Essays on Health Care Quality and Access: Cancer Care Disparities, Composite Measure Development, and Geographic Variations in Electronic Health Record Adoption

Essays on Health Care Quality and Access: Cancer Care Disparities, Composite Measure Development, and Geographic Variations in Electronic Health Record Adoption

A dissertation presented

by

Cleo Alda Samuel

to

The Committee on Higher Degrees in Health Policy

in partial fulfillment of the requirements

for the degree of

Doctor of Philosophy

in the subject of

Health Policy

Harvard University

Cambridge, Massachusetts

March 2014

Professor Thomas McGuire
Professor Alan Zaslavsky

Cleo Alda Samuel

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Abstract

Racial/ethnic disparities in cancer care are well documented in the research literature; however, less is known about the extent and potential source of cancer care disparities in the Veterans Health Administration (VA). In my first paper, I use logistic regression and hospital fixed effects models to examine racial disparities in 20 cancer-related quality measures and the extent to which racial differences in site of care explain VA cancer care disparities. I found evidence of racial disparities in 7 out of 20 cancer-related quality measures. In general, these disparities were primarily driven by racial differences in care for black and white patients within the same VA hospital, rather than racial differences in site of care.

There has been limited use of composite measures for cancer care quality measurement. In my second paper, I employ and compare several grouping (i.e., empirical factor analysis vs. cancer-specific vs. care-modality-specific) and weighting (i.e., fixed- vs. opportunity-weighting) approaches for computing VA hospital-level composite measures of cancer care quality. I assess correlations among composites and estimate all-cause survival for colorectal and lung cancers as a function of composite scores. The empirically-derived care dimensions summarized relationships among care processes and reflected a combination of cancer-specific and care-modality-specific composites. Patterns in predicting patient survival were similar for composites with comparable measure compositions. In addition, opportunity-based composites were subject to variation reflecting differences in the case mix of eligible patients at each hospital rather than actual differences in quality.

In my third paper, I assess geographic variations in electronic health record (EHR) adoption among primary care providers (PCPs) enrolled in the Regional Extension Center (REC) program. I employ hierarchical models to examine associations between EHR adoption among REC-enrolled PCPs and several county-level measures. I found that community health center presence, Medicaid enrollment, and Medicare Advantage enrollment within the county were positively associated with EHR adoption. However, health professional shortage area status and minority concentration were negatively associated with EHR adoption. My findings suggest that federal efforts, such as the Medicare and Medicaid EHR incentive programs, may be encouraging EHR adoption. Still, some geographic disparities in EHR adoption remain a concern.

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Acknowledgements

"Have I not commanded you? Be strong and courageous. Do not be afraid; do not be discouraged, for the Lord your God will be with you wherever you go." (Joshua 1:9)

"For I know the plans I have for you," declares the Lord, "plans to prosper you and not to harm you, plans to give you hope and a future. (Jeremiah 29:11)

"I am the vine; you are the branches. If you remain in me and I in you, you will bear much fruit; apart from me you can do nothing." (John 15:5)

"He shall be like a tree planted by the rivers of water, that brings forth its fruit in its season, whose leaf also shall not wither; and whatever he does shall prosper." (Psalm 1:3)

I give thanks first and foremost to my Lord God Almighty who has been a very present Help throughout my life and graduate school experience. Thank you Lord for giving me the strength and courage to persevere in the face of adversity. My victory is only by your grace and strength. Your praises shall forever be on my lips. Amen.

"Plans fail for lack of counsel, but with many advisers they succeed." (Proverbs 15:22)

I would like to thank my three amazing dissertation committee members, Tom McGuire, Nancy Keating, and Alan Zaslavsky. Thank you for reviewing and providing feedback on every outline, abstract, SAS analytic output, and dissertation/manuscript draft. Most of all, thank you for your time, counsel, and support. I feel very blessed to have had the opportunity to train under your mentorship. Amen.

"Honor your father and your mother, that your days may be long upon the land which the Lord your God is giving you." (Exodus 20:12)

"Start children off on the way they should go, and even when they are old they will not turn from it." (Proverbs 22:6)

"Sensible children bring joy to their [parents];" (Proverbs 15:20)

"Keep on loving each other as brothers and sisters." (Hebrews 13:1)

Family… I love you! Thank you so much for encouraging, loving, and praying for me since the very beginning. To my parents who have made tremendous sacrifices for my future, I love and honor you. Mommy, you remain the strongest person I know. Thank you for always believing in me. Daddy, thank you for sharing wonderful words of wisdom during our morning walks and car rides. To my siblings, Vanne, Homie (Robert), Shay, Jean, Mike, and Billy, thank you for being the best brothers and sisters a woman could ask for. I have learned so much from the six of you over the years and I cherish every moment we have shared. To my beautiful nieces and nephews, Keara, Shemaiah, Joshua, and Robert Jr, your aunt loves and is very proud of you. To my relatives in Haiti and other parts of the Caribbean, thank you for helping to keep me humble and reminded of my origins. Family, this dissertation belongs to all of us and I pray that I have brought you all much pride and joy in achieving this milestone. Amen.

"Blessed is she who believed, for there will be a fulfillment of those things which were told her from the Lord." (Luke 1:45)

Amen.

Dedication

I dedicate this dissertation to the courageous men, women, and families who have served our country in the armed forces. For the wounded and fallen, your sacrifices will never be forgotten. Thank you and God bless.

Chapter 1

Racial Disparities in Cancer Care in the Veterans Affairs Healthcare System and the Role of Site of Care

I. INTRODUCTION

Cancer is the second leading cause of death in the US.[1] Research indicates that overall cancer incidence and mortality rates are higher among blacks relative to whites.[2] This is true despite major advancements in cancer care and outcomes in recent decades. Past research indicates that racial/ethnic disparities in care and outcomes exist for many conditions, but that these disparities are attenuated in the Veterans Affairs (VA) health care system, where financial barriers to care are substantially reduced for eligible veterans.[3-5] However, less is known about the extent of cancer-related disparities in the VA hospital system.

The few studies that have assessed cancer disparities in the VA have generated mixed findings, with some studies finding disparities in cancer care and others reporting equitable care for black and white veterans.[3,4,6-11] Moreover, these studies offer little insight into the factors that might account for any observed disparities in cancer care and outcomes across the entire VA. Hospital care in the U.S. is highly concentrated for black Americans, with facilities caring for a larger share of black patients (minority-serving institutions) often providing lower quality care than non-minority serving institutions.[12,13] In addition, racial differences in hospital site of care have also been linked to racial disparities in receipt of recommended care and outcomes.[12,14,15]

In this study, we build upon and extend earlier work on cancer disparities by assessing racial disparities in cancer care and outcomes in the VA health care system. We also explore the extent to which racial differences in site of care explain any observed disparities in cancer care and outcomes in the VA. We use VA Central Cancer Registry (VACCR) data and VA

administrative data. These data sources capture patient-level characteristics and treatment patterns for all VA cancer patients.

II. BACKGROUND

Evidence of Racial/Ethnic Disparities in Cancer Care and Outcomes

Compared with all other racial/ethnic groups, blacks in the US experience the greatest burden of death from all of the most common forms of cancer.[16] Between 2000-2004 the age-adjusted overall mortality rate (deaths per 100,000) for blacks was 238.8, compared to 190.7 for whites;[2] and recent evidence indicates that disparities in cancer care and outcomes have persisted over time.[17,18]

A variety of factors contribute to the excess burden of cancer mortality among blacks, including differential access to health care, socioeconomic status, and racial differences in receipt of recommended care.[2] In terms of cancer-related care processes, blacks generally lag behind whites in receipt of recommended cancer screening and early diagnosis. In 2009, Virnig *et al.* examined racial differences in stage of diagnosis across 34 types of cancer and found that blacks were diagnosed later than whites for 31 of the 34 cancer types/sites.[19] Black cancer patients are also less likely to receive life-prolonging chemotherapy and treatments. For example, one study showed that compared to 52.4% of white non-Hodgkin lymphoma (NHL) patients, only 43.2% of black NHL patients received recommended chemotherapy.[20] Several studies have also reported lower rates of curative surgery among black early-stage (stage I/II) non-small cell lung cancer (NSCLC) patients. In a study on racial differences in the treatment of early-stage NSCLC patients, Bach *et al.* showed that curative surgery rates were 12.7 percentage points lower for older black patients relative to older white patients and that 5-year survival rates were also much lower for blacks.[21] In addition, their study revealed that the racial disparity in survival was largely attributed to racial differences in receipt of curative surgery.

Thus, it appears that black-white differences in cancer survival are partly attributable to racial differences in receipt of recommended care. And so, identifying the factors driving both, racial disparities in receipt of recommended care and cancer survival, is critical to efforts aimed at mitigating disparities in cancer outcomes.

The VA Hospital System: Context, Quality of Cancer Care, and Disparities

The Veterans Health Administration (VA) operates the largest integrated health care system in the United States. Today, the VA consists of 152 medical centers and close to 1,400 community-based outpatient clinics, community living centers, Vet Centers, and domicilaries serving over 8.3 million veterans annually.[22]

Cancer is the second leading cause of death among veterans.[23,24] Recent work suggests that cancer care in the VA is comparable to or of better quality than care provided to insured individuals in the private-sector.[25-27] Past research also indicates that racial/ethnic disparities in care and outcomes are less pronounced in the VA, where financial barriers to care are substantially reduced for eligible veterans;[3-5] however, these studies have typically focused on disparities in cardiovascular disease, mental health, and preventive/ambulatory care.[28] Less is known about the *extent* and *source* of VA cancer care disparities. The few studies that have assessed cancer disparities in the VA have generated mixed findings, with some studies observing disparities in cancer care and others reporting equitable care for black and white veterans.[3,4,6-11] In addition, most of these studies have typically focused on a few cancer types and/or cancer care quality measures or have examined care in a limited number of VA Medical Centers.

Potential Sources of Racial/Ethnic Disparities in Health Care

The Institute of Medicine's (IOM) 2003 report, *Unequal Treatment: Confronting Racial and Ethnic Disparities in Health Care,* documented the extent of racial/ethnic health care

disparities in the US.[29] The IOM's definition of health care disparities accounts for all racial/ethnic differences in care that are mediated through factors other than patient preferences and clinical appropriateness. This definition acknowledges that minorities typically have lower socioeconomic profiles than whites, that such differences can influence health care quality and use, and as a result, includes such racial differences in socioeconomic status (e.g., income, education) in the accounting of total disparities. Thus, adjusting for socioeconomic status in statistical models estimating racial disparities may reduce or eliminate the estimated independent effect of race on care, however, this does not diminish the measure of racial/ethnic disparity.[30]

Unequal Treatment also highlighted potential sources of racial and ethnic health care disparities including *patient characteristics, the clinical encounter, and health system level factors.* Patient characteristics such as racial and ethnic differences in financial resources, health care seeking behaviors, and health literacy can contribute to health care disparities. Uncertainty in the clinical encounter can contribute to doctors' reliance on stereotypes and biases when making diagnostic and treatment decisions. Finally, health care system level factors such as language barriers, care fragmentation, and differential availability of services can also contribute to racial/ethnic health care disparities.

Of particular interest in this research study is the potential role of health system level factors and whether cancer disparities are explained by differential patterns in care at facilities where black and white cancer patients receive care.

Racial Differences in Site of Care as a Potential Source of Health Care Disparities

Past studies indicate that a small share of hospitals provide care to a disproportionately large share of black patients. Approximately 5% of non-federal hospitals provide care to over 40% of all black elderly patients in the US.[12] This pattern of racially concentrated care has also been observed in the VA system, where 28% of hospitals provide care to over 75% of black

veterans.[13] In addition to care being highly concentrated for blacks, research also indicates that hospitals serving a disproportionate share of black patients (minority-serving institutions) tend to perform worse along quality indicators relative to hospitals serving lower volumes of black patients (non-minority serving institutions). For example, in a study on the racial concentration and quality of hospitals that disproportionately care for black patients, Jha *et al.* found that minority-serving institutions performed worse along quality measures related to acute myocardial infarction (AMI) and pneumonia care quality.[12] In another study on racial differences in definitive breast cancer therapy, Keating *et al.* found that older black women were less likely than older white women to undergo surgery at hospitals with higher rates of radiation following breast-conserving surgery.[14] Similarly, in a 2008 study on racial disparities in lung cancer, Lathan *et al.* found that older early-stage NSCLC patients receiving care at hospitals with high proportions of black patients (black racial composition >= 30%) were less likely to undergo curative surgery.[15]

Collectively, these studies offer some indication that racial disparities in quality of care are at least partly driven by "between-hospital" differences *or* differences in where black and white patients receive care. Assessing the relative contributions of within-hospital differences (differences in care and treatment for black and white patients treated at the same hospital) and between-hospital differences to racial disparities in care can help inform policies and interventions aimed at addressing racial disparities in care.

Research Aims

In this study, we assess the extent of race-based cancer care disparities in the VA across a broad range of cancer types and measures. In addition, we examine whether racial differences in where cancer patients were treated explain any observed disparities in cancer care and outcomes. In particular, we were interested in determining whether cancer care disparities were mainly attributable to between- or within-hospital differences in the VA.

III. METHODS

Overview

We first computed unadjusted racial differences across 20 cancer-related process and outcome measures for veterans who received care in a VA Medical Center during 2001-2004. We then estimated a series of adjusted logistic regression models (1 per cancer site-specific measure) assessing whether patient race was associated with receipt of recommended cancer care and outcomes (Model 1). Next, we adjusted for hospital fixed effects using conditional logistic regression models (Model 2). We then compared the race effect in Model 1 to the race effect in Model 2 to determine the degree to which racial differences in care were due to within- or between-hospital differences. Substantial changes in the magnitude of the race effect after adjustment for hospital fixed effects indicated that racial differences in site of care explained a substantial amount of the observed racial disparity in cancer care. Little to no change in the race effect indicated that disparities in cancer care were mainly driven by differences in care provided to black and white patients treated within the same hospital.

Data Sources

We obtained data on patients who were diagnosed with cancer and/or received their first course of cancer therapy in the VA during 2001-2004 from the VACCR. The registry maintains information on patient demographics, tumor characteristics, and primary treatment for each incident cancer. Registry data were linked with additional data from 2000-2005, including VA administrative data (inpatient, outpatient, pharmacy, and laboratory data), Medicare administrative data (for Medicare-eligible veterans), and pain score data from office visits. These data were also linked to the 2000 Census data to obtain zip code-level measures of socioeconomic status and the National Death Index to determine patient vital status through 2005.

Cancer Cohorts

We studied veterans with colorectal, lung, or prostate cancer, the most prevalent cancers among veterans. We excluded small numbers of patients whose cancers were reported based on autopsy or death certificate or for whom no reporting source was available, patients for whom data were incomplete (e.g., missing month of diagnosis, no administrative data between 45 days before diagnosis through 195 days after diagnosis), or patients with histologic features suggesting a primary cancer other than the cancer of interest.[26] We also restricted our cohorts to non-Hispanic black and white veterans because we were primarily interested in black-white differences in care and the number of patients in other racial/ethnic subgroups was small. The final cohorts include 12,897 colorectal cancer patients (10,027 colon, 2,870 rectal), 25,608 lung cancer patients, and 38,202 prostate cancer patients spanning 118 VA Medical Centers.

Cancer Care Performance Measures

We consulted with oncology specialists to identify measures of quality along the continuum of cancer care. In total, we assessed 20 cancer-related process and outcome measures[26,27,31] reflecting evidence-based nationally recommended guidelines for colorectal cancer, lung cancer, prostate cancer, and palliative/supportive care across cancer types during the study period of 2001-2005.[32-44] We also identified quality measures for hematological cancers, but did not include these measures in this analysis because the number of patients was too small to ensure adequate statistical power. However, hematological cancer patients were included in the palliative/supportive care measure cohorts.

Additional details about each measure and cohort eligibility are included in Table 1.1.

Table 1.1 Measures of Recommended Processes of Cancer Care and Outcomes

Quality Measure	Definition	Cohort
Colorectal Cancer		
Early Stage (Stage I/II vs. III/IV) at Presentation, Colon Cancer	Patients diagnosed with stage I & II vs. stage III & IV colon cancer	All patients with stage I-IV colon cancer.
Early Stage (Stage I/II vs. III/IV) at Presentation, Rectal Cancer	Patients diagnosed with stage I & II vs. stage III & IV rectal cancer	All patients with stage I-IV rectal cancer.
Curative Surgery for Stage I, II, or III Colon Cancer[32]	Proportion of patients with Stage I, II, or III colon cancer who underwent curative resection within 180 days of diagnosis; polypectomy/local excision of the tumor for stage 1 T1 tumors that have well- or moderately differentiated tumor grades were also included	All stage I/II/III colon cancer patients. Patients had to be alive and not enrolled in a Medicare HMO through 180 days from surgery.
Curative Surgery for Stage I, II, or III Rectal Cancer[33]	Proportion of patients with Stage I, II, or III colon cancer who underwent curative resection within 180 days of diagnosis; polypectomy/local excision of the tumor for stage 1 T1 tumors that have well- or moderately differentiated tumor grades were also included	All stage I/II/III rectal cancer patients. Patients had to be alive and not enrolled in a Medicare HMO through 180 days from surgery.
Adjuvant Chemotherapy for Stage III Colon Cancer[32]	Receipt of adjuvant 5 fluorouracil or capecitabine within 90 days following curative-intent resection of stage III colon cancer	All stage III colon cancer patients who underwent curative-intent resection. Patients had to be alive and not enrolled in a Medicare HMO through 90 days from surgery.
Adjuvant Chemotherapy and Radiation Therapy for Stage II or III Rectal Cancer[33]	Receipt of both adjuvant chemotherapy with 5-fluorouracil or capecitabine and radiation therapy before or within 140 days following curative intent resection for stage II or III rectal cancer	All stage II/III rectal cancer patients who underwent curative-intent resection. Patients had to be alive and not enrolled in a Medicare HMO through 180 days from surgery.

