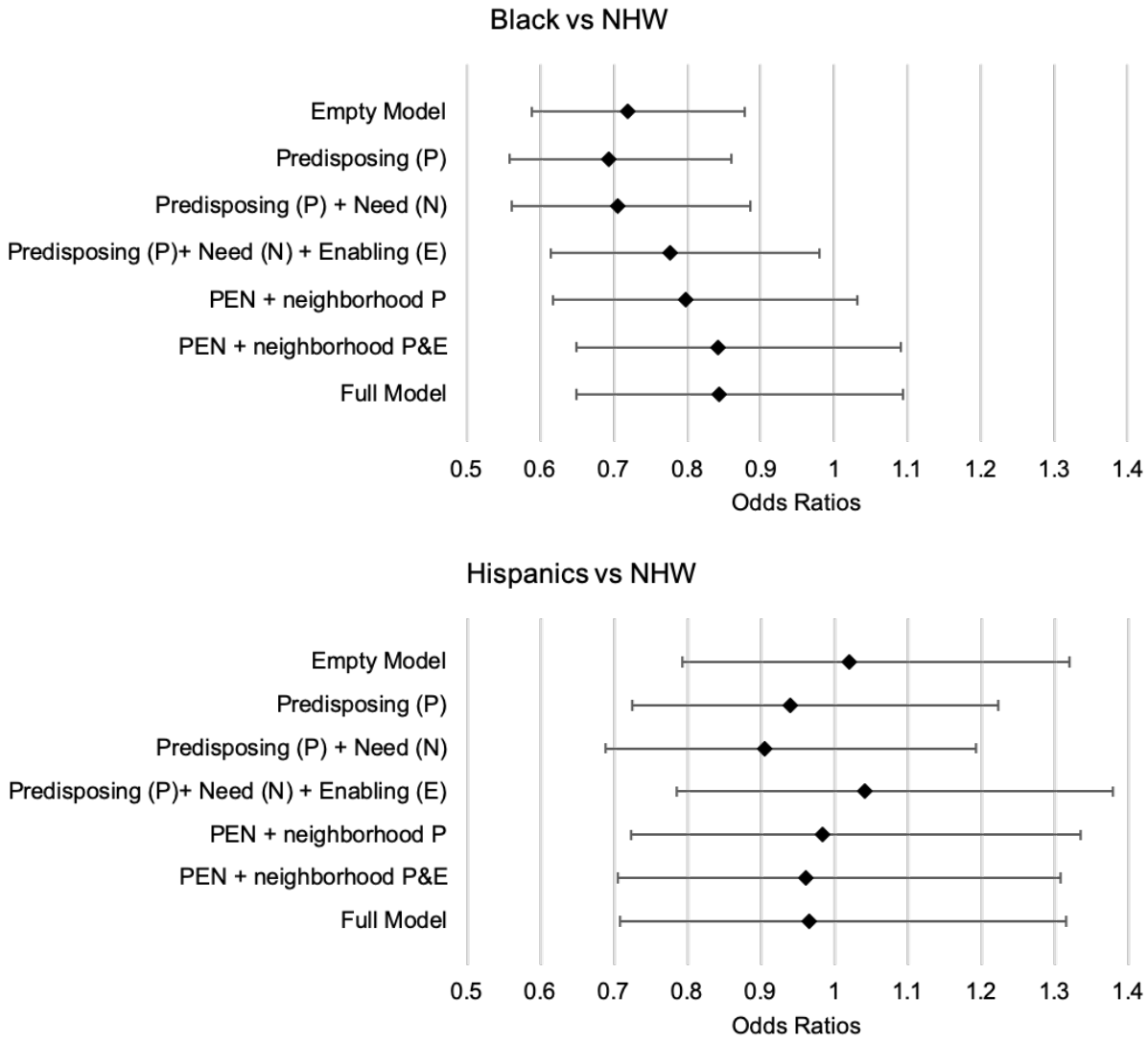
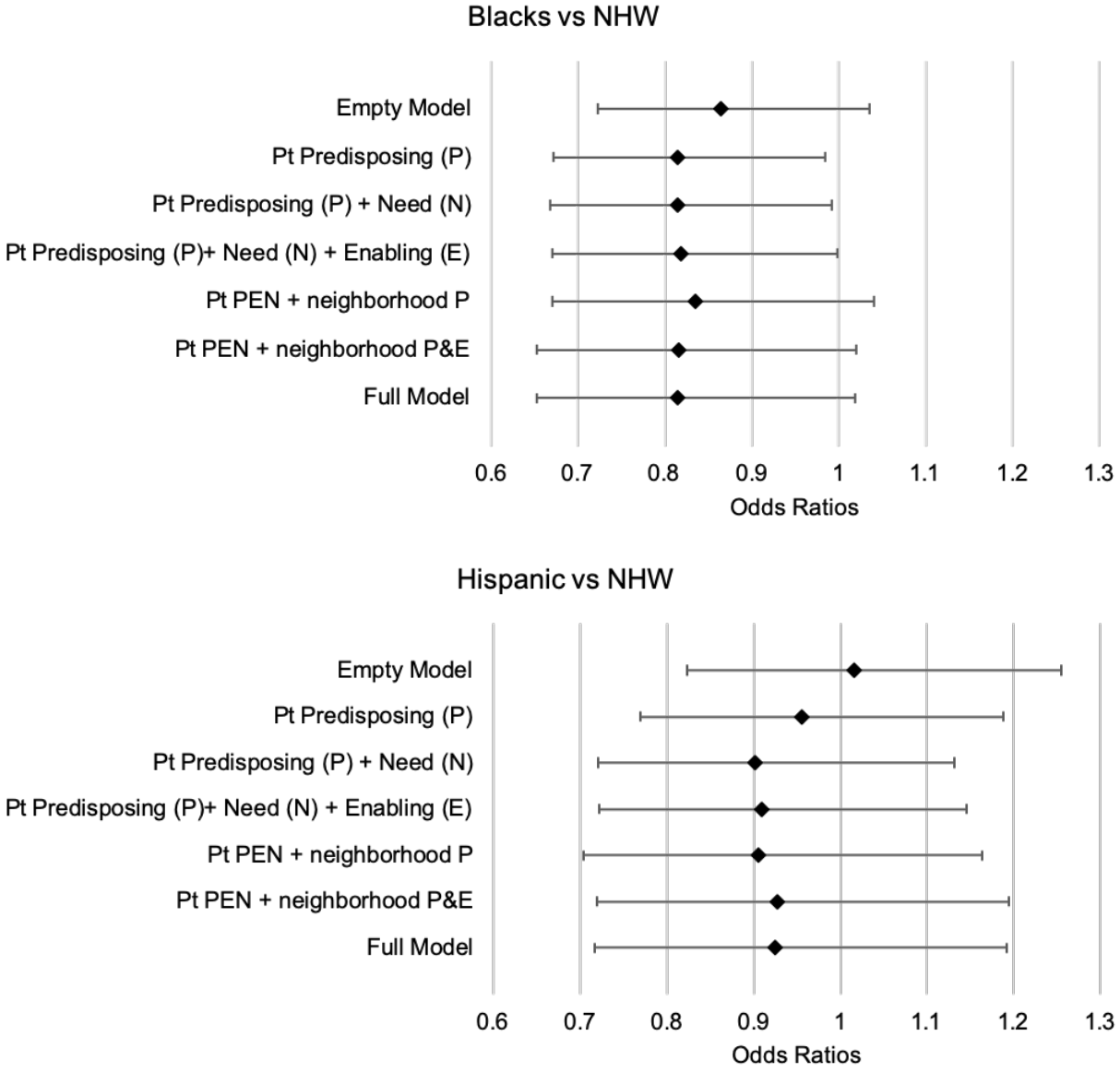


Figure 3.2 Odds of receipt of CEA tests by race/ethnicity



Odds ratio for NHW is equal to 1.

Figure 3.3 Odds of receipt of CT scans by race/ethnicity



Odds ratios for NHW is equal to 1

CHAPTER 4. Characteristics and surveillance behaviors of colorectal cancer patients with recurrence

Introduction

Since 1975, overall survival among colorectal cancer (CRC) patients has steadily increased from about 50% to 65%, primarily due to improvements in CRC screening, diagnostic procedures and treatments [13]. However, much of the progress in survival observed over the last decades is confined to non-Hispanic White (NHW) CRC patients, with racial/ethnic minorities and CRC patients residing in underserved areas (e.g., low income and rural areas) experiencing a 10% lower overall 5-year survival [3, 13-15, 18, 125]. Patients with recurrence also experience persistently poor health outcomes compared to patients without recurrence and many CRC-related deaths result from cancer recurrence after surgical resection [4, 16]. Given these differences in outcomes, significant efforts have focused on identifying recurrence and metastatic disease early [2, 60, 126-128]. If detected early through surveillance, the recurrent disease may be responsive to potentially effective secondary cancer treatment [16]. Yet, surveillance procedures are underutilized among eligible CRC patients, and minority populations are about 30% less likely to receive recommended surveillance procedures compared to NHWs [6]. Characterizing CRC patients with recurrent disease and assessing their surveillance behaviors is a first step for developing effective surveillance promotion interventions and improving cancer treatments for CRC patients who experience recurrence.

Information on who develops cancer recurrence has been gathered from clinical trials, patient self-report information, and medical records from single institutions. However, these data have limitations [45, 62, 75, 129, 130]. Clinical trials often only include patients with specific inclusion criterial that allows researchers to isolate the effects of a particular drug but as a result make the dataset unrepresentative of the general population of CRC patients [131-136]. Patients who are 65 years of age and older, low income, minority, residing in rural areas, and those with multiple comorbidities are underrepresented in such studies [131-136]. Medical records from single institutions are biased towards the populations that those institutions serve. Among older adults, comorbidities are common and the risk of death from competing events is relatively high, especially among cancer patients [20]. Population-based cancer registries, like the Surveillance, Epidemiology, and End Results (SEER) Program in the United States,

collect information on cancer incidence and mortality, but collecting information on cancer recurrence in the same individuals has proven to be systematically challenging [45, 137]. To address these limitations, researchers have developed algorithms to ascertain recurrence using administrative claims data. These algorithms identify secondary procedures and other care received after initial CRC treatment that may be indicative of cancer recurrence [45, 62, 77, 124, 129, 138, 139]. The SEER-Medicare linked data contain complete claims for procedures that may be indicative of cancer recurrence, such as surgery, chemotherapy, and radiation received by older adult cancer patients who are covered by Medicare fee-for-service [45, 75, 77, 140-144]. These data provide a unique opportunity to identify patient and neighborhood factors associated with recurrence and to assess the surveillance behaviors from a large population-based cohort of older adult Americans who experience recurrence [45, 75].

Identifying the patient and neighborhood characteristics of older adult CRC patients with recurrent disease can assist researchers in monitoring the effectiveness of surveillance strategies for the early detection of secondary cancers [137]. Research indicates that although patient clinical characteristics, such as stage at diagnosis, are contributing to differences in CRC-related outcomes, measures of socioeconomic status (SES) are important factors associated with racial/ethnic disparities in receipt of surveillance care and survival [18, 81, 107, 145]. Measures of SES may impact cancer outcomes by facilitating or hindering access to postoperative cancer care. For example, new chemotherapy and radiation therapies are not equally adopted across all SES groups, such that cancer patients in the lower SES strata are less likely to have access to and receive surveillance or newer treatments [81, 107, 145, 146]. At the neighborhood-level, median household income (MHI) is an important SES-related factor necessary for identifying and reducing financial, structural and personal barriers to surveillance and new cancer treatments [95]. Thus, there is growing interest in understanding how socioeconomic status impacts CRC-related outcomes, as well as understanding their surveillance behaviors of patients who experience recurrence [138].

Overall, the clinical guidelines for the management of cancer recurrence after a CRC diagnosis continue to evolve and patients with recurrent disease may receive different cancer care compared to that offered to patients with newly diagnosed metastatic CRC [16, 127, 139]. In this study, we describe patient- and neighborhood-level characteristics of CRC patients with cancer recurrence and their CRC

surveillance behaviors. This is timely information for understanding potential differences in disease-free survival, an important survival metric that incorporates the morbidity associated with recurrence [147].

Methods

Data source. This is a retrospective population-based cohort study using the Surveillance, Epidemiology and End Results (SEER) – Medicare linked data from 2009 – 2014. The SEER-Medicare data is an ideal dataset for assessing ongoing surveillance and follow-up of cancer care received by Medicare beneficiaries diagnosed with cancer, as well as their cancer-related outcomes [74, 148].

Cohort selection. We included Medicare beneficiaries between the ages of 66 and 85 with a diagnosis for CRC stages II and III and who received definitive surgical resection based on Medicare claims for resection, a colectomy, less than colectomy, or surgical excision with pathology specimen (Supplemental Table 1). The surgery date is based on receipt of surgical resection within 4-months after cancer diagnosis [35, 45, 74].

Exclusion criteria. Medicare beneficiaries were excluded if CRC was not the primary and only cancer and if their CRC diagnosis was ascertained in autopsy or in death certificates. Beneficiaries were also excluded if the patient was enrolled in a health maintenance organization (HMO) during the study period, or not enrolled in Medicare Parts A and B for at least 12-months prior to the CRC diagnosis, as we may not be able to fully capture surveillance claims.

Analytic Variables.

Recurrence. The recurrence period was defined as 18-months after definitive surgical resection for primary CRC when a patient may have claims for indicators of cancer recurrence (Figure 4.1) [45]. Claims for secondary surgical procedures, chemotherapy, radiation, and other claims that are indicative of liver, lung, and other metastases after 18-months post-surgical resection were considered possible markers for cancer recurrence (Supplemental Table 1) [45]. The 18-month recurrence period was selected to to ensure that additional cancer treatment claims are for recurrence and not an extension of adjuvant treatment and to provide patients time to complete initial CRC surveillance.

Clinically, adjuvant therapy (chemotherapy and/or radiation) should be initiated within 4-months of first surgical resection and completed within 12-months thereafter [8, 35, 45]. End of adjuvant therapy is identified as 12-months after a patient has surgical resection. It is possible that adjuvant therapy for

some patients may extend beyond 12 months after surgery. We assessed if adjuvant therapy was completed by identifying any claims for chemotherapy and/or radiation during a consecutive 90-day treatment-free period. The treatment-free period is defined as the period where a patient has zero claims for chemotherapy and radiation during 15- to 18-months post-surgery [45]. Patients who began adjuvant treatment within 4-months post-surgery but who had zero claims for 60 to 90 days, consecutively were excluded as these services may be either for additional adjuvant treatment for primary CRC or for treating cancer recurrence [45].

CRC surveillance behaviors. Receipt of initial surveillance procedures is based on recommendations from the American Society of Clinical Oncology (ASCO) and the National Comprehensive Cancer Network (NCCN) and defined as receiving one colonoscopy, at least two carcinoembryonic antigen (CEA) tests, and/or one computed tomography (CT) scan within an 18-month period following surgical resection. Receipt of surveillance was ascertained from monthly Medicare claims using ICD-9 and CPT-4 codes (Supplemental Table 1) [8, 11, 34, 35, 107, 145].

***Patient and neighborhood-level characteristics*.** Patient demographic characteristics include age, race/ethnicity (non-Hispanic White (NHW), Black, Hispanic), gender (male, female), marital status (single, married, other), and Medicaid coverage status. Patient clinical factors include stage (II, high-risk II, and III), receipt of adjuvant treatment (none, chemotherapy, radiation, chemotherapy and radiation) and presence of comorbidities based on the Charlson Comorbidity Index [78]. Neighborhood-level factors are measured at the census tract level and include the percent Black and Hispanic neighborhood composition, the percent of the population with less than high school educational attainment, median household income, urbanization and SEER registry site.

Statistical Analyses. We calculated the frequencies and proportions of CRC patients who experience recurrence and their surveillance behaviors. Differences in the distribution of patients were assessed using Pearson Chi-square test. We considered these differences to be significant if the p-value less than 0.05. Bivariate analyses were performed to assess the independent association between each patient and neighborhood factor and the risk of recurrence. We used multivariate logistic regression models to assess the association between patient and neighborhood factors and recurrence and to assess the effect of receipt of surveillance colonoscopy, CEA tests and CT scans on recurrence status.

We also included calendar time as a liner variable to control for the effect of time on whether or not patients were diagnosed with recurrent cancer and whether or not patients received surveillance procedures. Statistical analyses were performed using STATA 15.1 software (STATA, 2015).

Results

Patient Characteristics. The final eligible cohort included 6,079 Medicare beneficiaries diagnosed with CRC in stages II and III, 12.2% whom experienced recurrence 18 -months post-surgical resection. Study participants were predominantly NHW (85.5%), female (54.6%), married (56.0%), were not covered by Medicaid (82.1%), stage II (59.9%0, had not received adjuvant treatment (68.6%), and had at least one comorbid condition (62.6%) (Table 4.1). CRC patients resided in neighborhoods with a low concentration of racial/ethnic minorities, a low percentage of neighborhood population with less than high school education, and a median household income between $30K to $60K. Many of the CRC patients with and without recurrence lived in metro areas (79.7%) and in the southern region of the United States (46.3%).

Patients with and without recurrence differed by age, Medicaid coverage status, stage, receipt of adjuvant treatment, and presence of comorbidities (Table 4.1). The proportion of NHWs and Blacks without recurrence was higher compared to NHWs and Blacks with recurrence (86.8% vs 84.5% and 7.8% vs 6.8%, respectively), while the proportion of Hispanic patients with recurrence was approximately 1.6 times as high as the proportion of Hispanics without recurrence (8.7% vs 5.4%). Compared to CRC patients without recurrence, there was a higher proportion of patients with recurrence who were younger, were more likely to be male (47.0% vs 45.2%), were less likely to be covered by Medicaid coverage (22.1% vs 17.4%), were more likely to be diagnosed at stage III compared to stage II (52.2% vs 38.4%) and were more likely to have received chemotherapy and/or radiation as part of their adjuvant treatment (46.4% vs 29.3%). There were no significant differences in neighborhood characteristics by recurrence status.

Factors associated with recurrence. Patients with Medicaid coverage, stage III (vs stage II), and with at least two comorbidities had higher odds of having recurrence ($p < .05$) (Table 3.2). Patients who received chemotherapy alone or in combination with radiation had at least two times the odds of having recurrence. CRC patients residing in neighborhoods with 25% to 50% of Black composition had

47% higher odds of having recurrence. After adjusting for patient and neighborhood factors, stage III, receipt of adjuvant treatment, having two or more comorbidities, and residing in neighborhoods with 25% to 50% Black neighborhood composition remained significantly associated with higher odds of recurrence (Table 3.2).

Surveillance behaviors. Overall, 91.2% of CRC patients with recurrence received some type of surveillance compared to 86.6% patients without recurrence ($p < .001$) (Table 3.3). Among patients with recurrence, the majority (83.3%) had received a combination of surveillance procedures. Of these, 43.7% received all three surveillance procedures as recommended by national guidelines within 18-months after surgical resection. Compared to CRC patients without recurrence, patients with recurrence had a lower proportion of patients who received a colonoscopy and/or CEA test (Table 3.3).

Receipt of CEA tests and a CT scan was associated with higher odds of recurrence (51% and 64%, respectively) (Table 3.4). However, after adjusting for patient and neighborhood factors, only receipt of a CT scan was significantly associated with higher odds of recurrence among CRC patients (OR: 1.43, 95% CI: 1.18 to 1.74).