Table 1.1 (Continued)

Three-Year All Cause Survival for Colon Cancer	Proportion of patients alive 3 years after the date of diagnosis	All patients diagnosed with colon cancer during 2001 & 2002.
Three-Year All Cause Survival for Rectal Cancer	Proportion of patients alive 3 years after the date of diagnosis	All patients diagnosed with rectal cancer during 2001 & 2002.
Lung Cancer		
Curative Surgery for Stage I or II Non-Small Cell Lung Cancer[34]	Pneumonectomy, lobectomy, or wedge or segmental resection within 180 days of diagnosis	All stage I/II non-small cell lung cancer patients. Patients had to be alive and not enrolled in a Medicare HMO through 180 days from diagnosis. Patients were also included if they died within 180 days but underwent surgery.
Mediastinal Evaluation for Stage I or II Non-Small Cell Lung Cancer[34]	Mediastinal evaluation from 45 days before diagnosis through the date of surgery	All stage I/II non-small cell lung cancer patients who underwent lobectomy or pneumonectomy. Patients had to be alive and not enrolled in a Medicare HMO through 180 days from surgery.
Chemotherapy and/or Radiation for Resected Stage IIIA Non-Small Cell Lung Cancer[34]	Chemotherapy and/or radiation therapy from 30 days before diagnosis through 90 days after date of surgery	All stage IIIA non-small cell lung cancer patients who underwent lobectomy or pneumonectomy or wedge resection. Patients had to be alive and not enrolled in a Medicare HMO through 90 days from surgery.
Chemotherapy and Radiation for Limited-Stage Small Cell Lung Cancer[35]	Cisplatin or carboplatin and etoposide with concurrent radiation therapy within 180 days of diagnosis; chemotherapy must start between the start and end dates of radiation therapy	All limited-stage small cell lung cancer patients. Patients had to be alive through 45 days from diagnosis and not enrolled in a Medicare HMO through 180 days from diagnosis.
One-Year All Cause Survival for Non-Small Cell Lung Cancer	Proportion of patients alive 1 year after the date of diagnosis	All patients with non-small cell lung cancer.
One-Year All Cause Survival for Small Cell Lung Cancer	Proportion of patients alive 1 year after the date of diagnosis	All patients with small cell lung cancer.

Table 1.1 (Continued)

Prostate Cancer		
Androgen Ablation within 120 Days for Men with Stage IV Prostate Cancer[37,38,40,41]	Androgen deprivation therapy with a gonadotropin-releasing hormone (GnRH) agonist or bilateral orchiectomy within 120 days of diagnosis	All prostate cancer patients with stage IV cancer at diagnosis. Patients had to be alive and not enrolled in a Medicare HMO through 120 days from diagnosis.
Oral Anti-Androgen before Initiating Gonadotropin Releasing Hormone (GnRH) Agonist Therapy for Metastatic Prostate Cancer[36]	Proportion of men with metastatic cancer who are started on GnRH agonist who also fill a prescription for an oral anti-androgen for at least 2 weeks, beginning at least 1 week before first dose of GnRH agonist	All prostate cancer patients with stage IV cancer at diagnosis who started a GnRH agonist.
Adjuvant Androgen Deprivation Therapy for High-Risk Cancers Treated with Radiation Therapy[36]	Proportion of patients with high-risk prostate cancer (gleason 8-10 or PSA >20 or stage T3 or greater) treated with radiation who also receive hormonal therapy (adjuvant or neoadjuvant)	All patients with high risk, non-metastatic tumors treated with radiation therapy within 180 days of diagnosis. Patients were required to be alive and not enrolled in a Medicare HMO through 180 days from diagnosis. We only included cases in 2001-2002 because Gleason 7 tumors could not be distinguished from Gleason 8 tumors in 2003-2004.
3-Dimensional Conformal Radiotherapy (3-D CRT) or Intensity-Modulated Radiation Therapy (IMRT) for Prostate Cancer Patients Treated with Electron Beam Radiation Therapy (EBRT)[36,39,42]	Receipt of 3D-CRT or IMRT among men with local or regional prostate cancer who received external beam radiation therapy within 180 days of diagnosis	All patients with local or regional prostate cancer at diagnosis who also had evidence of external beam radiation therapy in administrative data. Patients had to be alive and not enrolled in a Medicare HMO through 180 days from diagnosis.

Table 1.1 (Continued)

Palliative/Supportive Care		
Use of Potent Antiemetics for Highly-Emetogenic Chemotherapy[43]	Receipt of 5-HT blockade (administered intravenously and/or orally) among patients treated with highly emetogenic chemotherapy. 5HT blockade assessed from 30 days before date of first dose of a highly emetogenic chemotherapy through 30 days following last dose of the same chemotherapy	All patients with colorectal cancer, lung cancer, prostate cancer, non-Hodgkins lymphoma, or multiple myeloma who are treated with one of the highly emetogenic chemotherapy drugs, including adriamycin, cisplatin, carbo-platin, cyclophosphamide, ifosphamide, idarubicin, epirubicin, daunorubicin. Patients could not be in a Medicare HMO during the time window of interest.
Prescription of Narcotic Pain Medication for Advanced Cancer Patients in Pain[44]	Opioid prescription filled among stage IV patients with 2 consecutive pain scores ≥5; script must be filled during the period between the 2 pain scores	All patients with colorectal cancer, lung cancer, prostate cancer, non-Hodgkins lymphoma, or multiple myeloma diagnosed at stage IV who have 2 consecutive pain scores of ≥5 from 3-30 days apart with no lower pain score between and no hospitalization. Patients could not be in a Medicare HMO during the time window of interest.

Covariates

The independent variable of primary interest was patient race/ethnicity (non-Hispanic black vs. non-Hispanic white). Race/ethnicity was reported by the registry based on self-identified information collected at VA enrollment; in the infrequent case where data were missing, registrars used medical record data. Patient-level sociodemographic characteristics include age, sex, marital status, and area-level socioeconomic status based on the zip code of the patient's residence (median household income, the percentage of college graduates, and the percentage of persons living below the poverty level). Patient-level clinical characteristics include presence of comorbidities (measured using the Klabunde modification of the Charlson score[45,46] separating chronic obstructive pulmonary disease [COPD] from the Charlson score for lung cancer patients), prior history of any cancer, year of diagnosis, stage of diagnosis, tumor size, and tumor grade.

Analyses

We first conducted descriptive analyses assessing racial differences in each process and outcome measure as well as in patient sociodemographic and clinical characteristics. We then categorized hospitals into deciles of hospital black racial concentration (i.e. the proportion of patients with cancer who are black); and for process and outcome measures exhibiting racial differences, we plotted rates of the measures for patients cared for at hospitals by deciles of hospital black racial concentration. Next, we estimated bivariate regression models predicting hospital-level rates of each disparity measure as a function of hospital racial concentration.

Modeling Approach. We estimated a series of logistic regression models (1 per cancer site-specific performance measure) to assess the effect of patient race on the odds of receiving recommended care and survival (Model 1). The covariates we examined varied slightly across models due to differences in the nature of our performance measures. All models adjusted for

age, sex (except prostate cancer models), marital status, prior cancer history, Charlson comorbidity score, and diagnosis year. All lung cancer models included COPD as a covariate. In models assessing treatment and survival, we also adjusted for tumor grade and stage, and survival models also adjusted for tumor size. We also adjusted for cancer type in the palliative/supportive care models.

As described earlier, racial disparities in care can be attributed to a number of factors, including racial differences in where care is received (between-hospital differences) as well as differences in the care provided to individual patients at a given hospital (within-hospital differences). A between-hospital explanation of racial disparities in care might highlight the disproportionate share of minority patients receiving care at lower quality hospitals while a within-hospital explanation might point to inequitable treatment patterns among patients of different racial backgrounds within the same facility. Each race effect obtained from Model 1 in our analyses reflects a total effect of race (within-hospital+between-hospital differences) on the receipt of recommended cancer care (or survival) after adjusting for patient-level characteristics. To determine the extent of between- vs. within-hospital effects on disparities in cancer care, we estimated a second set of models where we also adjusted for hospital-level fixed effects using conditional logistic regression models (Model 2). Hospital-level fixed effects models control for any hospital factors (between-hospital differences) that might be associated with cancer care (e.g., access to cancer specialists, availability of medical technologies).[47,48] Thus, the race parameter estimates obtained the from hospital-level fixed effects models (Model 2) reflect the within-hospital component of the disparity and can be compared with the race parameter estimates obtained from Model 1 to make determinations regarding the extent of between- vs. within-hospital disparities in cancer care.

Accounting for Socioeconomic Status. In accordance with the IOM's definition of health care disparities, we did not adjust for socioeconomic status in our main models. Thus, our

disparity estimates reflect the independent effect of race and not a "residual direct effect" of race on care. However, because understanding how disparities in care might arise is important to addressing health inequities, we conducted additional analyses to assess whether racial differences in socioeconomic status accounted for any observed disparities in cancer care and survival.

Adjustment for Multiple Comparisons. Lastly, we adjusted our model results for multiple comparisons using the Benjamini-Hochberg (B-H) procedure, a sequential approach to controlling the false discovery rate associated with multiple comparisons. The B-H procedure has been shown to yield greater statistical power than the more widely used Bonferroni correction, which controls the family-wise error rate.[49,50] In the B-H approach, *p* values obtained from a family of tests (family size=*m*) are ordered from largest to smallest and sequentially compared to a list of B-H critical values that range from α to α/*m*. Use of the B-H approach has become quite widespread in the field of genetics and other life sciences, and for well over a decade, the National Center for Education Statistics has employed the B-H approach in reporting results from the National Assessment of Educational Progress[49,51-54]

All analyses were conducted using SAS version 9.3.

IV. RESULTS

Unadjusted Racial Group Comparisons

Table 1.2 shows characteristics of each cancer cohort by race. Across all cancer cohorts, compared with white patients, black patients were younger, less likely to be married, and more likely to reside in areas with higher poverty, less college education, and lower median income.

Table 1.2 Characteristics of Cancer Cohorts by Race

Characteristics	Colorectal		Lung		Prostate	
	White *N* =10,636	Black *N* =2,261	White *N* =21,077	Black *N* =4,531	White *N* =27,889	Black *N* =10,313
Age - %						
<60 yrs	19.7	27.9	22.2	29.7	19.3	30.1
60-64 yrs	13.0	10.0	15.1	11.7	16.4	15.4
65-69 yrs	14.5	11.6	16.4	13.5	21.0	18.1
≥ 70 yrs	52.8	50.5	46.3	45.1	43.2	36.4
Gender - %						
Female	1.8	1.6	1.7	1.5		
Male	98.2	98.5	98.3	98.5		
Marital Status - %						
Unmarried	40.7	50.2	49.4	63.6	40.1	55.3
Married	56.2	47.5	48.0	34.7	57.4	43.0
Unknown	3.1	2.3	2.6	1.7	2.6	1.7
Prior History of Cancer - %						
No	86.6	85.5	83.0	83.1	92.4	94.9
Yes	13.4	14.6	17.0	16.9	7.6	5.1
Charlson Comorbidity Score - %						
0	52.1	54.0	61.4	62.2	62.6	61.6
1	28.1	26.7	22.4	21.6	25.2	24.4
2	11.4	11.2	9.6	9.1	8.0	8.1
3 +	8.3	8.2	6.6	7.2	4.2	5.8
Year of Diagnosis - %						
2001	23.0	25.3	24.2	25.2	24.6	24.7
2002	25.2	24.6	25.0	24.6	25.3	24.6
2003	25.6	25.7	25.2	25.7	24.7	24.9
2004	26.2	24.4	25.6	24.5	25.4	25.8

Table 1.2 (Continued)

% Population ≥ 65 Yrs Living Below Poverty in Zip Code of Residence - %						
Q1 (0 - <7.9%)	27.1	11.0	27.0	9.8	29.2	11.2
Q2 (7.9 - <12.8%)	26.6	13.6	26.2	13.4	27.4	15.4
Q3 (12.8 - <19.5%)	25.0	20.2	24.7	19.9	24.5	24.0
Q4 (19.5 - 76.9%)	15.5	51.0	16.9	53.7	13.2	45.0
Missing/Unknown	5.8	4.3	5.2	3.3	5.7	4.4
% Population College Graduates in Zip Code of Residence - %						
Q1 (<15.9%)	21.9	33.3	22.1	32.1	21.4	32.3
Q2 (15.9-21.6%)	24.0	21.9	23.8	23.8	23.4	23.2
Q3 (21.6-30.0%)	23.8	21.1	24.4	20.9	23.8	21.6
Q4 (30.0-100.0%)	24.4	19.7	24.5	20.0	25.7	18.5
Missing/Unknown	5.8	4.1	5.2	3.2	5.7	4.4
Median Income in Zip Code of Residence- $	45,919	39,347	45,722	38,456	46,055	39,859

Table 1.3 displays unadjusted rates for each cancer-related process and outcome measure stratified by race. For 8 of the 20 quality measures (40%), black cancer patients had lower rates of recommended care or survival than white patients. Of note, blacks exhibited *higher* unadjusted rates of receipt of oral anti-androgen before initiating gonadotropin releasing hormone (GnRH) agonist therapy for metastatic prostate cancer.

Overall, about one quarter of VA hospitals (N=30 hospitals) cared for close to 70% of all black cancer patients in the VA. Among hospitals in the lowest decile of black racial concentration, 0% to 1% of their cancer patients were black, compared with 45% to 72% of cancer patients in hospitals in the highest decile. Hospital black racial concentration was not associated with receipt of recommended care for 6 of the 8 measures (75%) exhibiting lower unadjusted rates for blacks relative to whites, including curative surgery for stage I/II/III rectal cancer (P=.54, Figure 1.1, Panel A). We did observe a statistically significant association between the proportion of black cancer patients at each hospital and receipt of 3-dimensional conformal radiation therapy or intensity-modulated radiation therapy for prostate cancer patients treated with external-beam radiation therapy (3-D-CRT/IMRT) (P=.001, Figure 1.1, Panel B) and 3-year all-cause survival for colon cancer (P=.02, data not shown). We also observed greater receipt of oral anti-androgen before initiating GnRH agonist therapy for metastatic prostate cancer at hospitals with more black patients (P=.04, data not shown).

Table 1.3 Unadjusted and Adjusted Associations of Race with Recommended Cancer Care and Survival

Quality Measure	Eligible Patients		Performance Rates		Unadjusted Differences	Adjusted Odds Ratios	
						Model 1[†]	Model 2[‡]
	White (N)	Black (N)	White (%)	Black (%)	Black-White (%) [95%CI]	Black vs. White AOR [95% CI]	Black vs. White AOR [95% CI]
Colon Cancer							
Early Stage (Stage I/II vs. III/IV) at Presentation, Colon Cancer	7262	1694	60.0	54.0	-6.0 [-8.6,-3.4]*	**0.80 [0.72, 0.90]***	**0.78 [0.70, 0.89]***
Early Stage (Stage I/II vs. III/IV) at Presentation, Rectal Cancer	2123	336	63.2	59.2	-3.9 [-9.5, 1.6]	0.87 [0.68, 1.11]	0.87 [0.66, 1.15]
Curative Surgery for Stage I, II, or III Colon Cancer	5375	1173	93.4	91.1	-2.2 [-3.8,-0.6]*	0.76 [0.58, 0.98]*	0.82 [0.61, 1.12]
Curative Surgery for Stage I, II, or III Rectal Cancer	1636	251	79.2	67.3	-11.9 [-17.4,-6.4]*	**0.57 [0.41, 0.78]***	**0.57 [0.39, 0.82]***
Adjuvant Chemotherapy for Stage III Colon Cancer	1381	343	70.2	65.0	-5.2 [-10.7, 0.2]	0.75 [0.58,0.98]*	0.87 [0.64, 1.18]
Adjuvant Chemotherapy and Radiation Therapy for Stage II or III Rectal Cancer	723	108	74.0	79.6	5.6 [-3.2, 14.4]	1.49 [0.87, 2.53]	1.39 [0.73, 2.64]
Three-Year All Cause Survival for Colon Cancer ¶	3745	897	61.2	53.3	-7.9 [-11.5,-4.3]*	**0.75 [0.62, 0.89]***	0.78 [0.64, 0.96]*
Three-Year All Cause Survival for Rectal Cancer ¶	1122	179	57.8	48.0	-9.7 [-17.5,-1.9]*	**0.61 [0.42, 0.87]***	0.66 [0.43, 1.00]
Lung Cancer							
Curative Surgery for Stage I or II Non-Small Cell Lung Cancer	3653	723	60.9	48.6	-12.4 [-16.3,-8.5]*	**0.50 [0.41, 0.60]***	**0.52 [0.41, 0.64]***

Table 1.3 (Continued)