Discussion

As the second leading cause of cancer-related deaths, improving CRC outcomes is a key public health priority [15]. In a large population-based sample of older adults, we found that 12.2% of CRC patients had recurrence after 18-months following definitive surgical resection. Other studies using administrative claims data have found similar prevalence of recurrence [45, 62, 129]. One study validating indicators of recurrence among a similar sample of CRC patients found that 14% of paitnets had recurrence in the Cancer Outcomes Research Surveillance (CanCORS) – Medicare linked data and 13% in the health maintenance organization (HMO) – Cancer Research Network (CRN) data. The HMO-CRN data included high-quality recurrence data and was used as a “gold standard” for prevalence of recurrence in that study. A higher proportion of CRC patients with recurrence were identified by Anaya et al, Deshpande et al, Augestad et al and Warren et al (18.4%, 18.4%, 15.7% and >33%, respectively) [45, 104, 129, 138]. The discordant prevalence of recurrence across studies may be the result of differences in the algorithms and diagnostic codes used as indicators of recurrence and when the recurrence surveillance period began and ended. Our study identified claims after 18-months and used a 90-day

treatment-free period to ensure that patients with claims for indicators of recurrence were only for recurrence and not for adjuvant therapy. These resulted in lower estimates than studies that used a 12-month period [45, 104, 129, 138].

Similar to other studies, our findings indicate that clinical factors are significantly associated with recurrence status [16, 42, 44, 45, 149]. Patients with a more advanced stage have worse CRC-related outcomes and receipt of chemotherapy and radiation therapy may be indicators of more advanced stage or higher cancer grade. Similarly, patients with two or more comorbidities had more than 50% higher odds of recurrence compared to those with one or no comobridity. Comorbidity is an important factor that has been demonstrated to be independently associated with cancer care utilization and outcomes [34, 85, 150]. The risk of cancer development and progression is higher among individuals with other chronic conditions such as obesity and diabetes that could lead to worse CRC prognosis and greater risk of recurrence and CRC-specific mortality [150, 151]. It is plausible that having multiple chronic conditions complicates the decision-making process in terms of which treatments and surveillance to receive and when to begin [150]. Among older adults, comorbidities, such as depression and dementia, may mask early CRC symptoms of recurrence causing patients to delay receipt of cancer surveillance and care and be diagnosed at more advanced stages of disease [150].

Although race/ethnicity was not associated with cancer recurrence in our study, differences in the proportion of patients with and without recurrence across racial ethnic groups varied, especially for Hispanics. Based on previous studies, Hispanics are more likely to receive radiation therapy compared to NHWs and Blacks [107]. Radiation therapy is more commonly used for treating rectal cancer, which has been demonstrated to have higher rates of local recurrence compared to colon cancers [104]. Tumor location may be a stronger predictor of survival than receipt of surveillance procedures and should be further assessed [152].

At the neighborhood level, only the percentage of Black composition was significantly associated with higher odds of recurrence. In our study, living in a neighborhood with 25% to 50% Black composition significantly increased odds of recurrence by 53%. Neighborhood composition can influence CRC outcomes through psychosocial mechanisms such as social norms, collective efficacy and social control [71]. Areas with higher racial/ethnic minority densities are more likely to be segregated,

socioeconomically disadvantaged and deprived, and have safety net clinics serving as primary sources of health care [73, 153, 154]. All these attributes contribute to having limited access to newer treatment options and lead to lower utilization of cancer care.

Overall, receipt of timely CRC surveillance remains low, with only 43.7% of patients with recurrence receiving surveillance procedures as recommended. After adjusting for patient and neighborhood factors, only receipt of a CT scan was associated with higher odds of recurrence. Research indicates that most metastatic disease occurs in the liver and lungs [27, 101, 102]. CT scans may be more useful in identifying recurrent liver metastasis than other laboratory tests, including CEA tests, and a CT colonography may be a cost-saving alternative for surveillance of local recurrence compared to a colonoscopy [155, 156]. In addition, patients with liver imaging had a 25% lower mortality compared to patients receiving non-imaging surveillance [26]. Thus, after its inclusion into the national CRC surveillance guidelines in 2005, a CT scan may be more likely to be recommended by a physician. Interestingly, CEA tests had the highest prevalence—possibly because it is easiest to receive in outpatient settings and is the least invasive of the three surveillance procedures.

Our study has limitations similar to other population-based studies that use claims data such as SEER-Medicare. Currently, there is no 'gold standard' measure of recurrence after initial CRC diagnosis in population-based data [109, 124]. To address this limitation, researchers are focusing on developing algorithms for ascertaining recurrence based on a treatment-based approach [45]. Treatment-based algorithms are necessarily dependent on the patient receiving treatment (e.g., chemotherapy, radiation, additional surgery) for recurrence and metastatic disease, i.e., if a patient has recurrence but does not receive treatment, then we would not identify them as a recurrent case using the treatment-based approach. As a result, caution should be used when estimating rates of recurrence and identify indicators of recurrence from Medicare claims data since the treatment-based algorithm may result in significant underestimation of recurrence [45]. Studies that validate these and/or other recurrence algorithms for CRC patients are needed in order to further elucidate the incidence of recurrence at the population-level.

A second limitation of our study is that in order to allow for a sufficient "wash-out" period, we were not able to capture early recurrence that may occur between 6- to 18-months after definitive surgical resection. This is a trade-off in having 'false-positives' – capturing someone who did not have a

recurrence as a recurrence case versus having 'false-negative' – missing a truly recurrent case. We chose to allow for this wash-out period and thus note that we may have 'false-negatives' as a result. Additionally, our short study period may limit our ability to capture CRC patients who may develop recurrent disease after two to three years. For example, CRC is a slow progressing cancer, with only about 2% of older adult CRC patients developing secondary primary malignancy over the study period [60, 157].

Our study does not asses how different factors influence the time course of recurrence and death beyond receipt of surgical resection or other important CRC-related outcomes (e.g., survival). Future research that focuses on conceptualizing the impact of multiple factors on recurrence and survival should assess time to recurrence and address competing risks. Competing risks, such as death from other causes are prevalent in CRC research. Failing to address this issue may lead to an overestimation of the outcome and mis-estimation of the degree to which a factor affects the incidence of CRC-specific survival [158, 159]. In addition, mediation analyses may be used to assess the impact of receipt of surveillance procedures on time to recurrence and on racial/ethnic disparities in survival. Since there are racial/ethnic disparities in receipt of surveillance procedures, further research is needed to determine the extent to which the effect of race/ethnicity on survival that is due to the association between receipt of surveillance procedures and time to recurrence across racial/ethnic groups.

A final limitation is in the construction of our cohort, which only included patients 65+ with CRC as their first and only cancer. Some studies suggest that specific populations, including minorities may be more likely to have complex cancer histories (e.g., diagnosed with multiple cancers throughout their lifetime) and that incidence of developing a secondary primary CRC is higher among females and Hispanic CRC patients [43, 160, 161]. Unfortunately, our sample of Blacks and Hispanics (n=64 and n=50, respectively) was too small to see any significant or meaningful associations with recurrence and surveillance behaviors. Given that the incidence of CRC among younger individuals is increasing, the algorithm used in this study might have different sensitivities in other populations and in different settings (e.g., clinical and community) [162].

Our results complement the body of research that focuses on understanding prevalence of recurrence among patients diagnosed with CRC by systematically describing differences in patient and

neighborhood characteristics of CRC patients with recurrent disease and their surveillance behaviors. Results from this study provide important information to guide comparative effectiveness studies of representative populations, which is essential for efficiently identifying cancer treatment strategies and care coordination. Findings from our study may also better inform and assist shared decision making for older adult patients, their families and providers.

Table 3.1 Characteristics of CRC patients by recurrence status				
	Overall n (%)	**No Recurrence n (%)**	**Recurrence n (%)**	
	(n=6079)	(n=5,337)	(n=742)	p-value
Patient-level characteristics				
Age (Mean)	75.1	75.2	74.9	p = .01
Race				p >.05
NHW	5,241 (85.5%)	4,618 (86.8%)	623 (84.5%)	
Black	481 (7.9%)	417 (7.8%)	64 (6.8%)	
Hispanic	337 (5.6%)	287 (5.4%)	50 (8.7%)	
Gender				p >.05
Male	2,760 (45.4%)	2,411 (45.2%)	349 (47.0%)	
Female	3,319 (54.6%)	2,926 (54.8%)	393 (53.0%)	
Marital Status				p > .05
Single	596 (10.3%)	530 (10.4%)	66 (9.4%)	
Married	3,246 (56.0%)	2,842 (55.7%)	404 (57.8%)	
Other	1,958 (33.8%)	1,729 (33.9%)	229 (32.8%)	
Medicaid				p = .002
No	4,988 (82.1%)	4,410 (82.6%)	578 (77.9%)	
Yes	1,091 (18.0%)	927 (17.4%)	164 (22.1%)	
Stage				p < .001
II	2,670 (43.9%)	2,423 (45.4%)	247 (33.3%)	
High-risk II	972 (16.0%)	864 (16.2%)	108 (14.6%)	
III	2,437 (40.1%)	2,050 (38.4%)	387 (52.2%)	
Adjuvant treatment				p < .001
None	4,171 (68.6%)	3,773 (70.7%)	398 (53.6%)	
Chemo	1,568 (25.8%)	1,292 (24.2%)	276 (37.2%)	
Rad	201 (3.3%)	169 (3.2%)	32 (4.3%)	
Chemo+ Rad	139 (2.3%)	103 (1.9%)	36 (4.9%)	
Comorbidity				p = .003
0	2,271 (37.4%)	2,034 (38.1%)	237 (31.9%)	
1	1,640 (27.0%)	1,440 (27.0%)	200 (27.0%)	
2	922 (15.2%)	794 (14.9%)	128 (17.3%)	
3+	1,246 (20.5%)	1,069 (20.0%)	177 (23.9%)	
Neighborhood-level characteristics				
% Black Composition				p = .062
Lowest Quartile	4,624 (87.7%)	4,061 (87.9%)	563 (86.1%)	
2nd Quartile	283 (5.4%)	235 (5.1%)	48 (7.3%)	
3rd Quartile	163 (3.1%)	140 (3.0%)	23 (3.5%)	
Highest Quartile	204 (3.9%)	184 (4.0%)	20 (3.1%)	
% Hispanic Composition				p > .05
Lowest Quartile	5,084 (85.8%)	4,476 (86.1%)	608 (83.9%)	
2nd Quartile	495 (8.4%)	428 (8.2%)	67 (9.2%)	
3rd Quartile	202 (3.41%)	172 (3.3%)	30 (4.1%)	
Highest Quartile	145 (2.5%)	125 (2.4%)	20 (2.8%)	
% < HS education				p > .05
Lowest Quartile	5,428 (89.8%)	4,768 (89.9%)	660 (89.7%)	
2nd Quartile	553 (9.2%)	482 (9.1%)	71 (9.1%)	
3rd Quartile	64 (1.1%)	56 (1.1%)	–	
Med Household Income				p > .05

0 – 30K	426 (7.0%)	377 (7.1%)	49 (6.6%)	
30K – 60K	3,256 (53.7%)	2,874 (54.0%)	382 (51.7%)	
60K – 90K	1,639 (27.0%)	1,423 (26.7%)	216 (29.2%)	
90K+	740 (12.2%)	648 (12.2%)	92 (12.5%)	
Urbanization				p > .05
Metro	4,845 (79.7%)	4,234 (79.3%)	611 (82.4%)	
Urban	1,069 (17.6%)	957 (17.9%)	112 (15.1%)	
Rural	165 (2.7%)	146 (2.7%)	19 (2.6%)	
Geographic region				p > .05
Northeast	355 (5.84%)	314 (5.9%)	41 (5.5%)	
Midwest	880 (14.5%)	788 (14.8%)	92 (12.4%)	
South	2,815 (46.3%)	2,450 (45.9%)	365 (49.2%)	
West	2,029 (33.4%)	1,785 (33.5%)	244 (32.9%)	

Table 3.2 Patient and neighborhood factors associated with recurrence				
	Unadjusted (n=742)		Adjusted (n=623)	
	OR	(95% CI)	OR	(95% CI)
Patient-level characteristics				
Age (Mean)	0.99	(0.98 – 1.00)	1.00	(0.99 – 1.02)
Race/ethnicity				
NHW	Ref.	–	Ref.	–
Black	1.14	(0.86 – 1.50)	1.13	(0.81 – 1.58)
Hispanic	1.29	(0.95 – 1.76)	1.16	(0.80 – 1.68)
Gender				
Male	Ref.	–	Ref.	–
Female	0.93	(0.80 – 1.08)	0.91	(0.75 – 1.10)
Marital Status				
Single	Ref.	–	Ref.	–
Married	1.14	(0.87 – 1.50)	1.14	(0.83 – 1.56)
Other	1.06	(0.80 – 1.42)	1.07	(0.77 – 1.50)
Medicaid				
No	Ref.	–	Ref.	–
Yes	**1.35**	**(1.12 – 1.63)**	1.17	(0.92 – 1.49)
Stage				
II	Ref.	–	Ref.	–
High-risk II	1.23	(0.97 – 1.56)	1.20	(0.92 – 1.58)
III	**1.85**	**(1.56 – 2.20)**	**1.49**	**(1.19 – 1.88)**
Adjuvant treatment				
None	Ref.	–	Ref.	–
Chemo	**2.03**	**(1.72 – 2.39)**	**1.86**	**(1.47 – 2.35)**
Rad	**1.80**	**(1.21 – 2.66)**	**2.09**	**(1.34 – 3.26)**
Chemo+ Rad	**3.31**	**(2.24 – 4.91)**	**3.21**	**(1.99 – 5.17)**
Comorbidity				
0	Ref.	–	Ref.	–
1	1.19	(0.98 – 1.46)	1.18	(0.93 – 1.48)
2	**1.38**	**(1.10 – 1.74)**	**1.56**	**(1.19 – 2.04)**
3+	**1.42**	**(1.15 – 1.75)**	**1.67**	**(1.30 – 2.15)**
Neighborhood-level characteristics				
% Black Composition				
Lowest Quartile	Ref.	–	Ref.	–
2nd Quartile	**1.47**	**(1.07 – 2.03)**	**1.53**	**(1.07 – 2.20)**
3rd Quartile	1.19	(0.76 – 1.86)	1.28	(0.75 – 2.16)
Highest Quartile	0.78	(0.49 – 1.25)	0.81	(0.44 – 1.47)
% Hispanic Composition				
Lowest Quartile	Ref.	–	Ref.	–
2nd Quartile	1.15	(0.88 – 1.51)	1.06	(0.77 – 1.45)
3rd Quartile	1.28	(0.86 – 1.91)	1.32	(0.79 – 2.22)
Highest Quartile	1.18	(0.73 – 1.90)	1.17	(0.56 – 2.41)
% < HS education				
Lowest Quartile	Ref.	–	Ref.	–
2nd Quartile	1.06	(0.82 – 1.38)	0.87	(0.59 – 1.30)
3rd Quartile	1.03	(0.49 – 2.17)	1.40	(0.51 – 3.84)

Med Household Income				
0 – 30K	Ref.	–	Ref.	–
30K – 60K	1.02	(0.75 – 1.40)	1.10	(0.73 – 1.65)
60K – 90K	1.17	(0.84 – 1.62)	1.15	(0.74 – 1.80)
90K+	1.09	(0.76 – 1.58)	1.33	(0.82 – 2.15)
Urbanization				
Metro	Ref.	–	Ref.	–
Urban	0.81	(0.66 – 1.00)	0.96	(0.74 – 1.25)
Rural	0.90	(0.55 – 1.47)	0.77	(0.40 – 1.45)
Geographic region				
Northeast	Ref.	–	Ref.	–
Midwest	0.89	(0.61 – 1.32)	0.91	(0.58 – 1.42)
South	1.14	0.81 – 1.61)	1.13	(0.77 – 1.66)
West	1.05	(0.74 – 1.49)	0.94	(0.63 – 1.39)

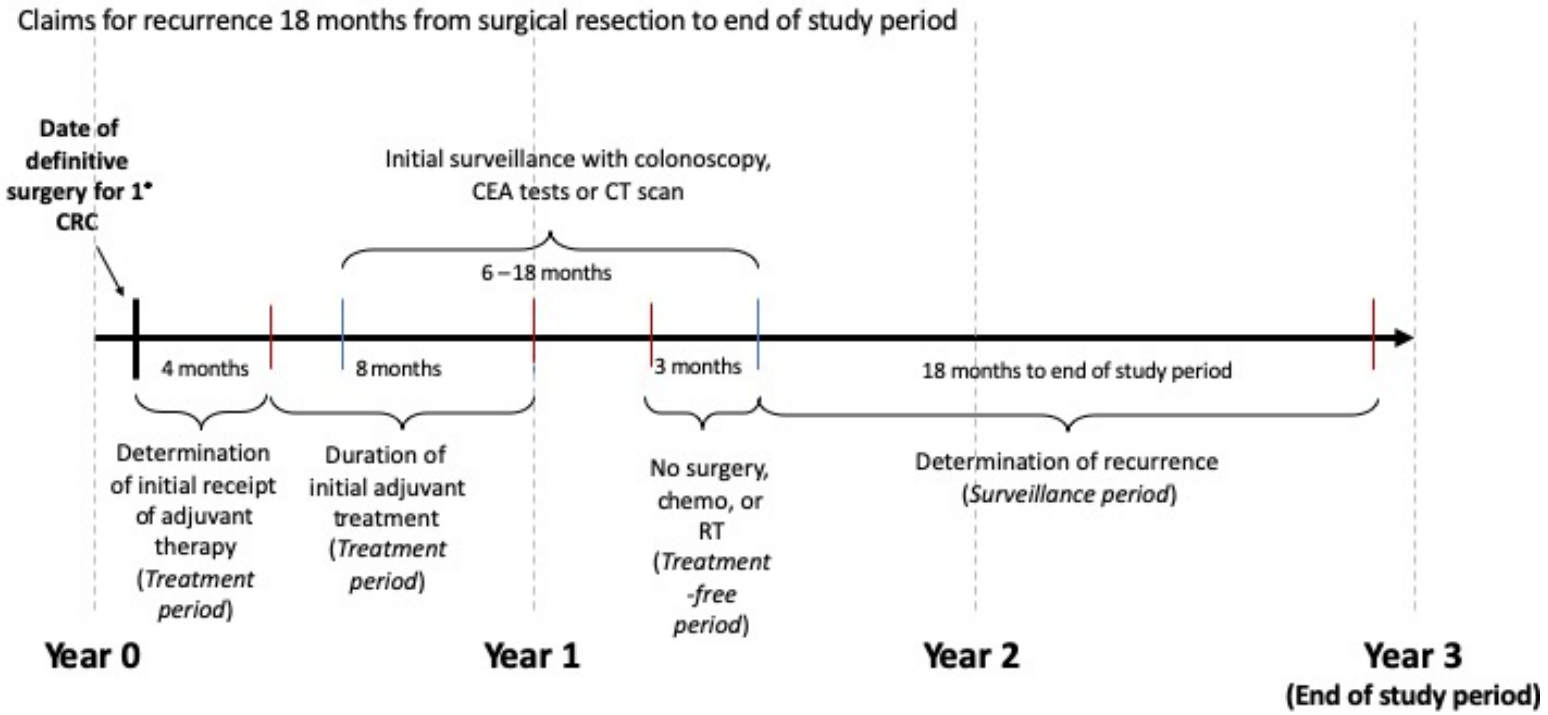
Table 3.3 Surveillance behaviors by recurrence status