Mediastinal Evaluation for Stage I or II Non-Small Cell Lung Cancer	1956	298	88.2	86.2	-2.0 [-6.0, 2.0]	0.75 [0.52, 1.09]	0.92 [0.59, 1.44]
Chemotherapy and/or Radiation for Resected Stage IIIA Non-Small Cell Lung Cancer	324	65	69.8	78.5	8.7 [-3.4, 20.8]	1.67 [0.86, 3.24]	1.35 [0.60, 3.05]
Chemotherapy and Radiation for Limited-Stage Small Cell Lung Cancer	981	141	60.5	58.9	-1.6 [-10.2, 7.1]	0.96 [0.66, 1.41]	0.80 [0.51, 1.25]
One-Year All Cause Survival for Non-Small Cell Lung Cancer	17848	4059	40.6	39.5	-1.1 [-2.80,0.6]	1.06 [0.98, 1.15]	1.05 [0.96, 1.15]
One-Year All Cause Survival for Small Cell Lung Cancer	3203	465	26.6	26.2	-0.4 [-4.6, 4.0]	1.04 [0.82, 1.33]	1.07 [0.82, 1.39]
Prostate Cancer							
Androgen Ablation within 120 Days for Men with Stage IV Prostate Cancer	1014	571	73.8	74.8	1.0 [-3.5, 5.5]	1.08 [0.84, 1.37]	0.99 [0.73, 1.33]
Oral Anti-Androgen before Initiating GnRH Agonist Therapy for Metastatic Prostate Cancer	916	535	78.4	83.2	4.8 [5.4, 9.1]*	1.34 [1.01, 1.77]*	0.99 [0.70, 1.41]
Adjuvant Androgen Deprivation Therapy for High-Risk Cancers Treated with Radiation Therapy	2853	970	56.5	55.5	-1.0 [-4.6, 2.6]	1.01 [0.87, 1.18]	0.86 [0.72, 1.04]
3-D CRT or IMRT for Prostate Cancer Patients Treated with EBRT	5731	2056	64.3	48.0	-16.3 [-18.8,-3.9]*	**0.53 [0.47, 0.59]***	**0.75 [0.65, 0.87]***
Palliative/Supportive Care							
Use of Potent Antiemetics for Highly-Emetogenic Chemotherapy	8579	1898	71.6	69.0	-2.6 [-4.8,-0.3]*	**0.87 [0.78, 0.98]***	0.95 [0.82, 1.10]

Table 1.3 (Continued)

Prescription of Narcotic Pain Medication for Advanced Cancer Patients in Pain	2030	638	68.3	67.9	-0.5 [-4.6, 3.7]	1.04 [0.85, 1.27]	1.04 [0.83, 1.31]

AOR – Adjusted Odds Ratio
GnRH – Gonadotropin Releasing Hormone
3-D CRT – 3-Dimensional Conformal Radiation Therapy
IMRT – Intensity Modulated Radiation Therapy
EBRT – External Beam Radiation Therapy
† Model 1 corresponds to adjusted logistic regression models *excluding* hospital fixed effects.
‡ Model 2 corresponds to adjusted logistic regression models *including* hospital fixed effects.
All models adjusted for age, sex (except prostate cancer models), marital status, prior cancer history, Charlson comorbidity score, and year of diagnosis. Lung cancer models also included chronic obstructive pulmonary disease (COPD) as a covariate, and for this group the Charlson score was calculated without COPD. Treatment and survival models adjusted for tumor grade and stage, and survival models also adjusted for tumor size. Palliative/supportive care models adjusted for cancer type.
***** indicates unadjusted difference or AOR is statistically significant at p<.05.
Boldface* indicates AOR is statistically significant after applying Benjamini-Hochberg multiple comparisons adjustment.
¶ Three-year survival for colon and rectal cancers captures patients diagnosed during 2001 & 2002.

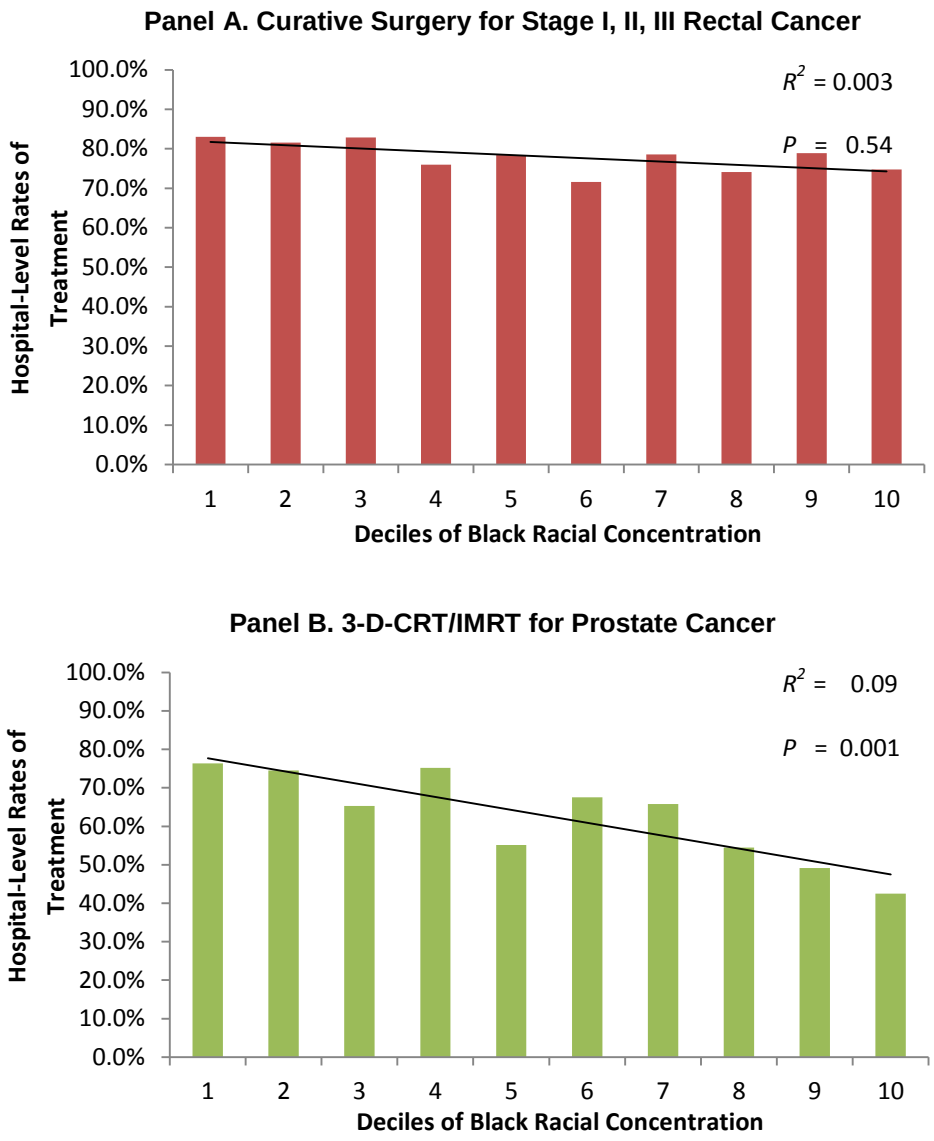

Figure 1.1 Hospital-level rates of recommended treatment plotted against deciles of black racial concentration across VA hospitals for two example measures. No association was noted in bivariate regression analyses assessing the relationship between hospital-level rates of curative surgery for stage I/II/III rectal cancer and black racial concentration across VA hospitals (Panel A). A statistically significant association was observed between hospital-level rates of 3-dimensional conformal radiation therapy or intensity-modulated radiation therapy for prostate cancer patients treated with external-beam radiation therapy (3-D-CRT/IMRT) and black racial concentration across VA hospitals (Panel B). Test statistics are

Figure 1.1 (Continued)

from bivariate regression analyses predicting hospital-level rates of each measure as a function of hospital racial concentration are reported in each panel.

Main Adjusted Models

Of the 20 quality measures examined using covariate-adjusted logistic regression analyses, 9 measures initially exhibited statistically significant lower rates of treatment for black vs. white patients; however, after adjustment for multiple comparisons, only 7 of these associations remained statistically significant. Compared with white patients, black patients had less early-stage diagnosis of colon cancer (adjusted odds ratio [AOR]=.80; 95%CI=.72-.90), less curative surgery for stage I/II/III rectal cancer ([AOR]=.57; 95%CI=.41-.78), lower 3-year all-cause survival for colon cancer ([AOR]=75; 95%CI=.62-.89) and rectal cancer ([AOR]=.61; 95%CI=.42-.87), less curative surgery for early-stage non-small cell lung cancer ([AOR]=.50; 95%CI=.41-.60), less 3-D-CRT/IMRT ([AOR]=.53; 95%CI=.47-.59), and were less likely to receive potent antiemetics for highly emetogenic chemotherapy ([AOR]=.87; 95%CI=.78-.98) (Table 1.3, Model 1; see Appendix Table 4.1 for detailed results from Benjamini-Hochberg multiple comparisons adjustment).

For 5 of these 7 quality measures where we observed lower odds of recommended care for black vs. white patients, additional adjustment for VA hospital fixed effects explained a very small portion (0% to 13%) of the observed racial gaps in performance (Table 1.3, Model 2). In the case of potent antiemetics for patients receiving highly emetogenic chemotherapy, the race-associated odds ratio changed from a statistically significant .87 [95%CI=.78-.98] to a non-statistically significant .95 [95% CI=.82-1.10] after adjustment for hospital fixed effects. Adjustment for hospital fixed effects had a substantial impact on 1 measure, receipt of 3-D-CRT/IMRT, where the race-associated odds ratio changed from .53 [95%CI=.47-.59] to .75 [95%CI=.65-.87] after adjusting for site of care.

Of note, we observed 1 measure where black patients had higher rates in adjusted analyses: receipt of oral anti-androgens before initiating GnRH agonist therapy for metastatic prostate cancer ([AOR]=1.34; 95%CI=1.01-1.77); and this higher rate was completely explained

by site of care ([AOR]=0.99; 95%CI=0.70-1.41). However, the association in the first model was not statistically significant after adjustment for multiple comparisons.

Models Adjusting for Socioeconomic Status

Additional adjustment for area-level socioeconomic status (median household income, percentage of college graduates, and percentage of persons living below the poverty level) in separate analyses accounted for a relatively small portion (2% to 23%) of the observed racial gaps in performance and yielded estimates that were generally consistent with our overall results (see Appendix Table 4.2).

IV. DISCUSSION

We assessed racial disparities in the quality of cancer care and outcomes within the VA health care system and the extent to which site of care accounted for any observed disparities in care and outcomes. For 13 of the 20 quality measures (65%) examined, black and white patients appeared to receive similar levels of care. These findings are consistent with previous research suggesting that disparities in care are mitigated in the VA.[3,4] However, we did observe racial disparities in several cancer care measures. Adjustment for socioeconomic status had relatively little impact on racial disparities in care and survival. This finding may reflect the "equal access" nature of the VA which reduces financial barriers to care for veterans and ultimately helps to lessen potential socioeconomic disparities in care.

Prior studies indicate that in the private sector, racial disparities in care are often driven by differences in where black and white patients receive care.[15,47,55] For example, one national study of racial disparities in AMI treatment and outcomes among Medicare beneficiaries found that racial disparities in non-surgical medical treatments and outcomes substantially narrowed after adjusting for site of care.[47] This site of care explanation for health care disparities is plausible given the high degree of racial concentration in U.S. hospital care as well as research

evidence indicating lower quality care among hospitals treating a higher proportion of black patients.[12,14,15] Few studies have examined the association between health care disparities and site of care in the VA setting; those that have are consistent with our study, suggesting that health care disparities are explained more by within-hospital differences than between-hospital differences in the VA. One study examining disparities in 30-day mortality rates across 6 conditions (AMI, hip fracture, stroke, congestive heart failure, gastrointestinal hemorrhage, and pneumonia) found that for most conditions, mortality rates were similar among minority and non-minority serving hospitals in the VA, and there was very little variation in the magnitude of disparities across hospitals.[13] A more recent study assessing the quality of VA ambulatory/preventive care for diabetes, cardiovascular disease, hypertension, and cancer screening found that racial disparities were mainly driven by within-hospital differences.[56] There remain high levels of racial concentration within relatively few hospitals in the VA. However, we found little evidence to suggest that differences in where black and white cancer patients obtained care contributed to disparities in cancer care. This lack of between-hospital disparities could be a result of ongoing system-wide quality initiatives undertaken by the VA.

Nevertheless, we observed some evidence of between-hospital differences in care for 2 measures. In the case of 3-D-CRT/IMRT, we observed a substantial between-hospital effect that accounted for nearly half of a relatively large adjusted racial gap in care. This finding is likely attributable to differences in the timing of adoption of these advanced radiation therapy techniques across VA hospitals. Adoption of 3-D-CRT and/or IMRT involves large investments in expensive medical equipment and the hiring of specialized staff,[57] which may be delayed in a system with a fixed budget and without financial incentives to adopt new technologies as in the private sector. The National Comprehensive Cancer Network guidelines began recommending use of 3-D-CRT in 2001. Direct communication with individual VA hospitals revealed that nearly all VA hospitals had adopted 3-D-CRT/IMRT by 2006. Our findings suggest that the hospitals where more black prostate cancer patients received care may have lagged behind other

hospitals in the adoption of 3-D-CRT/IMRT. We also observed some evidence that smaller racial differences in receipt of potent antiemetics for highly emetogenic chemotherapy may be partly explained by site of care; it will be important for the VA to be certain that there are no differences in the availability of these medications that could explain these results.

Limitations

Our study's strengths include the comprehensive measurement of cancer care quality, using both process and outcome measures, across the entire VA. We also accounted for both total race effects and residual direct effects of race on cancer care. To ensure accurate accounting of total racial disparities in care, future disparities studies should incorporate modeling approaches that reflect the IOM definition of racial disparities in health care. Furthermore, to our knowledge, no other study has explored site of care explanations for VA cancer care disparities.

The study's limitations include the focus on black and white veterans diagnosed with cancer in the first half of the last decade; the findings may not necessarily generalize to other racial/ethnic groups or patients with more recent diagnoses. Although more recent data would be ideal, other research suggests that disparities in cancer care and outcomes have continued to persist over time in the VA and the private sector.[9,17,18,58] In particular, racial disparities in surgical treatment and survival among cancer patients remain a challenge for the VA.[9,28,59] Our study, which distinguishes between the within-hospital and between-hospital sources of these health care inequities, therefore remains relevant and important to understanding cancer-related disparities in the VA.

Second, we studied quality across 4 common types of cancer. It is unclear whether these findings would generalize to other types of cancer, particularly less common forms. Third, we assessed socioeconomic status using area-level measures due to the unavailability of reliable patient-level socioeconomic status data. Although area-level measures are often used

when individual-level socioeconomic status measures are unavailable, past research indicates that area-level measures provide complementary contextual information on socioeconomic status and may not fully capture socioeconomic effects at the individual-level.[60] In addition, we were unable to account for additional patient-level factors that could impact the treatment decision-making process, such as racial differences in preferences for treatment and performance status.

Also, we used Medicare claims data to capture out of VA care by Medicare-eligible veterans; however, we may have missed care outside of the VA by veterans with private insurance who were not Medicare eligible. Still, other evidence suggests that older veterans with cancers diagnosed and/or treated in the VA receive very little cancer surgery outside of the VA[61] and in exploratory analyses, we also observed that few older VA patients received chemotherapy or radiation therapy outside of the VA. Finally, low statistical power may have obscured true racial differences in care for some measures with smaller cohorts like chemotherapy and/or radiation for resected stage IIIA non-small cell lung cancer. However, post-hoc power analyses revealed that most of our measure cohorts included a sufficiently large number of patients to detect at least a 10 percentage-point absolute difference in care by race.

Conclusion

Racial disparities in cancer care quality and outcomes in the VA were present for about a third of the measures assessed in this study. In general, these disparities were primarily driven by racial differences in care for black and white patients within the same hospital, rather than racial differences in where care was received. Future efforts should focus on understanding the sources of these within-hospital disparities. However, differential patterns in the adoption of some new technologies and use of medications across VA hospitals are potential sources of cancer disparities that deserve further exploration.

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Chapter 2

Developing and Evaluating Composite Measures of Cancer Care Quality

I. INTRODUCTION

Measuring and improving health care quality are important goals of health services research; however, the proliferation of quality indicators in recent years has created challenges for groups interested in using quality data (e.g., patients, providers, payers) for decision-making and/or quality improvement purposes. To address this issue, many health services researchers have advocated wider use of summary or "composite" measures, particularly in the domains of ambulatory, surgical, and cardiac care. However, use of composite measures of cancer care quality has been limited. Cancer care is highly complex and typically involves specialists from multiple disciplines providing cancer- and stage-specific care along the cancer care continuum. To be useful, cancer care composite measures should account for these various aspects of cancer care.

In research and practice, measures have commonly been grouped according to medical condition (e.g., heart disease, diabetes) or care-modality (e.g., surgical care quality) and combined using a variety of techniques.[1-5] For example, the composite measures developed for the Centers for Medicare and Medicaid Services (CMS) Premier Hospital Quality Incentive Demonstration (HQID) are condition-specific and computed using opportunity-based scoring models.[2] Given the complexity of cancer care, it is unclear whether condition-specific (i.e., cancer-specific) or care-modality-specific (e.g., screening, surgery) composites would be more appropriate for assessing cancer care quality.

An alternative composite method, exploratory factor analysis, identifies groups of highly correlated measures that reflect an underlying construct (e.g., quality). Composite measures defined using exploratory factor analysis may better represent the underlying dimensions of

care, and past work indicates that empirically-derived composites may be more strongly linked to patient outcomes than disease-specific composite measures.[6]

This study extends previous work on cancer care and quality measurement by comparing multiple approaches for developing composite quality measures for cancer care. We use Veterans Affairs Central Cancer Registry (VACCR) data and VA patient-level administrative data. These data sources capture patient-level characteristics and treatment patterns for all VA cancer patients.

II. BACKGROUND

Defining High Quality Cancer Care and Measuring Cancer Care Quality

The 1999 Institute of Medicine report, *Ensuring Quality Cancer Care*, documented that the quality of cancer care in the US is highly variable and many cancer patients do not receive recommended cancer care.[7] Since the IOM report, more research has gone into measuring and improving the quality of cancer care. More recently, the Affordable Care Act has prompted even greater interest in cancer care quality measurement by stipulating that 11 of the nation's comprehensive cancer centers submit cancer care quality reports to CMS beginning in 2014.[8] However, despite growing interest in measurement and reporting of cancer care quality, there is still no general consensus on what actually constitutes "high quality" cancer care.