	No Recurrence (n=5.337)	**Recurrence (n=742)**
Surveillance behaviors	n (%)	n (%)
Received no surveillance	716 (13.4%)	65 (8.8%)
Received some surveillance	4,621 (86.6%)	677 (91.2%)
Colonoscopy + CEA test + CT scan	1,796 (38.9%)	296 (43.7%)
Colonoscopy + CEA test	860 (18.6%)	100 (14.8%)
Colonoscopy + CT scan	113 (2.4%)	20 (3.0%)
CEA test + CT scan	826 (17.9%)	148 (21.9%)
Colonoscopy Only	268 (5.8%)	14 (2.1%)
CEA test Only	561 (12.1%)	68 (10.0%)
CT scans Only	197 (4.3%)	31 (4.6%)

Table 3.4 Association between surveillance procedures and recurrence

	Unadjusted OR (95% CI)	Adjusted OR (95% CI)
Colonoscopy	1.04 (0.89–1.22)	0.95 (0.79–1.15)
CEA	**1.51 (1.23–1.84)**	1.21 (0.95–1.55)
CT	**1.64 (1.40–1.93)**	**1.43 (1.18–1.74)**

Figure 4.1 Period of observation used for identifying indicators of recurrence and surveillance procedures



Supplemental Tables

Supplemental Table 1 Codes used to define recurrence and surveillance procedures	
	Codes
Surgical resection	ICD-9 diagnosis codes: 153-154.9, 158.x-159.x, 560, 560.8x-560.9 ICD-9-CM procedure codes: 45.7x, 45.8x or 17.3x, 48.4x, 48.6x, 46.1x, 46.2x HCPCS codes: 44140 – 44160, 44204-44212, 45110 – 45123, 45160, 45170 SEER surgical codes: 30-70
Adjuvant therapy	Chemotherapy ICD-9 procedure codes: 99.25 ICD-9 diagnosis codes: V58.1, V66.2, V67.2 CPT codes: 96408, 96410, 96412, 96414, 96520, 96530, 96545 Revenue Center Codes: 0331, 0332, 0335 HCPCS: G0921-G0932, J0640, J9190, J9263, J8520, J8521, J9206, J9035, J9055, J9303, J9400, J3590, J3490, J9999, Q0083-Q0085, C9205 Radiation ICD-9-CM procedure: 92.21-92.29 CPT codes: 77401-77499 or 77750-77799 Revenue Center Codes: 0330 or 0333
Colonoscopy	CPT codes: 44388-44389, 44392-44394, 45378, 45380, 45382-85, 45391, G0105, G0120-21 ICD9-CM procedure codes: 45.23, 45.25, 45.41, 45.42, 45.43
CEA test	CPT Code: 82378
CT scan	CPT Codes: (Thorax) 71250, 71260, 71270, 71275; (Abdomen) 74150, 74160, 74170, 74175-74178; (Pelvis) 72192-72194 ICD9-CM- (Thorax) 87.41; (Abdomen) 88.01; (Pelvis) 88.38
Indicators of recurrence	Surgery ICD-9 diagnosis codes: 153-154.9, 158.x-159.x, 560, 560.8x-560.9; ICD-9 procedure codes:45.7x, 45.8, 48.4x-48.6x, 46.1x, 46.2x, 68.8; HCPCS: 44140-44160, 44204-44212, 45111-45123, 45160, 45170, 45110, 45126, 51597, 58240, 44320, 44310 Chemotherapy ICD-9 diagnosis codes: V58.1 ICD-9 procedures: 99.25, HCPCS- 964xx, 965xx, Q0083-Q0085, G0355-G0362, C1167, C9205, C9213-215, C9217, C9235, C9247, C9257, C9431, C9432, C9417, C9418, C9420, C9421, J0640, J8520, J8521, J8530, J8610, J9000-J9999, Q2024 NDC Codes: 00004-1100-13, 54868-4143-03 Radiation ICD-9 diagnosis codes: V58.0, V67.1 ICD-9 procedures: 92.21-92.29 HCPCS: 77261, 77299, 77300-399, 77401-499, 77520, 77523, 77750, 77799, G0256, G0261 Revenue center codes: 0330, 0333 Metastasis (Lung) ICD-9 diagnosis: 197.0-197.3 ICD-9 procedures: 34.02, 32.x (except 32.22), 32.23, 32.34 HCPCS: 32095, 32100, 32440-32522

	Metastasis (Liver) ICD-9 diagnosis: 197.7 ICD-9 procedures: 50.2s (50.20-50.22), 50.29, 50.3, 50.4 HCPCS: 36246, 36247, 36260, 47100, 47120, 47122, 47125, 47130, 47370, 47371, 47380-82, 47399, 49200, 76362, 76394, 76490, C2618 Metastasis (Other) ICD-9 diagnosis: 197.4-197.6, 197.8, 199.0, 198.3, 196.xx, 198.0-198.2, 198.4, 198.6-198.8, 198.82, 198.89, 198.5, 733.1x ICD-9 procedures: 32.23, 32.24, 38.86, 50.23-.29, 17.63, 81.65, 81.66 HCPCS: 32095, 32100, 32440-32522, 37204, 75894-75898, 22520-22522, S2360-S2363, 76012, 76013, 20982

CHAPTER 5: Conclusion

The present studies assess the association between key sociodemographic and economic factors that measure access to care and receipt of surveillance procedures in a large population-based sample of Medicare beneficiaries with surgically resected CRC. Although national clinical guidelines recommend timely receipt of CRC surveillance for the early detection of second primary CRC and recurrent disease, evidence suggests underutilization of surveillance procedures among eligible CRC patients. In our study, receipt of initial colonoscopy remains low (57.5%). Similarly, utilization of guideline-recommended surveillance CEA tests and CT scans among CRC patients continues to be a challenge and many patients fail the meet the recommended national guidelines, with 78% and 58.2% of patients receiving CEA tests and a CT scan as recommended.

Our findings suggest significant differences in receipt of a colonoscopy between Blacks and NHW patients, but no racial/ethnic disparities in receipt of CEA tests and a CT scan were observed. Although this study found a lack of significant differences in receipt of surveillance procedures between Hispanics and NHWs, assessment of the socioeconomic factors that measure access to cancer care suggest inequitable access to receipt of surveillance procedures within and across racial/ethnic groups. In particular, we identified differential effects of Medicaid coverage on receipt of surveillance procedures across racial/ethnic groups. Among NHWs, Medicaid coverage was associated with lower odds of receipt of surveillance, while among minority patients Medicaid coverage served as an enabling factor that facilitated access to and receipt of surveillance procedures. We also identified potential spatial-related barriers in access to and receipt of CT scans among NHWs, such that patients living in the southern and western geographical areas of the U.S. were less likely to receive initial CT scans as recommended. Studies evaluating physician- and health system-related factors are needed to better understand geo-spatial barriers to access to CRC surveillance. Future studies with larger samples of racial/ethnically and geographically diverse populations may help to further disentangle these effect.

This research also described the characteristics of CRC patients with recurrence and their surveillance behaviors. In our study, 12.2% of patients had recurrent disease after 18-months following surgical resection and only 43.7% of these patients had received a colonoscopy, CEA tests, and a CT scan as recommended by national clinical guidelines. In addition to clinical factors, Black neighborhood

density was significantly associated with recurrence. Receipt of timely surveillance procedures for the early detection of recurrent disease was low (43.7%), and only CT scans were significantly associated with recurrence after adjusting for key patient and neighborhood factors.

Overall, there is a significant need for organized approaches to CRC surveillance in various settings including clinical and community settings. Results from these studies can guide policy to tailor clinical and public health interventions for Medicare populations at-risk of recurrence who may have limited access to CRC care and who experience disparities in CRC-related outcomes. Since the ultimate goal of CRC surveillance is to detect local and distant recurrent disease early, findings from this study may better inform and assist shared decision making for older adult patients, their families and providers.

References

1. Jorgensen, M.L., J.M. Young, and M.J. Solomon, *Optimal delivery of colorectal cancer follow-up care: improving patient outcomes.* Patient related outcome measures, 2015. **6**: p. 127.
2. Tjandra, J.J. and M.K. Chan, *Follow-up after curative resection of colorectal cancer: a meta-analysis.* Diseases of the colon & rectum, 2007. **50**(11): p. 1783-1799.
3. White, A., et al., *Colon cancer survival in the United States by race and stage (2001-2009): Findings from the CONCORD-2 study.* Cancer, 2017. **123**(S24): p. 5014-5036.
4. Steele, S.R., et al., *Practice guideline for the surveillance of patients after curative treatment of colon and rectal cancer.* Diseases of the Colon & Rectum, 2015. **58**(8): p. 713-725.
5. Moy, B., et al., *Surveillance after colorectal cancer resection.* UpToDateR, c2016. www. uptodate. com/ contents/ surveillance-after-colorectal-cancer-resection, 2016.
6. Carpentier, M.Y., et al., *Receipt of recommended surveillance among colorectal cancer survivors: a systematic review.* Journal of Cancer Survivorship, 2013. **7**(3): p. 464-483.
7. Brawarsky, P., et al., *Surveillance after resection for colorectal cancer.* Cancer, 2013. **119**(6): p. 1235-1242.
8. Cooper, G.S., T.D. Kou, and H.L. Reynolds, *Receipt of guideline-recommended follow-up in older colorectal cancer survivors.* Cancer, 2008. **113**(8): p. 2029-2037.
9. Knopf, K.B., et al., *Bowel surveillance patterns after a diagnosis of colorectal cancer in Medicare beneficiaries.* Gastrointestinal endoscopy, 2001. **54**(5): p. 563-571.
10. Cooper, G.S. and J.D. Payes, *Temporal trends in colorectal procedure use after colorectal cancer resection.* Gastrointestinal endoscopy, 2006. **64**(6): p. 933-940.
11. Lafata, J.E., et al., *Sociodemographic differences in the receipt of colorectal cancer surveillance care following treatment with curative intent.* Medical care, 2001. **39**(4): p. 361-372.
12. Lafata, J.E., et al., *Routine surveillance care after cancer treatment with curative intent.* Medical care, 2005. **43**(6): p. 592-599.
13. Siegel, R.L., et al., *Colorectal cancer statistics, 2017.* CA: a cancer journal for clinicians, 2017. **67**(3): p. 177-193.
14. Edwards, B.K., et al., *Annual report to the nation on the status of cancer, 1975-2006, featuring colorectal cancer trends and impact of interventions (risk factors, screening, and treatment) to reduce future rates.* Cancer, 2010. **116**(3): p. 544-573.
15. American Cancer Society. *Colorectal Cancer Facts & Figures 2017*. 2017 [cited 2017; Available from: https://www.cancer.org/content/dam/cancer-org/research/cancer-facts-and-statistics/colorectal-cancer-facts-and-figures/colorectal-cancer-facts-and-figures-2017-2019.pdf.
16. Ryuk, J.P., et al., *Predictive factors and the prognosis of recurrence of colorectal cancer within 2 years after curative resection.* Annals of surgical treatment and research, 2014. **86**(3): p. 143-151.
17. Sineshaw, H.M., A.S. Robbins, and A. Jemal, *Disparities in survival improvement for metastatic colorectal cancer by race/ethnicity and age in the United States.* Cancer Causes & Control, 2014. **25**(4): p. 419-423.
18. Albain, K.S., et al., *Racial disparities in cancer survival among randomized clinical trials patients of the Southwest Oncology Group.* JNCI: Journal of the National Cancer Institute, 2009. **101**(14): p. 984-992.
19. Sineshaw, H.M., et al., *Factors That Contribute to Differences in Survival of Black vs White Patients With Colorectal Cancer.* Gastroenterology, 2017.
20. Berry, J., et al., *Examining racial disparities in colorectal cancer care.* Journal of psychosocial oncology, 2009. **27**(1): p. 59-83.
21. Castells, A., *Postoperative surveillance in nonmetastatic colorectal cancer patients: yes, but….* 2015, Oxford University Press.
22. Doubeni, C.A. and A. Rustgi, *Racial disparities in colorectal cancer survival: Is elimination of variation in care the cure?* JNCI: Journal of the National Cancer Institute, 2015. **107**(10).
23. Rose, J., K.M. Augestad, and G.S. Cooper, *Colorectal cancer surveillance: what's new and what's next.* World Journal of Gastroenterology: WJG, 2014. **20**(8): p. 1887.
24. Young, P.E., et al., *Early detection of colorectal cancer recurrence in patients undergoing surgery with curative intent: current status and challenges.* Journal of Cancer, 2014. **5**(4): p. 262.

25. Kahi, C.J., et al., *Colonoscopy surveillance after colorectal cancer resection: recommendations of the US multi-society task force on colorectal cancer.* Gastroenterology, 2016. **150**(3): p. 758-768. e11.
26. Desch, C.E., et al., *Colorectal cancer surveillance: 2005 update of an American Society of Clinical Oncology practice guideline.* Journal of Clinical Oncology, 2005. **23**(33): p. 8512-8519.
27. Godhi, S., et al., *Colorectal Cancer: Postoperative Follow-up and Surveillance.* Indian Journal of Surgery, 2017. **79**(3): p. 234-237.
28. Primrose, J.N., et al., *Effect of 3 to 5 years of scheduled CEA and CT follow-up to detect recurrence of colorectal cancer: the FACS randomized clinical trial.* Jama, 2014. **311**(3): p. 263-270.
29. Meyerhardt, J.A., et al., *Follow-up care, surveillance protocol, and secondary prevention measures for survivors of colorectal cancer: American Society of Clinical Oncology clinical practice guideline endorsement.* J Clin Oncol, 2013. **31**(35): p. 4465-4470.
30. National Cancer Institute. *Cancer Stat Facts: Colorectal Cancer*. 2017; Available from: https://seer.cancer.gov/statfacts/html/colorect.html.
31. Rodríguez-Moranta, F., et al., *Postoperative surveillance in patients with colorectal cancer who have undergone curative resection: a prospective, multicenter, randomized, controlled trial.* Journal of Clinical Oncology, 2006. **24**(3): p. 386-393.
32. Ellison, G.L., et al., *Racial differences in the receipt of bowel surveillance following potentially curative colorectal cancer surgery.* Health services research, 2003. **38**(6p2): p. 1885-1904.
33. Salz, T., et al., *Variation in use of surveillance colonoscopy among colorectal cancer survivors in the United States.* BMC health services research, 2010. **10**(1): p. 256.
34. Hu, C.-Y., et al., *Post-treatment surveillance in a large cohort of patients with colon cancer.* The American journal of managed care, 2011. **17**(5): p. 329-336.
35. Paulson, E.C., et al., *Trends in surveillance for resected colorectal cancer, 2001-2009.* Cancer, 2015. **121**(19): p. 3525-3533.
36. Ford, M.E., et al., *Factors Influencing Adherence to Recommended Colorectal Cancer Surveillance: Experiences and Behaviors of Colorectal Cancer Survivors.* Journal of Cancer Education, 2018: p. 1-12.
37. Salz, T., et al., *Ethnic disparities in colonoscopy use among colorectal cancer survivors: a systematic review.* Journal of Cancer Survivorship, 2012. **6**(4): p. 372-378.
38. Abbott, D.E., et al., *Socioeconomic disparities, financial toxicity, and opportunities for enhanced system efficiencies for patients with cancer.* Journal of surgical oncology, 2017.
39. Courtney, E., et al., *Screen-detected colorectal cancers show improved cancer-specific survival when compared with cancers diagnosed via the 2-week suspected colorectal cancer referral guidelines.* Colorectal disease, 2013. **15**(2): p. 177-182.
40. Smoragiewicz, M., H. Lim, and R.D.A. Peixoto, *Surveillance for asymptomatic recurrence in resected stage III colon cancer: does it result in a more favorable outcome?* Journal of gastrointestinal oncology, 2015. **6**(3): p. 268.
41. Alnimer, Y., et al., *Factors associated with short recurrence-free survival in completely resected colon cancer.* Journal of community hospital internal medicine perspectives, 2017. **7**(6): p. 341-346.
42. Tsikitis, V.L., et al., *Predictors of recurrence free survival for patients with stage II and III colon cancer.* BMC cancer, 2014. **14**(1): p. 336.
43. Raj, K.P., et al., *Risk of second primary colorectal cancer among colorectal cancer cases: a population-based analysis.* Journal of carcinogenesis, 2011. **10**.
44. Holmes, A.C., et al., *Descriptive characteristics of colon and rectal cancer recurrence in a Danish population-based study.* Acta Oncologica, 2017. **56**(8): p. 1111-1119.
45. Warren, J.L., et al., *Sensitivity of Medicare claims to identify cancer recurrence in elderly colorectal and breast cancer patients.* Medical care, 2016. **54**(8): p. e47.
46. Zapka, J.G., et al., *A framework for improving the quality of cancer care: the case of breast and cervical cancer screening.* Cancer Epidemiology and Prevention Biomarkers, 2003. **12**(1): p. 4-13.
47. Taplin, S.H. and A.B. Rodgers, *Toward improving the quality of cancer care: addressing the interfaces of primary and oncology-related subspecialty care.* Journal of the National Cancer Institute Monographs, 2010. **2010**(40): p. 3-10.