Health services researchers have typically assessed cancer care quality based on evaluations of individual quality performance indicators (e.g., receipt of curative surgery).[9,10] Such an approach to measuring cancer care quality may be too narrow given the complex nature of care along the cancer care continuum. Processes along this continuum are often related and interdependent and include detection/screening, diagnosis, treatment, follow-up care, and end-of-life care.[11] Failures at any point along this continuum can have a substantial impact on patient outcomes and overall care quality.[12] Cancer type and stage add another layer of complexity to the assessment of cancer care quality because recommended care differs by

these characteristics. In addition, cancer care is typically delivered by a multidisciplinary group of cancer care specialists and must be coordinated across disciplines, including surgery, medical oncology, radiation oncology, and often palliative care and primary care. Because individual quality indicators typically assess a single aspect of care, such measures may not be sufficient for capturing the complexities and salient dimensions of cancer care quality.

Use of Composite Measures in Health Services Research

Steady growth in the number of reported quality indicators has contributed to information overload among users of quality data. One solution to this problem is to use composite measures that reduce the amount of data presented in quality reports by aggregating quality data into summary scores or indices.[13] Composite measures also can overcome some of the statistical challenges associated with many individual quality indicators, including small sample sizes and consequent low reliability. A composite measure that aggregates a group of related quality indicators with small samples may be more successful at discriminating true differences in care quality (i.e., "signal") than the individual quality indicators of which it is comprised.

Although use of composite measures of cancer care quality has been limited, disease-specific composite measures have been developed for many conditions, including diabetes, cardiovascular disease, and pneumonia.[2,3,5] Composite measures have also been employed to summarize quality for specific aspects of care such as treatment modality. For example, in 2009, Staiger *et al.* constructed composite measures of surgical quality performance for cardiovascular disease. Compared with individual surgical quality indicators, the composite surgical quality measures were superior in terms of differentiating quality performance across hospitals, explaining variation in aortic valve replacement (AVR) mortality rates, and forecasting future AVR mortality rates.[1]

Composite Approaches and Implications for Use in Cancer Care Quality Measurement

Previous studies have demonstrated that hospital performance scores and rankings often vary depending on the grouping and weighting approach utilized to generate composites.[14-16] Composite methods employed in the research literature include all-or-none scoring, linear combinations (e.g., simple averaging), and regression-based composites (see Appendix Table 4.3 for a description of common composite approaches).[13,17] For nearly a decade, the CMS HQID program has employed opportunity-based scoring methods to generate composite quality measures for inpatient cardiovascular disease, pneumonia, and hip/knee replacement care. In opportunity-based scoring, composites scores are generated by dividing the number of times a given set of care processes were actually performed (numerator) by the total number of opportunities for providing those recommended care processes to patients (denominator). Thus, unlike simple averaging where each quality indicator is weighted by an equal and *fixed* amount, in opportunity-based scoring, each quality indicator is implicitly weighted in proportion to the percentage of eligible patients that comprise the denominator (i.e., opportunity-based weights), which may vary from provider to provider. Approaches for conceptually grouping performance measures into composites also vary. For example, composites can be condition-specific (e.g., HQID heart failure care composite), care-modality-specific (e.g., surgical care composite), or reflect another grouping scheme that highlights other dimensions of care.

Alternative approaches for generating composite measures include latent variable analysis methods, such as empirical factor analysis and principal components analysis, which are useful for identifying groups of highly correlated measures that may reflect some underlying latent trait (e.g., dimension of care quality).[13,18] Factor-based composites are typically weighted by a *fixed* amount, the factor loading, based on the empirical relationships among quality indicators and their association with the hypothesized latent variable. One earlier study found that cardiac care composites developed using latent variable analysis were more consistent with the organizational structure of cardiac care in hospitals and more predictive of patient outcomes

than composite measures generated using the CMS condition-specific opportunity-based scoring method.[6]

Cancer care quality composites might be grouped according to condition/cancer type (e.g., lung cancer), care-modality (e.g., curative surgery), or empirical relationships among quality indicators (e.g., empirical factors). Weighting methods for quality indicators (e.g., fixed weights vs. opportunity-based weights) also vary.

Research Aims

In this study, we explore and compare several approaches for computing composite measures of cancer care quality, specifically six types of composite measures: (1) fixed- and opportunity-weighted empirical factor composites, (2) fixed- and opportunity-weighted cancer-specific composites, and (3) fixed- and opportunity-weighted care-modality-specific composites. We assess how well these composite measures summarize dimensions of cancer care quality and predict cancer patient survival.

III. METHODS

Overview

We computed hospital-level rates of recommended care processes for colorectal, lung, and prostate cancers across VA hospitals. Next, we generated six types of hospital-level composite measures of cancer care quality using fixed- and opportunity-based weighting approaches (see Table 2.1). To compute fixed- and opportunity-weighted (1) empirical factor composites, we first conducted exploratory factor analyses to identify groups of highly correlated hospital-level cancer care process measures. We then combined process measures based on either their fixed factor loading weights or opportunity-based weights. We also computed two sets of (2) cancer-specific and (3) care-modality-specific composite measures using simple averaging (fixed weights) and opportunity-based weighting methods. We compared the six

types of composite scores according to how well they summarized dimensions of cancer care quality and predicted patient-level survival. We also assessed the extent to which differences in weighting methods (opportunity-based vs. fixed weights) contributed to variations in hospital composite scores.

Table 2.1 Six Approaches for Generating Composite Measures of Cancer Care Quality

	Weighting Approach	
	Opportunity Based	*Fixed*
Grouping Approach		
Empirical Factor Domain	Opportunity-Weighted Empirical Factor Composites	Fixed-Weighted (Factor Loading) Empirical Factor Composites
Cancer-Specific	Opportunity-Weighted Cancer-Specific Composites	Fixed-Weighted (Simple Average) Cancer-Specific Composites
Care-Modality-Specific	Opportunity-Weighted Care-Modality-Specific Composites	Fixed-Weighted (Simple Average) Care-Modality-Specific Composites

Data Sources

Patient-level cancer registry and administrative data. We obtained data on patients who were diagnosed with cancer and/or received their first course of cancer therapy at a VA Medical Center (VAMC) during 2001-2004 from the VACCR. The VACCR maintains information on patient demographics, tumor characteristics, and primary treatment for each incident cancer. Registry data were linked with additional data from 2000-2005, including VA administrative data (inpatient, outpatient, pharmacy, and laboratory data), Medicare administrative data (for Medicare-eligible veterans), and pain score data from office visits. These data were also linked to the 2000 Census data to obtain zip code-level measures of socioeconomic status and the National Death Index to determine patient vital status through 2005.

We limited our analyses to veterans with colorectal, lung, or prostate cancer, the most prevalent cancers among veterans. Of note, we excluded patients with hematological cancers from our analysis because a number of hospitals had no eligible hematological cancer patients for quality measures of interest and the average number of hematological patients per hospital was too small to suggest reliable hospital-level measure estimates and interpretable empirical factor analysis results.[19,20] As described previously, we also excluded small numbers of patients whose cancers were reported based on autopsy or death certificate or for whom no reporting source was available, patients for whom data were incomplete (e.g., missing month of diagnosis, no administrative data between 45 days before diagnosis through 195 days after diagnosis), or patients with histologic features suggesting a primary cancer other than the cancer of interest.[21]

Hospital exclusions. Of the 128 VAMCs, 10 had no cancer patients and were excluded from our analysis. We then ranked the remaining 118 hospitals according to cancer patient volume. Hospitals with cancer patient volume below the median accounted for relatively few or no patients across most quality measures of interest and were also excluded leaving 59 hospitals accounting for roughly 70% of VA cancer patients.

Cancer Care Quality Measures

In total, we assessed 13 cancer-related process measures[21,22] reflecting evidence-based nationally recommended guidelines for colorectal cancer, lung cancer, and prostate cancer care during the study period of 2001-2005.[23-33] We computed unadjusted hospital-level rates of recommended cancer care and treatment by aggregating VA patient-level administrative process measure data for each hospital.

Interunit reliability. We computed the average interunit reliability (IUR) for each measure to determine how reliably each measure distinguished performance across the 59 hospitals.[34] The IURs ranged from 0.13 to 0.98 with most measures (8 out of 13) exhibiting an average

IUR ≥ 0.50. We also considered an additional measure, adjuvant chemotherapy for stage III colon cancer; however the IUR for this measure was less than 0.01, indicating that no variation in hospital performance could be determined. We therefore excluded this measure from our analysis.

A description of each measure, cohort eligibility, number of eligible patients, and each measure's interunit reliability is provided in Table 2.2.

Table 2.2 Hospital-Level Cancer Care Process Quality Measures (N=59 Hospitals)

Quality Measure	Definition	Cohort	Total # Patients	Average Interunit Reliability
Colorectal Cancer				
Early Stage (Stage I/II vs. III/IV) at Presentation, Colon Cancer[23]	Patients diagnosed with stage I & II vs. stage III & IV colon cancer	All patients with stage I-IV colon cancer.	7316	.62
Early Stage (Stage I/II vs. III/IV) at Presentation, Rectal Cancer[24]	Patients diagnosed with stage I & II vs. stage III & IV rectal cancer	All patients with stage I-IV rectal cancer.	2047	.12
Curative Surgery for Stage I, II, or III Colon Cancer[23]	Proportion of patients with Stage I, II, or III colon cancer who underwent curative resection within 180 days of diagnosis; polypectomy/local excision of the tumor for stage 1 T1 tumors that have well- or moderately differentiated tumor grades were also included	All stage I/II/III colon cancer patients. Patients had to be alive and not enrolled in a Medicare HMO through 180 days from surgery.	5009	.72
Curative Surgery for Stage I, II, or III Rectal Cancer[24]	Proportion of patients with Stage I, II, or III colon cancer who underwent curative resection within 180 days of diagnosis; polypectomy/local excision of the tumor for stage 1 T1 tumors that have well- or moderately differentiated tumor grades were also included	All stage I/II/III rectal cancer patients. Patients had to be alive and not enrolled in a Medicare HMO through 180 days from surgery.	1495	.29
Adjuvant Chemotherapy and Radiation Therapy for Stage II or III Rectal Cancer[24]	Receipt of both adjuvant chemotherapy with 5-fluorouracil or capecitabine and radiation therapy before or within 140 days following curative intent resection for stage II or III rectal cancer	All stage II/III rectal cancer patients who underwent curative-intent resection. Patients had to be alive and not enrolled in a Medicare HMO through 180 days from surgery.	648	.32

Table 2.2 (Continued)

Lung Cancer				
Curative Surgery for Stage I or II Non-Small Cell Lung Cancer[25]	Pneumonectomy, lobectomy, or wedge or segmental resection within 180 days of diagnosis	All stage I/II non-small cell lung cancer patients. Patients had to be alive and not enrolled in a Medicare HMO through 180 days from diagnosis. Patients were also included if they died within 180 days but underwent surgery.	3564	.87
Mediastinal Evaluation for Stage I or II Non-Small Cell Lung Cancer[25]	Mediastinal evaluation from 45 days before diagnosis through the date of surgery	All stage I/II non-small cell lung cancer patients who underwent lobectomy or pneumonectomy. Patients had to be alive and not enrolled in a Medicare HMO through 180 days from surgery.	1833	.68
Chemotherapy and/or Radiation for Resected Stage IIIA Non-Small Cell Lung Cancer[25]	Chemotherapy and/or radiation therapy from 30 days before diagnosis through 90 days after date of surgery	All stage IIIA non-small cell lung cancer patients who underwent lobectomy or pneumonectomy or wedge resection. Patients had to be alive and not enrolled in a Medicare HMO through 90 days from surgery.	311	.32
Chemotherapy and Radiation for Limited-Stage Small Cell Lung Cancer[26]	Cisplatin or carboplatin and etoposide with concurrent radiation therapy within 180 days of diagnosis; chemotherapy must start between the start and end dates of radiation therapy	All limited-stage small cell lung cancer patients. Patients had to be alive through 45 days from diagnosis and not enrolled in a Medicare HMO through 180 days from diagnosis.	854	.40

Table 2.2 (Continued)

Prostate Cancer				
Androgen Ablation within 120 Days for Men with Stage IV Prostate Cancer[28,29,31,32]	Androgen deprivation therapy with a gonadotropin-releasing hormone (GnRH) agonist or bilateral orchiectomy within 120 days of diagnosis	All prostate cancer patients with stage IV cancer at diagnosis. Patients had to be alive and not enrolled in a Medicare HMO through 120 days from diagnosis.	1281	.73
Oral Anti-Androgen before Initiating Gonadotropin Releasing Hormone (GnRH) Agonist Therapy for Metastatic Prostate Cancer[27]	Proportion of men with metastatic cancer who are started on GnRH agonist who also fill a prescription for an oral anti-androgen for at least 2 weeks, beginning at least 1 week before first dose of GnRH agonist	All prostate cancer patients with stage IV cancer at diagnosis who started a GnRH agonist.	1192	.56
Adjuvant Androgen Deprivation Therapy for High-Risk Cancers Treated with Radiation Therapy[27]	Proportion of patients with high-risk prostate cancer (gleason 8-10 or PSA >20 or stage T3 or greater) treated with radiation who also receive hormonal therapy (adjuvant or neoadjuvant)	All patients with high risk, non-metastatic tumors treated with radiation therapy within 180 days of diagnosis. Patients were required to be alive and not enrolled in a Medicare HMO through 180 days from diagnosis. We only included cases in 2001-2002 because Gleason 7 tumors could not be distinguished from Gleason 8 tumors in 2003-2004.	3190	.86
3-Dimensional Conformal Radiotherapy (3-D CRT) or Intensity-Modulated Radiation Therapy (IMRT) for Prostate Cancer Patients Treated with Electron Beam Radiation Therapy (XRT)[27,30,33]	Receipt of 3D-CRT or IMRT among men with local or regional prostate cancer who received external beam radiation therapy within 180 days of diagnosis	All patients with local or regional prostate cancer at diagnosis who also had evidence of external beam radiation therapy in administrative data. Patients had to be alive and not enrolled in a Medicare HMO through 180 days from diagnosis.	6413	.98

Cancer Survival

We determined patient vital status using the National Death Index, VA administrative data, and Medicare administrative data sources. We computed time to death from any cause and censored patients alive as of December 31, 2005, the last date where we had complete vital status data available from all sources.

Analysis

Empirical factor composite measures. We employed exploratory factor analyses to identify groups of highly correlated hospital-level cancer care process measures. Because a small number of hospitals exhibited missing values on a few measures where they had no eligible patients, we imputed missing hospital-level process measure data using the SAS *PROC MI* procedure. We analyzed the completed covariance matrix obtained from the SAS *PROC MI* procedure using the SAS *PROC FACTOR* procedure with an oblique rotation (*PROMAX*) specification, which allowed for correlations among factors.[18] We used a factor loading cutoff of .30 to make determinations about whether a factor loading was significant. In cases where a measure exhibited factor loadings greater than or equal to .30 on multiple factor domains, we only accounted for the contribution of that measure on the factor domain where its factor loading was the highest (i.e., dominant factor loading).

To compute fixed-weighted empirical factor composite scores for each of the empirical factor domains, we first standardized dominant factor loading weights within each factor domain so that they summed to 1. We then multiplied each hospital's cancer care process measure rate by its corresponding standardized factor loading weight and summed the weighted process measure scores within each factor domain. To compute opportunity-weighted empirical factor composite scores, we first computed the number of patients eligible for each process measure (i.e., care opportunities) and summed by empirical factor domain groupings to create care opportunity denominators for each empirical factor domain. We then computed and summed

the number of eligible patients that received recommended care for each empirical factor domain (i.e., care successes). Finally, we divided each empirical factor domain care success numerator by its corresponding care opportunity denominator.

Cancer-specific composite measures. We generated two sets of colorectal cancer, lung cancer, and prostate cancer care composite measures using fixed- and opportunity-based weighting. To compute fixed-weighted composite scores for each cancer type, we averaged process measure rates by cancer type. To compute opportunity-weighted cancer-specific composite scores, we employed the same opportunity based weighting methods described above. In particular, we first computed the number of patients eligible for each cancer-specific process measure and summed by cancer type to create cancer-specific care opportunity denominators. We then computed and summed the number of eligible patients that received recommended care by cancer type. Lastly, we divided each cancer-specific care success numerator by its corresponding care opportunity denominator.

Care-modality-specific composite measures. We also generated two sets of care-modality-specific composite measures for (1) early screening and evaluation, (2) surgical treatment, and (3) non-surgical treatment using the same fixed- and opportunity-based weighting methods described above.

Each of the resulting composite measures, of any type, could range in value from 0 to 1.0. We used Pearson correlations to assess associations and distinctions among the individual composite measures.

Modeling all-cause survival by cancer type. We estimated Cox proportional hazard models predicting survival time for colon cancer, rectal cancer, non-small cell lung cancer, and small cell lung cancer (separate models for each cancer type) as a function of the composite scores generated in each of the six approaches (one cancer type survival model per composite measure scheme). We did not model prostate cancer survival because the vast majority of

patients with prostate cancer are diagnosed with local or regional disease, for which the 5-year relative survival approaches 100%.[35] We used robust "sandwich" estimators of variance to adjust for within-hospital clustering. In all models, we adjusted for patient characteristics including age, race, sex, marital status, area-level socioeconomic status based on the zip code of the patient's residence (the percentage of college graduates and the percentage of persons living below the poverty level), distance from the patients' residence to the facility in which their cancer was reported, prior cancer history, comorbidities (measured using the Klabunde modification of the Charlson score[36,37] separating chronic obstructive pulmonary disease [COPD] from the Charlson score for lung cancer patients), and tumor grade, stage, and size. We did not adjust for hospital characteristics because we were concerned that some hospital structural measures (e.g., onsite availability of specialized services and providers) might capture aspects of cancer care quality that may also be reflected in our composite measures. For all models, we multiplied the parameter estimate associated with each composite measure by 2 times the measure's standard deviation (*SD*), so that the reported hazard ratios reflect survival differences associated with a 2 *SD* improvement in performance on that measure. Although this study was exploratory in nature, we also adjusted p-values for multiple comparisons using the Benjamini-Hochberg procedure.[38,39]

Impact of opportunity- vs. fixed-weights on composite scores. Compared with fixed-weighting, opportunity-based weights reflect the mix of eligible patients for each quality measure (i.e., case mix), which can vary across provider units (e.g., physicians, hospitals). This can be of concern if provider units differ in their case mix of eligible patients for "difficult to achieve" quality measures. For example, suppose that opportunity-based composites measures were generated for Hospital 1 (*N*=100 patients) and Hospital 2 (*N*=100) based on two quality indicators, Measure A ("more difficult to achieve") and Measure B ("less difficult to achieve"), where overall performance for both hospitals on Measure A is 0.40 and Measure B is 0.90. If

only 10 of the 100 patients at Hospital 1 are eligible for Measure A and the remaining 90 patients are eligible for Measure B, while 50 of the 100 patients at Hospital 2 are eligible for Measure A and the remaining 50 patients are eligible for Measure B, then the opportunity-based composite scores for Hospital 1 and Hospital 2 would equal 0.85 and 0.65, respectively. Thus, the opportunity-based composite scores for Hospitals 1 and 2 would reflect the relative mix of patients across hospitals and not necessarily true differences in care quality. To assess the relative impact of opportunity- vs. fixed-weighting on hospital composite scores, we recomputed the six types of composite measures for each hospital, replacing each individual hospital's performance measure rate with the overall mean of each performance measure. Thus, each set of recomputed fixed-weighted composite scores would be the same across all hospitals while the recomputed opportunity-based weighted composite scores could vary depending on the case mix of eligible patients at each hospital.

All analyses were conducted using SAS 9.3.

IV. RESULTS

Table 2.3 presents patient-level descriptive data by cancer type. On average, most VA cancer patients were over age 65, White non-Hispanic, male, married, and exhibited no prior history of cancer and a Charlson score of 0. Table 2.4 displays unadjusted hospital-level cancer care process measure rates.

Table 2.3 Patient Characteristics in Cancer Cohorts

Characteristics	Colon	Rectal	Non-Small Cell Lung	Small Cell Lung	Prostate
	N = 7,725	N = 2,233	N = 17,511	N = 2,875	N = 31,238
Age - %					
<60 yrs	20.3	28.4	23.6	25.0	22.4
60-64 yrs	12.4	12.7	14.1	16.6	16.3
65-69 yrs	14.0	13.0	15.9	15.4	20.2
≥ 70 yrs	53.3	45.9	46.4	43.0	41.1
Race - %					
White	71.3	76.4	76.1	82.3	62.2
Black	19.8	14.4	20.1	14.0	27.2
Hispanic	6.5	6.7	2.1	2.2	7.0
Other	2.5	2.5	1.7	1.6	3.7
Gender - %					
Female	2.0	1.0	1.7	2.0	
Male	98.0	99.0	98.3	98.0	100.0
Marital Status - %					
Unmarried	39.4	40.2	53.0	51.1	45.1
Married	50.7	49.3	45.5	47.8	53.3
Unknown	9.9	10.6	1.6	1.1	1.7
Prior History of Cancer - %					
No	85.8	87.1	82.0	84.4	93.1
Yes	14.2	13.0	18.0	15.7	7.0
Charlson Comorbidity Score - %					
0	51.2	61.2	61.5	61.6	63.3
1	28.3	24.3	22.3	21.6	24.5
2	11.7	8.3	9.5	9.6	7.7
3 +	8.8	6.1	6.7	7.3	4.5

Table 2.3 (Continued)

Year of Diagnosis - %					
2001	24.1	23.1	24.7	23.5	24.5
2002	25.6	24.3	24.8	24.8	25.3
2003	25.3	25.0	25.3	25.0	25.1
2004	25.0	27.6	25.2	26.7	25.1
Tumor Stage - %					
Stage I (least advanced)	30.0	34.5	25.4		81.8‡
Stage II	25.3	24.0	7.1	36.1†	
Stage III	21.6	18.9	26.7		7.8‡
Stage IV (most advanced)	18.4	16.2	37.7	60.2†	4.9‡
Stage Missing/Unknown	4.7	6.5	3.2	3.7	5.6
% Population ≥ 65 Yrs Living Below Poverty in Zip Code of Residence - %					
Q1 (0 - <7.9%)	23.8	24.4	23.8	25.3	23.7
Q2 (7.9 - <12.8%)	21.8	22.6	22.0	24.1	21.4
Q3 (12.8 - <19.5%)	23.0	23.1	23.6	22.7	23.0
Q4 (19.5 - 76.9%)	26.1	25.3	25.8	23.9	26.8
Missing/Unknown	5.4	4.7	4.8	5.0	5.1
% Population College Graduates in Zip Code of Residence - %					
Q1 (<15.9%)	23.6	25.9	24.3	24.4	24.3
Q2 (15.9- <21.6%)	22.7	22.4	23.3	23.7	22.8
Q3 (21.6- <30.0%)	22.6	23.3	22.9	22.4	23.0
Q4 (30.0-100.0%)	25.8	23.7	24.7	24.5	24.8
Missing/Unknown	5.4	4.6	4.8	5.0	5.1
Average Distance to Reporting Hospital - Miles	50.6	50.9	58.0	56.5	49.6

† – Small cell lung cancer stage categories (in order from least advanced to most advanced): limited stage, extensive stage
‡ – Prostate cancer stage categories (in order from least advanced to most advanced): local, regional, distant

Table 2.4 Unadjusted Hospital-Level Cancer Care Process Measure Rates (N= 59 Hospitals)

Hospital-level Cancer Care Process Measures – Mean Hospital Rates (SD)	
Colon Cancer	
Early Stage (Stage I/II vs. III/IV) at Presentation, Colon Cancer	55.3 (7.9)
Early Stage (Stage I/II vs. III/IV) at Presentation, Rectal Cancer	58.1 (9.8)
Curative Surgery for Stage I, II, or III Colon Cancer	93.9 (4.7)
Curative Surgery for Stage I, II, or III Rectal Cancer	76.4 (17.3)
Adjuvant Chemotherapy and Radiation Therapy for Stage II or III Rectal Cancer	75.8 (9.9)
Lung Cancer	
Curative Surgery for Stage I or II Non-Small Cell Lung Cancer	54.5 (19.2)
Mediastinal Evaluation for Stage I or II Non-Small Cell Lung Cancer	88.5 (10.6)
Chemotherapy and/or Radiation for Resected Stage IIIA Non-Small Cell Lung Cancer	69.6 (29.6)
Chemotherapy and Radiation for Limited-Stage Small Cell Lung Cancer	59.7 (21.3)
Prostate Cancer	
Androgen Ablation within 120 Days for Men with Stage IV Prostate Cancer	74.3 (18.4)
Oral Anti-Androgen before Initiating GnRH Agonist Therapy for Metastatic Prostate Cancer	81.5 (13.5)
Adjuvant Androgen Deprivation Therapy for High-Risk Cancers Treated with Radiation Therapy	56.5 (18.1)
3-D CRT or IMRT for Prostate Cancer Patients Treated with EBRT	58.6 (28.5)

PET – Positron Emission Tomography
XRT – External Beam Radiation Therapy
GnRH – Gonadotropin Releasing Hormone
3-D CRT – 3-Dimensional Conformal Radiation Therapy
IMRT – Intensity Modulated Radiation Therapy
EBRT – External-Beam Radiation Therapy

Factor Analysis

A four-factor solution emerged as most interpretable and accounted for 52.2% of the total variation in the facility-level cancer care process measures (see Table 2.5). The first factor, “colorectal early screening,” consisted of two measures: early stage at presentation for colon cancer and early stage at presentation for rectal cancer. The second factor, “prostate cancer treatment,” included three measures: androgen ablation within 120 days for men with stage IV prostate cancer, adjuvant deprivation therapy for high-risk cancers treated with radiation therapy, and 3-dimensional conformal radiation therapy or intensity modulated radiation therapy (3-D CRT or IMRT) for prostate cancer patients treated with external beam radiation therapy.

The third factor, “surgical treatment and related care,” consisted of curative surgery for stage I, II, or III colon and rectal cancers, curative surgery for stage I or II non-small cell lung cancer, mediastinal evaluation for stage I or II non-small cell lung cancer, and adjuvant chemotherapy and radiation therapy for stage II or III rectal cancer. The adjuvant rectal cancer therapy measure loaded negatively on this factor. The fourth factor, “non-surgical treatment,” included four measures: chemotherapy and/or radiation for resected stage IIIA non-small cell lung cancer, chemotherapy and radiation for limited-stage small cell lung cancer, and oral anti-androgen before initiating gonadotropin release hormone (GnRH) agonist therapy for metastatic prostate cancer.

Correlations Within and Among Composite Measure Groupings

The groupings for the cancer-specific and care-modality-specific composite measures are also included in Table 2.5. The measure groupings that emerged from the empirical factor analysis were consistently organized neither by cancer type nor by modality of care. Instead, the factor domains included cancer-specific factors for "colorectal early screening" and "prostate

cancer treatment" and care-modality-specific factors for "surgical treatment and related care" and "non-surgical treatment."

Table 2.5 Cancer Care Composite Measure Grouping Results: Empirical Factor Domains, Cancer-Specific, and Care-Modality-Specific

	Empirical Factor Analysis				Cancer-Specific			Care-Modality-Specific		
	Colorectal Early Screening	Prostate Treatment	Surgical Treatment & Related Care	Non-Surgical Treatment	Colorectal Care	Lung Care	Prostate Care	Screening & Evaluation	Surgical Treatment	Non-Surgical Treatment
Quality Measure	*Factor Loading*	*Factor Loading*	*Factor Loading*	*Factor Loading*						
Colon Cancer										
Early Stage (Stage I/II vs. III/IV) at Presentation, Colon Cancer	0.82† ✓	0.01	-0.09	-0.01	✓			✓		
Early Stage (Stage I/II vs. III/IV) at Presentation, Rectal Cancer	0.81† ✓	-0.27	-0.06	-0.01	✓			✓		
Curative Surgery for Stage I, II, or III Colon Cancer	0.04	0.02	0.72† ✓	0.05	✓				✓	
Curative Surgery for Stage I, II, or III Rectal Cancer	-0.25	-0.27	0.52† ✓	0.25	✓				✓	
Adjuvant Chemotherapy and Radiation Therapy for Stage II or III Rectal Cancer	0.04	-0.04	-0.44† ✓	0.11	✓					✓
Lung Cancer										
Curative Surgery for Stage I or II Non-Small Cell Lung Cancer	0.30	-0.11	0.44† ✓	-0.21		✓			✓	

Table 2.5 (Continued)

Mediastinal Evaluation for Stage I or II Non-Small Cell Lung Cancer	-0.09	0.09	0.46† ✓	-0.12		✓	✓	
Chemotherapy and/or Radiation for Resected Stage IIIA Non-Small Cell Lung Cancer	0.24	0.06	-0.19	0.76† ✓		✓		✓
Chemotherapy and Radiation for Limited-Stage Small Cell Lung Cancer	-0.07	-0.14	0.12	0.62† ✓		✓		✓
<u>Prostate Cancer</u>								
Androgen Ablation within 120 Days for Men with Stage IV Prostate Cancer	-0.17	0.81† ✓	0.16	0.00			✓	✓
Oral Anti-Androgen before Initiating GnRH Agonist Therapy for Metastatic Prostate Cancer	-0.14	0.05	-0.13	0.65† ✓			✓	✓
Adjuvant Androgen Deprivation Therapy for High-Risk Cancers Treated with Radiation Therapy	-0.10	0.78† ✓	-0.25	-0.05			✓	✓
3-D CRT or IMRT for Prostate Cancer Patients Treated with XRT	0.48	0.54† ✓	0.36	0.11			✓	✓

GnRH – Gonadotropin Releasing Hormone
3-D CRT – 3-Dimensional Conformal Radiation Therapy
IMRT – Intensity Modulated Radiation Therapy
XRT – External-Beam Radiation Therapy
† – Dominant factor loading with a value greater than or equal to .30

Compared with the empirically-derived "colorectal early screening" composite measure group, the cancer-specific "colorectal care" composite group consisted of a broader set of colorectal care measures reflecting early screening/diagnosis, curative surgery, and adjuvant therapy. Correlations (*r*) between the empirically-derived "colorectal early screening" composites (fixed- and opportunity-weighted) and cancer-specific "colorectal care" composites were strong, ranging from $r = 0.56$ to 0.89, $p<.0001$ (see Table 2.6). Correlations were also strong among the empirically-derived "colorectal early screening" composites and the care-modality-specific "screening and evaluation" composites ($r = 0.75$ to 0.89; $p<.0001$), which consisted of the two colorectal early screening/diagnosis measures and mediastinal evaluation for early-stage non-small cell lung cancer.

The empirically-derived "prostate cancer treatment" and cancer-specific "prostate care" composites were nearly identical in terms of measure composition and strongly correlated ($r = 0.86$ to 0.99, $p<.0001$). We also observed strong correlations among the empirically-derived "surgical treatment and related care" composites and the care-modality-specific "surgical treatment" composites, which strictly consisted of curative surgery measures ($r = 0.61$ to 0.96, $p<.0001$). Compared with the empirically-derived "non-surgical treatment" composite measure group, the care-modality-specific "non-surgical treatment" composite measure group reflected a broader set of chemotherapy, radiation, and hormonal treatments. Correlations between the empirically-derived "non-surgical treatment" composites and fixed-weighted care-modality-specific "non-surgical treatment" composites ranged from $r = 0.47$ to 0.68, $p<.0001$; however, we observed no associations between the empirically-derived "non-surgical treatment" composites and the opportunity-weighted care-modality-specific "non-surgical treatment" composite, which primarily consisted of care opportunities for prostate hormonal treatments relative to other non-surgical treatments.

We also observed correlations among several other composite measures that were largely driven by similarities in measure composition. For example, the opportunity-weighted

cancer-specific "lung care" composite mostly consisted of lung surgery and surgery-related care opportunities and was strongly associated with the empirically-derived "surgical treatment and related care" composites (r = 0.68 to 0.70, p<.0001). In addition, the care-modality-specific "non-surgical treatment" composites, which largely reflected prostate cancer measures, were strongly correlated with the empirically-derived "prostate cancer treatment" composites (r = 0.63 to 0.98, p<.0001) and cancer-specific "prostate care" composites (r = 0.65 to 0.99, p<.0001).

In general, correlations were strongest among composites with both similar measure compositions and weightings. Although, compared with weighting scheme, grouping approach was the primary driver of correlations among most composites. We did not observe correlations among similarly weighted composites that exhibited dissimilar measure compositions.

Within each of the three composite measure groupings (empirical factor, cancer-specific, care-modality-specific), correlations for any given set of fixed- and opportunity-weighted composites were also strong, ranging from r = 0.51 to 0.95, p<.0001; however, we observed little to no correlation across the different domains of care. For example, within the empirical factor grouping, the fixed- and opportunity-weighted "prostate cancer treatment" composites were strongly correlated (r = 0.86, p<.0001); although, neither of the "prostate cancer treatment" composites were associated with the empirical factor composites reflecting other domains of cancer care.

Table 2.6 Pearson Correlations for Empirical Factor, Cancer-Specific, and Care-Modality-Specific Composites

		FWEF				OWEF			
		Colorectal Early Screening	Prostate Treatment	Surgical Treatment & Related Care	Non-Surgical Treatment	Colorectal Early Screening	Prostate Treatment	Surgical Treatment & Related Care	Non-Surgical Treatment
FWEF	Colorectal Early Screening	1.00							
	Prostate Treatment	-0.04	1.00						
	Surgical Treatment & Related Care	0.03	-0.01	1.00					
	Non-Surgical Treatment	0.07	-0.03	-0.12	1.00				
OWEF	Colorectal Early Screening	0.95***	0.03	0.02	0.06	1.00			
	Prostate Treatment	0.12	0.86***	0.10	-0.01	0.17	1.00		
	Surgical Treatment & Related Care	0.11	0.01	0.62***	-0.10	0.07	0.15	1.00	
	Non-Surgical Treatment	-0.07	-0.10	-0.02	0.80***	-0.08	-0.14	-0.02	1.00
FWCS	Colorectal Care	0.58***	-0.08	-0.20	0.09	0.56***	0.08	0.29*	-0.02
	Lung Care	0.16	-0.02	0.31*	0.82***	0.13	0.06	0.28*	0.60***
	Prostate Care	-0.01	0.95***	-0.01	0.13	0.05	0.88***	0.00	0.08
OWCS	Colorectal Care	0.84***	0.08	0.18	0.04	0.89***	0.26	0.29*	-0.07
	Lung Care	0.24	-0.01	0.68***	0.03	0.20	0.12	0.70***	0.01
	Prostate Care	0.10	0.86***	0.09	0.03	0.15	0.99***	0.14	-0.08
FWCMS	Screening & Evaluation	0.82***	0.00	0.27*	0.00	0.75***	0.13	0.22	-0.06
	Surgical Treatment	0.08	-0.05	0.81***	-0.10	0.08	0.11	0.75***	-0.07
	Non-Surgical Treatment	0.06	0.66***	-0.24	0.68***	0.09	0.63***	-0.04	0.47***
OWCMS	Screening & Evaluation	0.87***	0.05	0.30*	-0.04	0.89***	0.22	0.23	-0.17
	Surgical Treatment	0.07	-0.03	0.61***	-0.09	0.05	0.11	0.96***	0.02
	Non-Surgical Treatment	0.11	0.84***	0.06	0.08	0.16	0.98***	0.14	-0.04

Table 2.6 (Continued)

		FWCS			OWCS			FWMS			OWMS		
		Colorectal Care	Lung Care	Colorectal Care	Lung Care	Colorectal Care	Lung Care	Screening & Evaluation	Surgical Treatment	Non-Surgical Treatment	Screening & Evaluation	Surgical Treatment	Non-Surgical Treatment
FWCS	Colorectal Care	1.00											
	Lung Care	0.07	1.00										
	Prostate Care	-0.04	0.06	1.00									
OWCS	Colorectal Care	0.72***	0.16	0.10	1.00								
	Lung Care	0.09	0.51***	0.00	0.27*	1.00							
	Prostate Care	0.07	0.07	0.90***	0.23	0.11	1.00						
FWCMS	Screening & Evaluation	0.41**	0.23	0.00	0.70***	0.28*	0.09	1.00					
	Surgical Treatment	0.18	0.31*	-0.02	0.29*	0.82***	0.11	0.08	1.00				
	Non-Surgical Treatment	0.20	0.53***	0.75***	0.14	-0.01	0.65***	-0.01	-0.13	1.00			
OWCMS	Screening & Evaluation	0.48**	0.22	0.05	0.86***	0.49***	0.18	0.80***	0.34*	0.01	1.00		
	Surgical Treatment	0.20	0.22	-0.02	0.25	0.61***	0.11	0.09	0.75***	-0.09	0.13	1.00	
	Non-Surgical Treatment	0.11	0.12	0.88***	0.24	0.12	0.99***	0.09	0.11	0.69***	0.19	0.10	1.00

FWEF – Fixed Weighted Empirical Factor; OWEF – Opportunity Weighted Empirical Factor
FWCS – Fixed Weighted Cancer-Specific; OWCS – Opportunity Weighted Cancer-Specific
FWCMS – Fixed Weighted Care-Modality Specific; OWCMS – Opportunity Weighted Care-Modality-Specific
* – Statistically significant at p<.05; ** – Statistically significant at p<.01; *** – Statistically significant at p<.001

Composite Measure Associations with Cancer Patient Survival

Colon cancer. In adjusted analyses, higher hospital performance on the fixed-weighted care-modality-specific "non-surgical treatment" composite was associated with better survival among colon cancer patients (adjusted hazard ratio (HR)=0.89 [0.82-0.97]; see Table 2.7). No other composite measures were associated with colon cancer survival in adjusted analyses.