48. Pita-Fernandez, S., et al., *Intensive follow-up strategies improve outcomes in nonmetastatic colorectal cancer patients after curative surgery: a systematic review and meta-analysis.* Annals of Oncology, 2014. **26**(4): p. 644-656.
49. Nannini, M., M.A. Pantaleo, and G. Biasco, *The Follow-up After Radical Surgery of Colorectal Cancer: Is it Time for a "Tailored" Strategy?* Clinical colorectal cancer, 2011. **10**(2): p. 81-84.
50. Fahy, B.N., *Follow-up after curative resection of colorectal cancer.* Annals of surgical oncology, 2014. **21**(3): p. 738-746.
51. Andersen, R.M., *Revisiting the behavioral model and access to medical care: does it matter?* Journal of health and social behavior, 1995: p. 1-10.
52. Andersen, R. and L.A. Aday, *Access to medical care in the US: realized and potential.* Medical care, 1978: p. 533-546.
53. Babitsch, B., D. Gohl, and T. von Lengerke, *Re-revisiting Andersen's Behavioral Model of Health Services Use: a systematic review of studies from 1998–2011.* GMS Psycho-Social-Medicine, 2012. **9**.
54. Cheung, W.Y., et al., *Adherence to surveillance guidelines after curative resection for stage II/III colorectal cancer.* Clinical colorectal cancer, 2008. **7**(3): p. 191-196.
55. Aday, L.A. and R. Andersen, *A framework for the study of access to medical care.* Health services research, 1974. **9**(3): p. 208.
56. Andersen, R.M., *National health surveys and the behavioral model of health services use.* Medical care, 2008. **46**(7): p. 647-653.
57. Institute of Medicine, *Access to health care in America.* Institute of Medicine (IOM) Committee on Monitoring Access to Personal Health Care Services, 1993.
58. Gulzar, L., *Access to health care.* Journal of nursing scholarship, 1999. **31**(1): p. 13-19.
59. Khan, A.A. and S.M. Bhardwaj, *Access to health care: a conceptual framework and its relevance to health care planning.* Evaluation & the health professions, 1994. **17**(1): p. 60-76.
60. Ramsey, S.D., et al., *Surveillance endoscopy does not improve survival for patients with local and regional stage colorectal cancer.* Cancer, 2007. **109**(11): p. 2222-2228.
61. Figueredo, A., et al., *Follow-up of patients with curatively resected colorectal cancer: a practice guideline.* BMC cancer, 2003. **3**(1): p. 26.
62. Deshpande, A.D., M. Schootman, and A. Mayer, *Development of a claims-based algorithm to identify colorectal cancer recurrence.* Annals of epidemiology, 2015. **25**(4): p. 297-300.
63. Walker, A.S., et al., *Future directions for the early detection of colorectal cancer recurrence.* Journal of cancer, 2014. **5**(4): p. 272.
64. Murphy, C.C., et al., *Underuse of surveillance colonoscopy in patients at increased risk of colorectal cancer.* The American journal of gastroenterology, 2015. **110**(5): p. 633.
65. Kirby, J.B. and T. Kaneda, *Neighborhood socioeconomic disadvantage and access to health care.* Journal of health and social behavior, 2005. **46**(1): p. 15-31.
66. Ellis, L., et al., *Racial and ethnic disparities in cancer survival: the contribution of tumor, sociodemographic, institutional, and neighborhood characteristics.* Journal of Clinical Oncology, 2017. **36**(1): p. 25-33.
67. Fang, C.Y. and M. Tseng, *Ethnic density and cancer: A review of the evidence.* Cancer, 2018.
68. Attri, K.S., D. Murthy, and P.K. Singh, *Racial disparity in metabolic regulation of cancer.* Frontiers in bioscience (Landmark edition), 2017. **22**: p. 1221.
69. Breen, N., et al., *Assessing disparities in colorectal cancer mortality by socioeconomic status using new tools: health disparities calculator and socioeconomic quintiles.* Cancer Causes & Control, 2017. **28**(2): p. 117-125.
70. Byers, T.E., et al., *The impact of socioeconomic status on survival after cancer in the United States.* Cancer, 2008. **113**(3): p. 582-591.
71. Pickett, K.E. and R.G. Wilkinson, *Income inequality and health: a causal review.* Social science & medicine, 2015. **128**: p. 316-326.
72. Pruitt, S.L., et al., *Missed opportunities: racial and neighborhood socioeconomic disparities in emergency colorectal cancer diagnosis and surgery.* BMC cancer, 2014. **14**(1): p. 927.
73. Gomez, S.L., et al., *The impact of neighborhood social and built environment factors across the cancer continuum: current research, methodological considerations, and future directions.* Cancer, 2015. **121**(14): p. 2314-2330.

74. Warren, J.L., et al., *Overview of the SEER-Medicare data: content, research applications, and generalizability to the United States elderly population.* Medical care, 2002. **40**(8): p. IV-3-IV-18.
75. Warren, J.L. and K.R. Yabroff, *Challenges and opportunities in measuring cancer recurrence in the United States.* JNCI: Journal of the National Cancer Institute, 2015. **107**(8).
76. Bach, P.B., et al., *Patient demographic and socioeconomic characteristics in the SEER-Medicare database: applications and limitations.* Medical care, 2002. **40**(8): p. IV-19-IV-25.
77. Lund, J.L., et al., *Identifying specific chemotherapeutic agents in Medicare data: a validation study.* Medical care, 2013. **51**(5): p. e27.
78. Austin, S.R., et al., *Why summary comorbidity measures such as the Charlson comorbidity index and Elixhauser score work.* Medical care, 2015. **53**(9): p. e65.
79. Egleston, B.L. and Y.N. Wong, *Sensitivity analysis to investigate the impact of a missing covariate on survival analyses using cancer registry data.* Statistics in medicine, 2009. **28**(10): p. 1498-1511.
80. Kupfer, S.S., et al., *Adherence to postresection colorectal cancer surveillance at National Cancer Institute‐designated Comprehensive Cancer Centers.* Cancer medicine, 2018. **7**(11): p. 5351-5358.
81. White, A., et al., *Racial disparities in colorectal cancer survival.* Cancer, 2010. **116**(19): p. 4622-4631.
82. Du, X.L., et al., *Racial disparities and socioeconomic status in association with survival in a large population‐based cohort of elderly patients with colon cancer.* Cancer, 2007. **110**(3): p. 660-669.
83. Neugut, A.I., et al., *Adherence to colonoscopy at 1 year following resection of localized colon cancer: a retrospective cohort study.* Therapeutic Advances in Gastroenterology, 2018. **11**: p. 1756284818765920.
84. Manzoli, L., et al., *Marital status and mortality in the elderly: a systematic review and meta-analysis.* Social science & medicine, 2007. **64**(1): p. 77-94.
85. Gomez, S.L., et al., *Longitudinal, population-based study of racial/ethnic differences in colorectal cancer survival: impact of neighborhood socioeconomic status, treatment and comorbidity.* BMC cancer, 2007. **7**(1): p. 193.
86. Aizer, A.A., et al., *Marital status and survival in patients with cancer.* Journal of clinical oncology, 2013. **31**(31): p. 3869-3876.
87. Pinquart, M. and P.R. Duberstein, *Associations of social networks with cancer mortality: a meta-analysis.* Critical reviews in oncology/hematology, 2010. **75**(2): p. 122-137.
88. National Academies of Sciences, E. and Medicine, *Accounting for Social Risk Factors in Medicare Payment: Data*. 2016, Washington, DC: The National Academies Press. 82.
89. Halpern, M. and D. Holden, *Disparities in timeliness of care for US Medicare patients diagnosed with cancer.* Current Oncology, 2012. **19**(6): p. e404.
90. Pulte, D., L. Jansen, and H. Brenner, *Social disparities in survival after diagnosis with colorectal cancer: contribution of race and insurance status.* Cancer epidemiology, 2017. **48**: p. 41-47.
91. Murphy, C.C., et al., *Longitudinal predictors of colorectal cancer screening among participants in a randomized controlled trial.* Preventive medicine, 2014. **66**: p. 123-130.
92. Murphy, C.C., et al., *Race and insurance differences in the receipt of adjuvant chemotherapy among patients with stage III colon cancer.* Journal of Clinical Oncology, 2015. **33**(23): p. 2530.
93. Gorey, K.M., et al., *Effects of being uninsured or underinsured and living in extremely poor neighborhoods on colon cancer care and survival in California: historical cohort analysis, 1996—2011.* BMC Public Health, 2012. **12**(1): p. 897.
94. Abdelsattar, Z.M., S. Hendren, and S.L. Wong, *The impact of health insurance on cancer care in disadvantaged communities.* Cancer, 2017. **123**(7): p. 1219-1227.
95. Dawes, A.J., et al., *The impact of continuous Medicaid enrollment on diagnosis, treatment, and survival in six surgical cancers.* Health services research, 2014. **49**(6): p. 1787-1811.
96. Fieldston, E.S., et al., *Community household income and resource utilization for common inpatient pediatric conditions.* Pediatrics, 2013. **132**(6): p. e1592-e1601.
97. Kietzman, K.G., et al., *Multisectoral Collaborations to Increase the Use of Recommended Cancer Screening and Other Clinical Preventive Services by Older Adults.* The Gerontologist, 2019. **59**(Supplement_1): p. S57-S66.
98. Purnell, T.S., et al., *Achieving health equity: closing the gaps in health care disparities, interventions, and research.* Health Affairs, 2016. **35**(8): p. 1410-1415.

99. Dohan, D. and D. Schrag, *Using navigators to improve care of underserved patients: current practices and approaches.* Cancer, 2005. **104**(4): p. 848-855.
100. Kind, A.J., et al., *Neighborhood socioeconomic disadvantage and 30 day rehospitalizations: an analysis of Medicare data.* Annals of internal medicine, 2014. **161**(11): p. 765.
101. Jeffery, M., et al., *Follow-up strategies for patients treated for non-metastatic colorectal cancer.* The Cochrane Library, 2016.
102. Kanas, G.P., et al., *Survival after liver resection in metastatic colorectal cancer: review and meta-analysis of prognostic factors.* Clinical epidemiology, 2012. **4**: p. 283.
103. Pfannschmidt, J., H. Hoffmann, and H. Dienemann, *Reported outcome factors for pulmonary resection in metastatic colorectal cancer.* Journal of thoracic oncology, 2010. **5**(6): p. S172-S178.
104. Augestad, K., et al., *Metastatic spread pattern after curative colorectal cancer surgery. A retrospective, longitudinal analysis.* Cancer epidemiology, 2015. **39**(5): p. 734-744.
105. Lian, M., et al., *Geographic variation in colorectal cancer survival and the role of small-area socioeconomic deprivation: a multilevel survival analysis of the NIH-AARP Diet and Health Study Cohort.* American journal of epidemiology, 2011. **174**(7): p. 828-838.
106. Hiatt, R.A. and N. Breen, *The social determinants of cancer: a challenge for transdisciplinary science.* American journal of preventive medicine, 2008. **35**(2): p. S141-S150.
107. Sanchez JI, S.V., Unger J, Selukar S, Thompson B, *Inequitable access to receipt of surveillance colonoscopy among Medicare beneficiaries with surgically resected colorectal cancer.* In preparation.
108. Andersen, R.M., et al., *Access to medical care for low-income persons: how do communities make a difference?* Medical care research and review, 2002. **59**(4): p. 384-411.
109. Nattinger, A.B., et al., *Methodological issues in the use of administrative claims data to study surveillance after cancer treatment.* Medical care, 2002. **40**(8): p. IV-69-IV-74.
110. Engels, E.A., et al., *Use of surveillance, epidemiology, and end results-medicare data to conduct case-control studies of cancer among the US elderly.* American journal of epidemiology, 2011. **174**(7): p. 860-870.
111. Renehan, A.G., et al., *Impact on survival of intensive follow up after curative resection for colorectal cancer: systematic review and meta-analysis of randomised trials.* Bmj, 2002. **324**(7341): p. 813.
112. Halpern, M.T., et al., *Association of insurance status and ethnicity with cancer stage at diagnosis for 12 cancer sites: a retrospective analysis.* The lancet oncology, 2008. **9**(3): p. 222-231.
113. Doubeni, C.A., et al., *Racial differences in tumor stage and survival for colorectal cancer in an insured population.* Cancer, 2007. **109**(3): p. 612-620.
114. Shankaran, V., et al., *Risk factors for financial hardship in patients receiving adjuvant chemotherapy for colon cancer: a population-based exploratory analysis.* J Clin Oncol, 2012. **30**(14): p. 1608-1614.
115. Arpey, N.C., A.H. Gaglioti, and M.E. Rosenbaum, *How socioeconomic status affects patient perceptions of health care: a qualitative study.* Journal of primary care & community health, 2017. **8**(3): p. 169-175.
116. Tucker-Seeley, R.D. and K.R. Yabroff, *Minimizing the "financial toxicity" associated with cancer care: advancing the research agenda.* JNCI: Journal of the National Cancer Institute, 2016. **108**(5).
117. Altman, D. and W.H. Frist, *Medicare and Medicaid at 50 years: perspectives of beneficiaries, health care professionals and institutions, and policy makers.* Jama, 2015. **314**(4): p. 384-395.
118. Rogers, S.O., W.A. Ray, and W.E. Smalley, *A population-based study of survival among elderly persons diagnosed with colorectal cancer: does race matter if all are insured?(United States).* Cancer Causes & Control, 2004. **15**(2): p. 193-199.
119. Phelan, J.C., B.G. Link, and P. Tehranifar, *Social conditions as fundamental causes of health inequalities: theory, evidence, and policy implications.* Journal of health and social behavior, 2010. **51**(1_suppl): p. S28-S40.
120. Marcus, A.F., et al., *Relationships between social isolation, neighborhood poverty, and cancer mortality in a population-based study of US adults.* PloS one, 2017. **12**(3): p. e0173370.
121. Palos, G.R., et al., *Providers' adherence to surveillance recommendations for colon and rectal cancer survivors.* Journal of Clinical Oncology, 2016. **34**(15_suppl): p. e21571-e21571.