Rectal cancer. Several of the cancer-specific composites were associated with rectal cancer survival. Higher performance on the fixed-weighted “colorectal care” composite and opportunity-weighted “colorectal care” composite were, respectively, associated with improved survival outcomes for rectal cancer patients (HR=0.80 [0.72-0.90]; HR=0.80 [0.70-0.91]). Interestingly, both the fixed- and opportunity-weighted “prostate care” composite measures were associated with worse survival outcomes for rectal cancer patients (HR=1.14 [1.02-1.28]; HR=1.18 [1.04-1.34]). In addition, higher performance on the opportunity-weighted empirical factor "prostate cancer treatment" composite was also associated with lower rectal cancer survival (HR=1.16 [1.01-1.33]). None of the care-modality-specific composites were associated with survival among rectal cancer patients.

Non-small cell lung cancer. Three composite measures were associated with non-small cell lung cancer survival. Among the fixed-weighted empirical factor composite measures, higher performance on the “surgical treatment and related care” composite measure was associated with better survival for non-small cell lung cancer patients (HR=0.93 [0.88-0.98]). Survival was also better among non-small cell lung cancer patients treated at hospitals with higher performance on the opportunity-weighted cancer-specific “lung care” composite (HR=0.93 [0.88-0.99]), which due to the mix of lung cancer patients across hospitals, largely reflected care opportunities for lung cancer surgery and related care. In addition, higher hospital performance on the fixed-weighted care-modality-specific “surgical treatment” composite was associated with better survival among non-small cell lung cancer patients (HR=0.94 [0.89-0.99]).

Small cell lung cancer. Only two composite measures were associated with survival for small cell lung cancer, a cancer for which surgical treatments do not have a role. Both the fixed- and opportunity-weighted empirical factor "non-surgical treatment" composites were associated with better survival for small cell lung cancer patients (HR=0.93 [0.87-0.99]; HR=.91 [0.85-0.98]). None of the cancer-specific or care-modality specific composites were associated with survival among small cell lung cancer patients.

In total, we observed 11 statistically significant associations between the composite measures and cancer patient survival. After adjusting for multiple comparisons using the Benjamini-Hochberg procedure, only 2 of the 11 associations remained statistically significant; both the fixed- and opportunity-weighted "colorectal care" composites remained associated with better rectal cancer survival.

Table 2.7 Adjusted Hazard of Cancer Death According to Hospital Cancer Care Composite Quality Scores: Comparison of Fixed- and Opportunity- Weighted Empirical Factor, Cancer-Specific, and Care-Modality-Specific Composites

	Colon Cancer N = 7,308 HR (95%CI)	**Rectal Cancer** N = 2,082 HR (95%CI)	**Non-Small Cell Lung Cancer** N = 17,380 HR (95%CI)	**Small Cell Lung Cancer** N = 2,831 HR (95%CI)
Hospital Composite Quality Measures				
Fixed-Weighted Empirical Factor				
Colorectal Early Screening	1.01(0.93-1.11)	0.94(0.81-1.09)	1.04(0.99-1.10)	0.94(0.87-1.01)
Prostate Treatment	0.94(0.86-1.03)	1.10(0.96-1.26)	0.96(0.91-1.02)	0.96(0.90-1.03)
Surgical Treatment and Related Care	1.02(0.94-1.11)	1.00(0.83-1.20)	0.93(0.88-0.98)**	0.98(0.92-1.05)
Non-Surgical Treatment	0.92(0.85-1.01)	0.99(0.90-1.09)	1.02(0.96-1.08)	0.93(0.87-0.99)*
Opportunity-Weighted Empirical Factor				
Colorectal Early Screening	1.01(0.93-1.09)	0.90(0.77-1.06)	1.04(0.98-1.10)	0.93(0.86-1.01)
Prostate Treatment	0.93(0.85-1.02)	1.16(1.01-1.33)*	0.99(0.93-1.05)	0.98(0.91-1.06)
Surgical Treatment and Related Care	1.00(0.91-1.10)	0.90(0.80-1.02)	0.96(0.91-1.01)	0.98(0.93-1.04)
Non-Surgical Treatment	0.93(0.84-1.02)	1.04(0.92-1.17)	1.00(0.94-1.06)	0.91(0.85-0.98)*
Fixed-Weighted Cancer-Specific				
Colorectal Care	0.97(0.89-1.05)	0.80(0.72-0.90)***†	1.03(0.97-1.09)	0.98(0.92-1.04)
Lung Care	0.92(0.85-0.99)	0.97(0.88-1.06)	0.97(0.92-1.03)	0.94(0.88-1.01)
Prostate Care	0.95(0.87-1.03)	1.14(1.02-1.28)*	0.98(0.93-1.03)	0.96(0.89-1.02)
Opportunity-Weighted Cancer-Specific				
Colorectal Care	1.01(0.93-1.09)	0.80(0.70-0.91)**†	1.04(0.98-1.12)	0.95(0.87-1.03)
Lung Care	0.96(0.86-1.06)	1.04(0.90-1.21)	0.93(0.88-0.99)*	0.98(0.91-1.07)
Prostate Care	0.94(0.86-1.03)	1.18(1.04-1.34)*	0.99(0.94-1.05)	0.99(0.91-1.06)
Fixed-Weighted Care-Modality-Specific				
Screening and Evaluation	1.00(0.91-1.10)	0.89(0.76-1.05)	1.00(0.95-1.06)	0.94(0.87-1.01)
Surgical Treatment	0.99(0.90-1.09)	0.96(0.83-1.10)	0.94(0.89-0.99)*	1.00(0.94-1.06)
Non-Surgical Treatment	0.89(0.82-0.97)**	1.02(0.93-1.11)	1.00(0.94-1.06)	0.93(0.86-1.02)

Table 2.7 (Continued)

Opportunity-Weighted Care-Modality-Specific				
Screening and Evaluation	1.01(0.92-1.10)	0.92(0.79-1.08)	1.00(0.94-1.06)	0.96(0.89-1.03)
Surgical Treatment	1.02(0.93-1.11)	0.94(0.83-1.06)	0.97(0.92-1.03)	0.98(0.93-1.04)
Non-Surgical Treatment	0.92(0.84-1.01)	1.13(0.99-1.29)	1.00(0.95-1.06)	0.98(0.90-1.05)

HR – All-cause adjusted Hazard Ratio reflecting survival differences associated with a 2 standard deviation (*SD*) improvement in performance on each composite measure

Adjusted HRs obtained from Cox proportional hazard models with sandwich estimators to adjust for within-hospital clustering. All models adjusted for patient characteristics including age, race, sex, marital status, area-level socioeconomic status based on the zip code of the patient's residence (the percentage of college graduates, and the percentage of persons living below the poverty level), distance from the patients' residence to the facility in which their cancer was reported, prior cancer history, comorbidities (measured using the Klabunde modification of the Charlson score with chronic obstructive pulmonary disease [COPD] examined separately from the Charlson score for lung cancer patients), and tumor grade, stage, size, and hospital characteristics including teaching hospital status, cancer patient volume, presence of cancer-specific tumor boards, and onsite availability of positron emission tomography and external radiation therapy.

* – Statistically significant at p<.05

** – Statistically significant at p<.01

*** – Statistically significant at p<.001

† – Statistically significant after adjustment for multiple comparisons

Impact of Opportunity- vs. Fixed-Weighting on Composite Scores

Table 2.8 summarizes data for the recomputed (calculated at the overall mean of each measure) fixed- and opportunity-weighted composite measures. As expected, computing the fixed-weighted composite measures using the overall mean of each performance measure resulted in identical fixed-weighted composite scores across all hospitals. Compared with the recomputed fixed-weighted composites, the recomputed opportunity-weighted composite scores varied extensively across hospitals. For example, all hospitals exhibited a score of 0.83 on the recomputed fixed-weighted empirical factor "surgical treatment and related care" composite; however, scores on the recomputed opportunity-weighted "surgical treatment and related care" composite ranged from 0.75 to 0.87. Thus, differences in the case mix of eligible patients across hospitals was an additional source of variation in the opportunity-weighted composite scores.

Table 2.8 Summary of Recomputed Fixed- and Opportunity-Weighted Empirical Factor, Cancer-Specific, and Care-Modality-Specific Composite Scores Calculated at the Mean of Each Quality Measure: Comparing Impact of Opportunity- vs. Fixed-Weighting

Score	Fixed Colorectal Early Screening	OBS Colorectal Early Screening	Fixed Prostate Treatment	OBS Prostate Treatment	Fixed Surgical Treatment & Related Care	OBS Surgical Treatment & Related Care	Fixed Non-Surgical Treatment	OBS Non-Surgical Treatment	Fixed Colorectal Care	OBS Colorectal Care	Fixed Lung Care	OBS Lung Care	Fixed Prostate Care	OBS Prostate Care	Fixed Screening & Evaluation	OBS Screening & Evaluation	Fixed Surgical Treatment	OBS Surgical Treatment	Fixed Non-Surgical Treatment	OBS Non-Surgical Treatment
Min	0.57	0.56	0.66	0.57	0.83	0.75	0.69	0.67	0.72	0.67	0.70	0.62	0.67	0.57	0.68	0.56	0.76	0.72	0.68	0.58
Max	0.57	0.56	0.66	0.65	0.83	0.87	0.69	0.80	0.72	0.72	0.70	0.71	0.67	0.70	0.68	0.68	0.76	0.88	0.68	0.69
SD	0.00	0.00	0.00	0.02	0.00	0.02	0.00	0.03	0.00	0.01	0.00	0.02	0.00	0.02	0.00	0.03	0.00	0.04	0.00	0.02

OBS – Opportunity-Based Scoring Weight

V. DISCUSSION

In this study we compared multiple approaches for grouping and weighting individual hospital-level cancer-related quality indicators into composite measures of cancer care quality. Compared with cancer-specific and care-modality-specific composite measure groupings, the empirically-derived grouping approach reflected the natural relationships among cancer-related quality indicators. These empirically-derived cancer care dimensions reflected a combination of cancer-specific and care-modality-specific process measure groupings and indicate that relationships among cancer care processes in the hospital setting may cross traditional boundaries of condition- or treatment-specific care delivery.

In general, the factor-based measure groupings closely resembled many of the cancer-specific and care-modality-specific measure groupings. For example, the empirically-derived "prostate cancer treatment" and cancer-specific "prostate care" composites were strongly associated and comprised of nearly the same set of treatment measures, suggesting that prostate cancer treatment processes are a unique dimension of cancer care. This is consistent with the fact that prostate cancer care is often delivered by urologists, who are not oncologists and do not take care of other types of cancer patients. The empirical factor "colorectal early screening" composite and cancer-specific "colorectal care" composite were also strongly associated; although, the cancer-specific "colorectal care" group consisted of a broader set of colorectal screening and treatment measures. In addition, the empirical factor "surgical treatment and related care" composites and "non-surgical treatment" composites were, respectively, associated with the care-modality-specific "surgical treatment" and "non-surgical treatment" composites. Thus, surgical and non-surgical treatment emerged as important dimensions of cancer care. We did not observe associations among different care domains within each of the three composite measure groupings (empirical factor, cancer-specific, care-modality-specific), suggesting that each care domain may reflect a distinct dimension of care.

Despite differences in the methods used to generate the composite measures, patterns in predicting patient survival were generally similar, particularly for composites with similar measure compositions. For example, although neither of the "colorectal early screening" empirical factor composites were associated with survival among colon or rectal cancer patients, both the fixed- and opportunity-weighted cancer-specific "colorectal care" composite measures were similarly associated with improved rectal cancer survival. These findings suggest that a combination of care processes along the colorectal cancer care continuum (e.g., screening, surgery, chemotherapy) may be collectively important to rectal cancer care quality and survival outcomes. We also observed nearly identical associations between both the empirical factor and care-modality-specific fixed-weighted surgical treatment composites and non-small cell lung cancer survival. In addition, the opportunity-weighted cancer-specific “lung care” composite, which mostly reflected lung cancer surgery cases, was similarly associated with improved survival for non-small cell lung cancer. These findings suggest that surgical treatment is an important dimension of non-small cell lung cancer care quality. Unlike non-small cell lung cancer, surgical treatment is not indicated as a recommended course of treatment for small cell lung cancer. We found that both the fixed- and opportunity-weighted empirical factor “non-surgical treatment” composites were positively associated with survival for small cell lung cancer. Of note, neither of the care-modality-specific “non-surgical treatment” composites, which contained a broader set of less related non-surgical quality indicators, were associated with small cell lung cancer survival.

Each of the composite methods explored in this study has strengths and weaknesses. Empirically-derived factor groupings reflect the underlying associations among cancer care processes and can identify important dimensions of cancer care quality and delivery. Still, factor interpretability and plausibility can be a major challenge with this approach, particularly when the factor domains and empirical relationships among measures lack face validity. Cancer- and care-modality-specific composite groupings may be more immediately face-valid to

clinicians. However, because cancer care quality and delivery may reflect a combination of cancer-specific and care-modality-specific care dimensions, use of simple condition- or treatment-specific grouping approaches may not be entirely sufficient.

Simple averaging is often easier to implement and interpret than factor loading weights; however, this approach entails applying equal weights across quality indicators and hence implicitly suggests that each indicator is equally important to a particular dimension or composite measure of quality. Empirical factor loading weights reflect both the relationships among quality indicators and the relative importance of each quality indicator to its underlying quality dimension. However, the interpretation and plausibility of factor loadings weights can be a challenge with this approach (e.g., negative factor loading for the adjuvant rectal cancer therapy measure).

Opportunity-based weighting, on the other hand, is a relatively simple and commonly used approach for generating composites;[3,6,13,17] however, this approach also presents some challenges to quality measurement. Although we observed strong associations within each set of fixed- and opportunity-weighted composites, additional analyses revealed that opportunity-based weights, due to differences in hospital case mix of eligible patients, are a source of chance variation (i.e., noise) in composite score calculations. Thus, users of opportunity-based scoring methods should consider and assess the potential impact of case mix differences on opportunity-based composite scores.

This exploratory study did not identify an optimal approach for grouping and weighting quality indicators into cancer care composites. However, understanding the goals of potential users of cancer care quality data can also help inform the process for developing and reporting cancer care composite measures and ensure acceptance and use among stakeholders. For example, health care providers (e.g., physicians, hospitals) are more likely to be interested in composite measures that can help stimulate and direct quality improvement efforts.[40,41] Cancer patients in search of a health care provider may be especially interested in composite measures

that summarize care quality, survival, and patient-reported outcomes by cancer type. And in an effort to steer patients toward cancer care providers that deliver cost-efficient and high quality care, insurers may favor composite measures that give weight to both costs and quality. In addition, recent qualitative work that examined multistakeholder perspectives (i.e., consumers, payers, providers, purchasers) on composite measure use and development in ambulatory care revealed that most stakeholders preferred composite measures that were disease-specific and constructed using simple and transparent methods.[40] Thus, understanding and balancing perspectives from various stakeholders during the measure development process remains an important issue.

Limitations

To our knowledge, no previous study has examined approaches for generating composite measures of cancer care quality. Our study's strengths include our use of a broad set of cancer care process measures that reflect cancer care quality for three common types of cancer. We also employed and compared a range of grouping and weighting approaches for generating cancer care composites.

Our study's limitations highlight some common challenges in quality measurement including the difficulty of measuring care quality for low-volume hospitals. In this study, we excluded hospitals with very few cancer patients due to measure reliability concerns. Thus, our findings may not generalize to hospitals with lower cancer patient volume. We also did not risk adjust the hospital-level quality indicators used to compute our composite measures; although, in this first-step exploratory study, we were most interested in comparing methods for grouping and weighting measures into cancer care composite measures. We did, however, adjust for patient clinical and demographic characteristics in our survival models. In addition, we were unable to assess associations between our composite measures and other important outcomes of cancer care such as treatment toxicity, quality of life, and patient satisfaction. Furthermore, to

our surprise, we observed negative associations between a few of our prostate cancer composite measures and rectal cancer survival. Additional research is needed to better understand the nature of this relationship and/or whether these associations are spurious in nature.

Conclusion

Compared with individual quality indicators, cancer care composite measures may be better suited for capturing the most salient dimensions of cancer care and summarizing quality performance across hospitals. However, these care dimensions and hospital performance scores can often vary depending on the methods used to generate composite measures; thus, use of transparent methods and consideration of stakeholders' (e.g., patients, providers, insurers) needs and objectives should be integrated into the composite measure development process.

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Chapter 3

Area-Level Factors Associated with Electronic Health Record Adoption in the Regional Extension Center Program

I. INTRODUCTION

Research suggests that practices using electronic health record systems (EHR) systems experience several benefits including greater efficiency, enhanced care quality, and improved patient outcomes.[1-4] Despite this evidence, adoption of EHRs has been slow in the US relative to other developed nations.[5] Much of the literature on facilitators and barriers to EHR adoption has primarily focused on provider- and practice-level factors, with less attention given to potential system- and area-level factors associated with EHR adoption.

Insights from the diffusion of innovation literature highlight the important role of contextual factors in the innovation diffusion process. For example, pre-existing inequalities in a given society are typically reflected in its pattern of innovation diffusion.[6] Given the large federal investment in promoting EHR adoption in recent years, identifying the contextual factors that could promote or impede EHR adoption is an area of great policy relevance.

In this study, I explore associations between area-level factors and the adoption of EHR systems in the context of the Regional Extension Center (REC) Program, a federally funded program consisting of 62 diverse organizations that specialize in providing technical assistance to primary care providers during the EHR adoption and meaningful use process. To conduct this study, I use county-level Regional Extension Center Performance data from the Office of the National Coordinator (ONC) for Health Information Technology (IT) supplemented with data from other county-level data sources, such as the American Community Survey, Area Resource File, and the Federal Communications Commission's Local Telephone Competition and Broadband Deployment database.

II. BACKGROUND

Electronic Health Record Adoption in the US: Current State of Affairs

The Institute of Medicine (IOM) has long supported use of EHRs and clinical decision support systems as tools for improving care quality and efficiency.[1] However, evidence pertaining to the actual benefits of EHRs and other forms of health IT has been mixed. Some earlier studies indicate that health IT use is associated with less efficient medication prescribing, increases in patient care errors (e.g., medication errors, procedure errors), and clinical workflow challenges.[5,7-9] However, more recent work suggests that practices with well-implemented EHR systems benefit from greater efficiency, enhanced care quality, and improved patient outcomes.[2-4] Still, rates of EHR adoption have been relatively low in the US. In 2008, only 16.9% of all non-federal office-based providers had adopted at least a basic EHR system (see Table 3.1 for descriptions of basic and comprehensive EHRs).[10] By 2010, this number had increased to about 25% office-based providers, and by 2012, approximately 40% of office-based providers reported having a basic EHR system in place.[11] Several factors account for this trend of low EHR adoption in the US, including large financial barriers, physician attitudes and unwillingness to change practice patterns, lack of interoperability across EHR systems, and misaligned incentives.[12,13]

Table 3.1 Basic versus Comprehensive Electronic Health Record Systems

Required EHR Functionalities	Basic EHR no Clinician Notes	Basic EHR with Clinician Notes	Comprehensive EHR
Electronic Clinical Information			
Patient demographics	x	x	x
Physician notes		x	x
Nursing assessments		x	
Problem lists	x	x	x
Medication lists	x	x	x
Discharge summaries	x	x	x
Advance directives			
Computerized Provider Order Entry			
Lab reports			x
Radiology tests			x
Medications	x	x	x
Consultation requests			x
Nursing orders			x
Results Management			
View lab reports	x	x	x
View radiology reports	x	x	x
View radiology images			x
View diagnostic test results	x	x	x
View diagnostic test images			x
View consultant report			x
Decision Support			
Clinical guidelines			x
Clinical reminders			x
Drug allergy results			x
Drug-drug interactions			x
Drug-lab interactions			x
Drug dosing support			x

Source: Office of the National Coordinator for Health IT [14]

Disparities in EHR Adoption

Rates of EHR adoption are particularly low for providers based in small practices and those working in underserved areas and communities with high levels of unmet need. In a 2009 study on EHR adoption in US hospitals, Jha *et al.* found that hospitals serving a larger proportion of poor patients were less likely than other hospitals to adopt EHRs.[15] These same hospitals also provided care to a higher proportion of Medicaid patients, elderly black patients, and elderly Hispanic patients. Another study found that increases in unemployment rates and poverty rates were associated with lower rates of EHR adoption among providers.[16] Des Roches *et al.* also found that providers based in rural areas, small practices, and non-teaching hospitals were less likely than other hospitals to adopt EHR systems.[17] Providers in smaller practices and/or underserved areas share barriers similar to those faced by most other providers; however, given their smaller practice size and/or general lack of financial resources, financial barriers are particularly pronounced for this group of providers.

HITECH and the REC Program

In an effort to spur widespread adoption and meaningful use[a] of EHRs throughout the US, Congress passed the Health Information Technology for Economic and Clinical Health (HITECH) Act as part of the American Recovery and Reinvestment Act of 2009.[18] Among its many provisions, HITECH called for the establishment of the Centers for Medicare and Medicaid Services (CMS) EHR Incentive Programs as well as the REC Program.

CMS EHR Incentive Programs. The Medicare and Medicaid EHR Incentive Programs provide incentive payments to eligible hospitals and non-hospital based health professionals

[a] "Meaningful Use" is an evolving concept consisting of three stages. Meaningful use determinations are based on whether the provider has adopted a certified EHR system and is using the EHR to achieve specific objectives. See Appendix Table 4.3 for ONC's full description of "Meaningful Use".

that demonstrate meaningful use of certified EHR technologies.[b, 19] Although hospitals are allowed to receive payment from both programs, non-hospital based health providers can only participate in one program. To qualify as a "Medicaid eligible" provider for the Medicaid EHR Incentive Program, health professionals must demonstrate a Medicaid or "needy individual" patient volume of at least 30% (20% for pediatricians) in addition to meeting other credential criteria.[18,20] Eligibility for the Medicare EHR Incentive Program depends on the type of Medicare program that is applicable to a health provider. In the case of Medicare's managed care program, Medicare Advantage, providers employed by (or contracted with) a Medicare Advantage Organization (MAO) must provide at least 80% of Medicare patient services to enrollees of their MAO to qualify as a "Medicare Advantage eligible" health professional.[21] There are no patient volume requirements for traditional fee-for-service (FFS) Medicare.[18,22]

The Medicare and Medicaid versions of the program are similar in many respects; yet, there are some key differences between the two programs. Compared to the Medicare version of the program, the Medicaid EHR Incentive Program offers a larger maximum incentive payment for individual providers ($63,750 vs. $44,000), captures a broader group of eligible providers (i.e., physicians, nurse practitioners, certified nurse mid-wives, dentists, and physician assistants), and stipulates less stringent requirements for receiving payment (e.g., in the first year, Medicaid providers can receive payment for adopting, implementing, or upgrading EHR systems, while Medicare providers must demonstrate meaningful use of an EHR to receive payment).[23] In addition, HITECH includes language that financially penalizes "Medicare FFS eligible" health professionals who fail to demonstrate meaningful use of an EHR system by 2015. "Medicare FFS eligible" health professionals who fail to achieve meaningful use will face

[b] The designation of "certified EHR technology" is determined by an ONC-Authorized Testing and Certification Body (ONC-ATCB). A complete list of ONC-ATCB certified EHRs appear on ONC's Certified Health IT Product List (CHPL). Certified EHRs are eligible for use in attestation in the Medicare and Medicaid EHR Incentive Programs.

1% reductions in Medicare reimbursement payments in 2015, 2% reductions in 2016, and 3% reductions in 2017.[18]

REC Program. The REC Program is administered by ONC and consists of 62 diverse non-profit organizations throughout the US that were selected though a grant application process (see Appendix Table 4.4 for a listing of all 62 RECs and service areas). RECs promote EHR adoption and meaningful use among providers through the provision of technical assistance, dissemination of best practices for EHR implementation, and outreach and education on the availability of financial resources to support EHR adoption (e.g., CMS EHR Incentive Payment Program). These services are offered at little to no cost.

In most instances, an REC is assigned to an individual state; however, for some RECs, service area jurisdictions span multiple states and/or a collection of counties within a state. REC organizations vary widely in terms of their experience and areas of expertise. For example, a few RECs are extensions of quality improvement organizations that work closely with state Medicaid agencies, some RECs are based in medical schools and local universities, and a few are affiliated with regional health information exchange initiatives. In addition to the range of organizations that make up the REC program, RECs may differ in the types of strategies they implement to engage and assist providers.

The REC program uses three key milestones (or performance measures): Milestone 1 (provider enrollment and engagement), Milestone 2 (provider adoption of a certified EHR technology), and Milestone 3 (meaningful use of the EHR system). Although RECs are permitted to offer services to all providers within their regional jurisdiction, HITECH includes language that prioritizes a select group of providers referred to as priority primary care providers. Priority primary care providers are primary care providers (PCPs) working in the following settings:

1. Individual and small group practices of ten or fewer professionals with prescriptive privileges

2. Public hospitals
3. Critical access hospitals
4. Community health centers
5. Rural health clinics; and
6. Other settings that predominantly serve uninsured, underinsured, and medically underserved populations

Insights from the Diffusion of Innovation Literature

The diffusion of innovation literature characterizes factors associated with an innovation's diffusion, including attributes of the innovation, characteristics of innovators, the type of innovation process (e.g., diffusion encouraged via policy), the nature of communication channels (e.g., media, interpersonal networks), environmental context, and the extent and nature of change agent efforts.[6,24] For the purposes of this study, I focus on the role of environmental context and change agents as potential sources of variation in EHR adoption within the REC program. By environmental context, I am specifically referring to area-level facilitating (and inhibiting) factors, such as the availability of financial, human, and informational resources, the extent of infrastructure development, and the presence of incentives. As mentioned earlier, providers practicing in areas and health care facilities with fewer available resources (e.g., low income areas, rural clinics) are less likely to invest in expensive innovations like EHR systems.[12,16,25] The state of the local technological infrastructure (e.g., broadband access) is also important to the EHR diffusion process. For example, limited broadband capability in a given area can create additional challenges to EHR use and health information exchange.[26] Also, financial incentives, such as cost savings and the CMS EHR Incentive Payment Programs can stimulate interest in EHR adoption. In addition, awareness and knowledge of the benefits of an innovation also serve as motivators for adoption.[12,27,28]

Moreover, social context and system-level factors also matter when considering potential sources of health care disparities. For example, research indicates that investments in innovative medical technologies may result in better patient outcomes;[25] however, racial/ethnic minorities generally have less access to “high technology” hospitals where care may be of a higher quality.[29,30] Assuming that adoption and meaningful use of EHRs facilitate improvements in care delivery, then a "digital divide" in EHR adoption could exacerbate health care disparities affecting communities already at greatest risk for lower care quality and worse health outcomes. In *Diffusion of Innovations,* Rogers emphasized the importance of accounting for pre-existing inequalities in a society before an innovation is introduced, arguing that when a system's structure is already unequal, introduction of an innovation could lead to greater inequalities if the strategy for promoting innovation diffusion fails to target vulnerable groups.[27,28] Thus, identifying the area-level factors that might account for lower rates of EHR adoption in specific geographic areas and provider groups is of great importance and deserves special policy attention.

The diffusion of innovation literature also describes the influence of change agents in the innovation adoption process.[27] Characteristics of the change agent such as their communication strategies, experience with the client population, and trustworthiness play a critical role in the client's adoption decision. Previous studies exploring patterns of EHR adoption in the context of other change agent programs have typically focused on provider characteristics and individual needs with little attention to the area-level factors and change agent differences that might account for variations in EHR adoption. In addition, these earlier studies examined EHR adoption patterns prior to HITECH implementation.[31,32] More recently, one study assessed geographic variations in REC participation among PCPs and found that REC penetration was higher in underserved areas;[33] however, this study focused on Milestone 1 of the REC program and did not assess geographic differences in EHR adoption among REC-enrolled providers. Thus, there exists a gap in our current knowledge about area-level factors associated with EHR adoption, specifically in the era of HITECH where initiatives like the CMS

EHR Incentive Program and change agents like the REC Program are actively engaged in the EHR diffusion process. Filling this knowledge gap would be helpful to policymakers seeking to maximize widespread uptake and use of EHR systems among health providers.

Research Aims

In this study, I examine associations between EHR adoption among REC-enrolled PCPs and a broad range of contextual factors, including county-level indicators of underservice, presence of EHR-related incentives, technological infrastructure and capability, and exposure and engagement with health IT. I am particularly interested in geographic inequities in EHR adoption according to county-level racial composition, urban/rural status, or health resource need. In addition, I assess whether differences across RECs explain any variations in county-level EHR adoption.

III. METHODS

Overview

I used hierarchical models to assess associations between county characteristics and county-level rates of EHR adoption among REC-enrolled PCPs. I accounted for the following county characteristics in my analyses:

a) *"Underserved area" status and resource availability* - metropolitan status, federally qualified health center (FQHC) presence, health professional shortage area (HPSA) status, minority concentration
b) *Potential eligibility for EHR adoption incentives* - concentration of Medicaid enrollees, concentration of Medicare fee-for-service enrollees, concentration of Medicare Advantage enrollees
c) *Technological infrastructure and capacity* - broadband internet service access

d) *Exposure and engagement with health IT Initiatives* - proximity to major academic teaching hospitals, proximity to other ONC HITECH grantees, REC penetration/enrollment

I also computed the intraclass correlation to determine whether differences across RECs explained any variations in county-level EHR adoption.

Data Sources

Data on REC enrollment and EHR adoption among REC-enrolled PCPs, as well as estimated counts of PCPs were obtained from ONC's Health IT Dashboard website.[34] Regional Extension Center performance data are organized at the county-level and include county-level estimates of the number of PCPs who have enrolled with an REC (Milestone 1), adopted an EHR (Milestone 2), and achieved meaningful use (Milestone 3). These REC performance data are self-reported by each REC using customer relationship management software. All RECs collect documentation of milestone achievements from each provider and retain records for program management and federal auditing purposes.[35,36] Documentation of Milestone 1 (REC enrollment) consists of a signed technical assistance contract between each REC and individual provider. Milestone 2 (EHR adoption) documentation consists of verification from the provider or provider representative that an EHR system has been implemented with quality reporting and electronic prescribing capabilities enabled. To verify Milestone 2 achievement, providers or their representatives typically submit a copy of an electronic prescribing summary from their EHR system along with a signed affidavit indicating that an EHR system with enabled quality reporting and electronic prescribing capabilities has been implemented. Milestone 3 (meaningful use) is documented based on certification of meaningful use attestation from the Centers for Medicare and Medicaid Services (CMS).[35,37]

Counts of PCPs within each county were computed by ONC using data from the 2011 SK&A Office-based Providers Database (SK&A Information Services, Irvine, CA, 2012). Within

the ONC Health IT Dashboard, PCPs are defined as physicians, physician assistants, and nurse practitioners with specialties of Family Practice, General Practice, Internal Medicine, Geriatrics, Obstetrics and Gynecology, Pediatrics, and Adolescent Medicine.

Additional county-level data on metropolitan status, FQHC presence, primary care HPSA status, Medicaid enrollment, and Medicare enrollment were obtained from the 2011-2012 Area Resource File. County population and racial composition data were obtained from the 2006-2010 (5-year estimate) American Community Survey. Information on 2011 county-level broadband availability was obtained from the Federal Communications Commission's Local Telephone Competition and Broadband Deployment database.[38] Addresses for major teaching hospitals and ONC HITECH grantees were obtained from the Council of Teaching Hospitals and Health Systems and ONC's Health IT Data Dashboard, respectively.

Cohort

For this analysis, the REC provider cohort consisted of PCPs enrolled with a REC as of September 2012, excluding PCPs located in the US territories. Counties with no PCPs were excluded. The final cohort included 126,472 REC-enrolled PCPs spanning 2,721 counties and 59 RECs.

Measures

Outcome measure

The outcome measure examined in this study was the county-level rate of EHR adoption among REC-enrolled PCPs, expressed as percentages.

Explanatory measures

Underserved area status. County-level indicators of underserved area status and low resource availability included metropolitan status (non-metropolitan [rural] vs. metropolitan [urban]), FQHC presence (at least 1 FQHC in county vs. none), HPSA status (whole county

HPSA, population group HPSA, geographic area HPSA, or non-HPSA), and minority concentration (proportion of minorities within total county population).

Potential eligibility for CMS EHR adoption incentives. Because the impact of the Medicare and Medicaid EHR Incentive Programs and Medicare payment penalties is to some extent dependent on each provider's payer mix, geographic variations in the concentration of Medicaid and Medicare enrollees are likely to be associated with EHR adoption patterns. To account for the potential impact of geographic variations in provider eligibility for CMS EHR financial incentives on differences in EHR adoption across counties, county-level measures of Medicaid enrollee concentration (proportion of Medicaid enrollees within total county population), Medicare FFS enrollee concentration, and Medicare Advantage enrollee concentration were included in the analysis. Medicare FFS and Medicare Advantage (i.e., Medicare managed care) enrollment were examined as separate variables in this analysis because past research indicates that managed care penetration in an area is positively associated with EHR adoption among health providers;[16] thus, the association between Medicare enrollment and EHR adoption may differ depending on the concentration of each type of Medicare program within the county population.