122. Hawkins, N.A., et al. *Examining adherence with recommendations for follow-up in the Prevention Among Colorectal Cancer Survivors Study*. in *Oncology nursing forum*. 2015. NIH Public Access.
123. Mollica, M.A., et al., *Examining colorectal cancer survivors' surveillance patterns and experiences of care: a SEER-CAHPS study.* Cancer Causes & Control, 2017. **28**(10): p. 1133-1141.
124. Earle, C.C., et al., *Identifying cancer relapse using SEER-Medicare data.* Medical care, 2002. **40**(8): p. IV-75-IV-81.
125. Lai, Y., et al., *Effects of cancer stage and treatment differences on racial disparities in survival from colon cancer: a United States population-based study.* Gastroenterology, 2016. **150**(5): p. 1135-1146.
126. Lang, K., et al., *Factors associated with improved survival among older colorectal cancer patients in the US: a population-based analysis.* BMC cancer, 2009. **9**(1): p. 227.
127. Gallagher, D.J. and N. Kemeny, *Metastatic colorectal cancer: from improved survival to potential cure.* Oncology, 2010. **78**(3-4): p. 237-248.
128. Boland, G.M., et al., *Association between adherence to National Comprehensive Cancer Network treatment guidelines and improved survival in patients with colon cancer.* Cancer, 2013. **119**(8): p. 1593-1601.
129. Hassett, M.J., et al., *Detecting lung and colorectal cancer recurrence using structured clinical/administrative data to enable outcomes research and population health management.* Medical care, 2017. **55**(12): p. e88.
130. Chawla, N., et al., *Limited validity of diagnosis codes in Medicare claims for identifying cancer metastases and inferring stage.* Annals of epidemiology, 2014. **24**(9): p. 666-672. e2.
131. Hutchins, L.F., et al., *Underrepresentation of patients 65 years of age or older in cancer-treatment trials.* New England Journal of Medicine, 1999. **341**(27): p. 2061-2067.
132. Unger, J.M., et al., *Patient income level and cancer clinical trial participation: a prospective survey study.* JAMA oncology, 2016. **2**(1): p. 137-139.
133. Unger, J.M., et al., *The role of clinical trial participation in cancer research: barriers, evidence, and strategies.* American Society of Clinical Oncology Educational Book, 2016. **36**: p. 185-198.
134. Unger, J.M., et al., *Geographic distribution and survival outcomes for rural patients with cancer treated in clinical trials.* JAMA network open, 2018. **1**(4): p. e181235-e181235.
135. Unger, J.M., et al., *Association of patient comorbid conditions with cancer clinical trial participation.* JAMA oncology, 2019. **5**(3): p. 326-333.
136. Unger, J.M., et al., *Systematic review and meta-analysis of the magnitude of structural, clinical, and physician and patient barriers to cancer clinical trial participation.* JNCI: Journal of the National Cancer Institute, 2019. **111**(3): p. 245-255.
137. McClish, D., L. Penberthy, and A. Pugh, *Using Medicare claims to identify second primary cancers and recurrences in order to supplement a cancer registry.* Journal of clinical epidemiology, 2003. **56**(8): p. 760-767.
138. Anaya, D.A., et al., *Use of administrative data to identify colorectal liver metastasis.* Journal of Surgical Research, 2012. **176**(1): p. 141-146.
139. Hassett, M.J., et al., *Comparing survival after recurrent vs de novo stage IV advanced breast, lung, and colorectal cancer.* JNCI cancer spectrum, 2018. **2**(2): p. pky024.
140. Du, X., et al., *Accuracy and completeness of Medicare claims data for surgical treatment of breast cancer.* Medical care, 2000. **38**(7): p. 719-727.
141. Cooper, G.S., et al., *Agreement of Medicare claims and tumor registry data for assessment of cancer-related treatment.* Medical care, 2000: p. 411-421.
142. Virnig, B.A., et al., *Studying radiation therapy using SEER-Medicare-linked data.* Medical care, 2002. **40**(8): p. IV-49-IV-54.
143. Cooper, G.S., et al., *Use of SEER-Medicare data for measuring cancer surgery.* Medical care, 2002: p. IV43-IV48.
144. Virnig, B. and A. Dotson Madeira, *Strengths and limitations of CMS administrative data in research.* Research Data Assistance Center: Minneapolis, MN. Retrieved from March, 2012. **23**: p. 2015.
145. Sanchez JI, S.V., Unger J, Thompson B, *Access to and receipt of surveillance CEA tests and CT scans among Medicare beneficiaries with surgically resected colorectal cancer.* In preparation.
146. Jackson, C.S., et al., *Health disparities in colorectal cancer among racial and ethnic minorities in the United States.* Journal of gastrointestinal oncology, 2016. **7**(Suppl 1): p. S32.

147. Lamont, E.B., et al., *Measuring disease-free survival and cancer relapse using Medicare claims from CALGB breast cancer trial participants (companion to 9344).* Journal of the National Cancer Institute, 2006. **98**(18): p. 1335-1338.
148. National Cancer Institute. *SEER-Medicare Linked Database*. 2018 [cited 2018 April 30]; Available from: https://healthcaredelivery.cancer.gov/seermedicare/.
149. Shah, M.A., et al., *Impact of patient factors on recurrence risk and time dependency of oxaliplatin benefit in patients with colon cancer: analysis from modern-era adjuvant studies in the adjuvant colon cancer end points (ACCENT) database.* Journal of Clinical Oncology, 2016. **34**(8): p. 843.
150. Sogaard, M., et al., *The impact of comorbidity on cancer survival: a review.* Clinical epidemiology, 2013. **5**(Suppl 1): p. 3.
151. Mills, K.T., et al., *Diabetes and colorectal cancer prognosis: a meta-analysis.* Diseases of the colon and rectum, 2013. **56**(11): p. 1304.
152. Boehmer, U., et al., *Surveillance after colorectal cancer diagnosis in a safety net hospital.* Journal of health care for the poor and underserved, 2010. **21**(4): p. 1138-1151.
153. Zhang, D., et al., *Does neighbourhood composition modify the association between acculturation and unhealthy dietary behaviours?* J Epidemiol Community Health, 2015. **69**(8): p. 724-731.
154. Bécares, L., et al., *Ethnic density effects on physical morbidity, mortality, and health behaviors: a systematic review of the literature.* American journal of public health, 2012. **102**(12): p. e33-e66.
155. Tan, C.H. and R. Iyer, *Use of computed tomography in the management of colorectal cancer.* World journal of radiology, 2010. **2**(5): p. 151.
156. Porté, F., et al., *CT colonography for surveillance of patients with colorectal cancer: Systematic review and meta-analysis of diagnostic efficacy.* European radiology, 2017. **27**(1): p. 51-60.
157. Shureiqi, I., et al., *Effect of age on risk of second primary colorectal cancer.* Journal of the National Cancer Institute, 2001. **93**(16): p. 1264-1266.
158. Austin, P.C., D.S. Lee, and J.P. Fine, *Introduction to the analysis of survival data in the presence of competing risks.* Circulation, 2016. **133**(6): p. 601-609.
159. Austin, P.C. and J.P. Fine, *Practical recommendations for reporting Fine-Gray model analyses for competing risk data.* Statistics in medicine, 2017. **36**(27): p. 4391-4400.
160. Calip, G.S., E.H. Law, and N.Y. Ko, *Racial and ethnic differences in risk of second primary cancers among breast cancer survivors.* Breast cancer research and treatment, 2015. **151**(3): p. 687-696.
161. American Cancer Society, *Cancer Facts and Figures 2009: Multiple Primary Cancers*. 2009.
162. Meyer, J.E., et al., *Increasing incidence of rectal cancer in patients aged younger than 40 years: an analysis of the surveillance, epidemiology, and end results database.* Cancer, 2010. **116**(18): p. 4354-4359.