Technological infrastructure and capability. County-level broadband internet technology infrastructure and capability was measured by the number of broadband connections per 1,000 households.

Exposure and engagement with health IT. Health provider exposure and engagement with health IT varies geographically and may contribute to variations in EHR adoption. For example, in addition to the REC program, ONC oversees other HITECH programs that promote health IT and EHR adoption in different geographic areas. These ONC HITECH programs include the State Health Information Exchange Cooperative Agreement which is helping to build capacity for health information exchange within and between states, the Strategic Health IT Advanced Research Projects (SHARP) which support EHR adoption and meaningful use

through innovative research, Community College and University-Based Training Programs which are tasked with training a skillful health IT workforce, and the Beacon Communities which are leveraging health IT to improve healthcare delivery and quality. Furthermore, past research indicates that teaching hospitals are more likely to adopt EHRs than non-teaching hospitals;[17,39] and as a result, teaching hospital presence may contribute to greater awareness and interest in EHRs among health providers within a given area.

The level of health IT exposure and engagement within each county was represented by proximity to the nearest major academic teaching hospital, proximity to the nearest ONC HITECH program grantee, and the REC enrollment rate among all PCPs in the county. Distances were computed using the "Near" spatial analysis tool in ArcMap 10.1[40] and reflect the distance from the county centroid to the point of interest (e.g., nearest teaching hospital).

To facilitate comparisons of EHR adoption across different sets of county characteristics, all explanatory measures were coded as dichotomous variables. In the case of continuous measures reflecting population concentrations/rates (e.g., minority concentration), four dichotomous variables corresponding to quartile values for each measure were generated (e.g., Q1 – quartile group for counties with lowest concentrations; Q4 – quartile group for counties with highest concentrations).

Analysis

In descriptive analyses, mean county unadjusted EHR adoption rates were computed for each category of county characteristics (explanatory measures) and compared using one-way ANOVA tests.

Within the REC program, each REC is assigned to a collection of counties within a specific state or group of states, making RECs a potential source of variation in this analysis. To account for the multilevel nature of the data, hierarchical models were employed. To assess the proportion of the total variance in EHR adoption that is attributable to differences across

RECs, a hierarchical linear model with random intercepts for RECs, but no covariates (Model 1) was estimated followed by computation of the intraclass correlation.

Model 1: Unadjusted Random Intercepts Model

Equation 1: $Y_{ij} = \beta_{0j} + e_{0ij}$

Equation 2: $\beta_{0j} = \beta_0 + u_{0j}$

Random Part (Level 2): $u_{0j} \sim N(0, \sigma^2_{u0})$

Random Part (Level1): $e_{0ij} \sim N(0, \sigma^2_{e0})$

$i =$ County

$j =$ REC

Intraclass Correlation = $\frac{\sigma^2_{u0}}{\sigma^2_{u0}+\sigma^2_{e0}}$

$\sigma^2_{u0} + \sigma^2_{e0} =$ Total Variance in Outcome

where β_{0j} represents the intercept for REC *j* consisting of β_0 (the mean intercept value) and u_{0j} (the REC-specific random effect), e_{0ij} represents the residual term for county *i* of REC *j*, σ^2_{u0} represents the amount of variance in outcome Y_{ij} (i.e., county-level EHR adoption rate) that is attributable to REC-level differences, and σ^2_{e0} represents the amount of variance in outcome Y_{ij} that is attributable to county-level differences.

Next, to examine associations between county-level characteristics and county-level EHR adoption, fixed effect covariates for the county-level explanatory measures (i.e., metropolitan status, FQHC presence, HPSA status, concentration of minorities, Medicaid enrollees, Medicare FFS enrollees, and Medicare Advantage enrollees, broadband connections per 1,000 households, distance to nearest teaching hospital, distance to nearest ONC HITECH grantee, and REC enrollment rate among PCPs) were added to “Equation 1” of the unadjusted

random intercepts model of EHR adoption. This adjusted random intercepts model (Model 2) estimates associations between county-level characteristics and EHR adoption while allowing for random variation in intercepts at the REC-level.

All analyses were conducted using SAS 9.3.[41]

IV. RESULTS

Descriptive analyses

Table 3.2 presents descriptive data for the 2,721 counties included in this study. About two-thirds of study-eligible counties were non-metropolitan, about one-half of counties were served by at least one FQHC, and the majority of counties were designated as a HPSA of some type. On average (i.e., in the average county), about one-fifth of the population were minorities, one-fifth were enrolled in Medicaid, one-sixth were enrolled in Medicare FFS, and about 2.9% were enrolled in Medicare Advantage. The majority of counties exhibited broadband capabilities in excess of 400 connections per 1000 households. On average, PCPs in each county were about 94.7 miles away from the nearest major teaching hospital and 70.5 miles away from the nearest ONC HITECH grantee. The average REC enrollment rate among PCPs in each county was 53.3%.

Table 3.3 presents unadjusted comparisons of county-level EHR adoption rates among REC-enrolled PCPs for each category of county-level characteristics. On average, about 73.1% (IQR=42.1; SD=33.4) of the 126,472 study-eligible REC-enrolled PCPs have adopted an EHR system. Metropolitan counties, counties with FQHC presence, non-HPSA counties, counties with lower Medicare FFS enrollment rates, and counties with higher Medicare Advantage enrollment rates had higher EHR adoption rates. Moreover, counties located in closer proximity to major teaching hospitals and ONC HITECH grantees also exhibited higher EHR adoption rates among REC-enrolled PCPs.

Table 3.2 Geographic and Population Characteristics of US Counties (excludes US Territories)

Characteristics	US Counties (N =2,721)
Underserved Area Status and Resource Availability	
Metropolitan Status	
Metropolitan (Urban)	37.8%
Non-Metropolitan (Rural)	62.2%
FQHC Presence	
No FQHC in County	50.0%
At Least 1 FQHC in County	50.0%
HPSA Status	
Non-HPSA	35.2%
Population Group HPSA	35.0%
Geographic Area HPSA	9.8%
Whole County HPSA	20.0%
Minority Concentration	
Mean Proportion Minorities in Population	21.5%
Eligibility for EHR Adoption Incentives	
Medicaid Enrollment Concentration	
Mean Proportion Medicaid Enrollees in Population	20.4%
Medicare FFS Enrollment Concentration	
Mean Proportion Medicare FFS Enrollees in Population	15.4%
Medicare Advantage Enrollment Concentration	
Mean Proportion Medicare Advantage Enrollees in Population	2.9%
Technological Infrastructure and Capacity	
Broadband Connections per 1000 Households	
x≤ 200	7.0%
200< x ≤ 400	28.0%
400< x ≤ 600	41.9%
x >600	23.1%
Exposure and Engagement with Health IT	
Distance to Nearest Major Teaching Hospital	
Mean Distance in Miles	94.7
Distance to Nearest ONC HITECH Grantee	
Mean Distance in Miles	70.5
REC Enrollment Rate	
Mean Proportion of PCPs Enrolled with an REC	53.3%

Table 3.2 (Continued)

FQHC – Federally Qualified Health Center
HPSA – Health Professional Shortage Area
EHR – Electronic Health Record
FFS – Fee-for-Service
ONC – Office of the National Coordinator for Health Information Technology
HITECH – Health Information Technology for Economic and Clinical Health Act
PCP – Primary Care Provider
REC – Regional Extension Center

Table 3.3 Unadjusted County-Level EHR Adoption Rates among REC-Enrolled PCPs by Geographic and Population Characteristics of US Counties (excludes US Territories)

	County-Level EHR Adoption Rate	*p-value*
Mean County-Level EHR Adoption Rate	73.1%	
Characteristics		
Underserved Area Status and Resource Availability		
Metropolitan Status		**.0001**
Metropolitan (Urban)	76.2%	
Non-Metropolitan (Rural)	71.2%	
FQHC Presence		**<.0001**
No FQHC in County	69.1%	
At Least 1 FQHC in County	77.1%	
HPSA Status		**<.0001**
Non-HPSA	77.0%	
Population Group HPSA	72.2%	
Geographic Area HPSA	71.1%	
Whole County HPSA	68.8%	
Minority Concentration		.8440
Q1 (<6.0%)	72.8%	
Q2 (6.0%-14.2%)	73.2%	
Q3 (14.3%-32.6%)	74.0%	
Q4 (32.7%-98.8%)	72.4%	
Eligibility for EHR Adoption Incentives		
Medicaid Enrollment Concentration		.1296
Q1 (<14.4%)	72.4%	
Q2 (14.4%-19.3%)	71.2%	
Q3 (19.4%-25.2%)	73.5%	
Q4 (25.3%-62.9%)	75.3%	
Medicare FFS Enrollment Concentration		**.0008**
Q1 (<12.1%)	74.2%	
Q2 (12.1%-15.3%)	76.6%	
Q3 (15.4%-18.3%)	72.1%	
Q4 (18.4%-37.2%)	69.5%	
Medicare Advantage Enrollment Concentration		**.0015**
Q1 (<1.3%)	69.3%	
Q2 (1.3%-2.3%)	73.6%	
Q3 (2.4%-4.0%)	73.1%	
Q4 (4.1%-14.1%)	76.3%	
Technological Infrastructure and Capacity		
Broadband Connections per 1000 Households		.2033
x≤ 200	73.8%	
200< x ≤ 400	71.9%	
400< x ≤ 600	72.4%	
x >600	75.5%	

Table 3.3 (Continued)

Exposure and Engagement with Health IT		
Distance to Nearest Major Teaching Hospital		**<.0001**
≤30 miles	76.8%	
31-60 miles	75.5%	
61-90 miles	73.4%	
>90 miles	68.3%	
Distance to Nearest ONC HITECH Grantee		**<.0001**
≤30 miles	77.4%	
31-60 miles	73.8%	
61-90 miles	74.8%	
>90 miles	67.5%	
REC Enrollment Rate		.6512
Q1 (<31.0%)	74.2%	
Q2 (31.0%-50.0%)	72.5%	
Q3 (50.1%-80.0%)	73.6%	
Q4 (80.1%-100%)	72.1%	

Boldface values are statistically significant at the P<.05 level.
EHR – Electronic Health Record
PCP – Primary Care Provider
FQHC – Federally Qualified Health Center
HPSA – Health Professional Shortage Area
FFS – Fee-for-Service
ONC – Office of the National Coordinator for Health Information Technology
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Hierarchical models

Approximately 7% of the total variance in EHR adoption rates among REC-enrolled PCPs across counties was explained by differences at the REC level (see Table 3.4 for covariance parameter estimates for Model 1). Compared with the 32.4 percentage point standard deviation in county-level EHR adoption rates within RECs (σ_{e0}), the REC-level standard deviation in EHR adoption rates (σ_{u0}) was approximately 8.7 percentage points. Thus, RECs accounted for a modest amount of the total variation in county-level EHR adoption rates.

Underserved area status. Table 3.4 also presents results from the adjusted hierarchical model (Model 2). In this model, FQHC presence was associated with EHR adoption among REC-enrolled PCPs. On average, EHR adoption rates among counties with FQHC presence were 7.2 percentage points (p<.0001) higher than EHR adoption rates in otherwise similar counties with no FQHC presence. REC-enrolled PCPs based in HPSA counties of all types were less likely to adopt EHRs relative to REC-enrolled PCPs based in non-HPSA counties. Compared with non-HPSA counties, EHR adoption rates were, on average, 5.3 percentage points lower in population group HPSAs (p=.002), 6.3 percentage points lower in geographic area HPSAs (p=.007), and 9.4 percentage points lower in whole county HPSAs (p <.0001). Minority concentration was also associated with EHR adoption among REC-enrolled PCPs. Counties in the highest quartile of minority concentration (Q4) exhibited EHR adoption rates that were, on average, 6.8 percentage points (p=.008) lower than EHR adoption rates in counties with the lowest concentration of minorities (Q1).

County-level metropolitan status was not associated with county-level EHR adoption among REC-enrolled PCPs in adjusted analyses.

Potential eligibility for EHR adoption incentives. Concentration of Medicaid enrollees was associated with rates of EHR adoption among REC-enrolled PCPs. Compared with counties with the lowest concentration of Medicaid enrollees (Q1), counties with the highest concentration of Medicaid enrollees (Q4) exhibited EHR adoption rates that were, on average,

5.8 percentage points (p=.02) higher. In addition, county-level EHR adoption rates among REC-enrolled PCPs were also associated with Medicare Advantage enrollment concentration, with counties having the highest Medicare Advantage enrollment concentrations (Q4) exhibiting EHR adoption rates that were, on average, 4.7 percentage points higher (p = .03) than EHR adoption rates among counties with the lowest concentration of Medicare Advantage enrollment (Q1).

County-level Medicare FFS enrollment was negatively associated with EHR adoption in unadjusted comparisons, but not in adjusted analyses.

Technological infrastructure and capability. County-level broadband internet access was not associated with county-level EHR adoption among REC-enrolled PCPs in adjusted analyses.

Exposure and engagement with health IT. Distance to the nearest major teaching hospital, distance to the nearest ONC HITECH grantee, and rates of REC enrollment and were not associated with EHR adoption among REC-enrolled PCPs in adjusted analyses.

Table 3.4 Random Intercepts Models Estimating County-Level EHR Adoption among REC-Enrolled PCPs

	Unadjusted Model 1 β (SE)	Adjusted Model 2 β (SE)
Intercept	73.06 (1.40)	73.26 (4.85)
Underserved Area Status and Resource Availability		
Metropolitan Status		
Non-Metropolitan (Rural)		Reference
Metropolitan (Urban)		0.62 (1.74)
FQHC Presence		
No FQHC in County		Reference
At Least 1 FQHC in County		**7.21 (1.42)**
HPSA Status		
Non-HPSA		Reference
Population Group HPSA		**-5.26 (1.67)**
Geographic Area HPSA		**-6.26 (2.33)**
Whole County HPSA		**-9.44 (1.97)**
Minority Concentration		
Q1 (<6.0%)		Reference
Q2 (6.0%-14.2%)		-1.02 (1.86)
Q3 (14.3%-32.6%)		-1.71 (2.16)
Q4 (32.7%-98.8%)		**-6.83 (2.59)**
Eligibility for EHR Adoption Incentives		
Medicaid Enrollment Concentration		
Q1 (<14.4%)		Reference
Q2 (14.4%-19.3%)		-1.68 (1.89)
Q3 (19.4%-25.2%)		0.22 (2.16)
Q4 (25.3%-62.9%)		**5.81 (2.55)**
Medicare FFS Enrollment Concentration		
Q1 (<12.1%)		Reference
Q2 (12.1%-15.3%)		1.42 (1.91)
Q3 (15.4%-18.3%)		-3.12 (2.17)
Q4 (18.4%-37.2%)		-3.61 (2.38)
Medicare Advantage Enrollment Concentration		
Q1 (<1.3%)		Reference
Q2 (1.3%-2.3%)		1.77 (1.86)
Q3 (2.4%-4.0%)		1.28 (1.98)
Q4 (4.1%-14.1%)		**4.65 (2.20)**
Technological Infrastructure and Capacity		
Broadband Connections per 1000 Households		
x≤ 200		Reference
200< x ≤ 400		-1.47 (2.70)
400< x ≤ 600		-0.02 (2.79)
x >600		1.35 (3.20)

Table 3.4 (Continued)

Exposure and Engagement with Health IT		
Distance to Nearest Major Teaching Hospital		
≤30 miles		Reference
31-60 miles		1.69 (2.15)
61-90 miles		0.60 (2.50)
>90 miles		-0.17 (2.64)
Distance to Nearest ONC HITECH Grantee		
≤30 miles		Reference
31-60 miles		-1.58 (2.13)
61-90 miles		0.32 (2.34)
>90 miles		-3.84 (2.52)
REC Enrollment Rate		
Q1 (<31.0%)		Reference
Q2 (31.0%-50.0%)		-0.12 (1.75)
Q3 (50.1%-80.0%)		2.30 (1.84)
Q4 (80.1%-100%)		3.33 (1.91)
Covariance Parameter Estimates		
σ^2_{e0} : County-Level Variance	1046.91	1015.69
σ^2_{u0} : REC-Level Variance	75.81	79.56
$\sigma^2_{u0} + \sigma^2_{e0}$: Total Variance	1122.72	1095.25
Intraclass Correlation (ICC): $\frac{\sigma^2_{u0}}{\sigma^2_{u0} + \sigma^2_{e0}}$	0.07	

Boldface values are statistically significant at the P<.05 level.
EHR – Electronic Health Record
PCP – Primary Care Provider
FQHC – Federally Qualified Health Center
HPSA – Health Professional Shortage Area
FFS – Fee-for-Service
ONC – Office of the National Coordinator for Health Information Technology
HITECH – Health Information Technology for Economic and Clinical Health Act
REC – Regional Extension Center

V. DISCUSSION

In 2012, roughly three-quarters of REC-enrolled PCPs had adopted an EHR with capabilities that met CMS meaningful use requirements (i.e., ONC certified EHR technology), compared with about 40% of primary care physicians nationwide who had adopted a basic EHR system.[42] These impressive rates of EHR adoption within the REC program may reflect the successful efforts of REC program staff to engage, educate, and train health providers and staff on the benefits and effective implementation of EHRs. County-level rates of EHR adoption among REC-enrolled PCPs also varied widely across geographic areas. Most of this variation was attributable to differences at the county-level in this study, although differences across RECs accounted for 7% of the total variation in county-level EHR adoption. Thus, there was relatively little variation in EHR adoption rates at the REC-level.

Several area-level factors and population characteristics exhibited strong associations with county-level EHR adoption among REC-enrolled PCPs. Rates of EHR adoption were lower in counties with the greatest concentration of minorities and across HPSAs of all types, particularly in whole county HPSAs. This finding is in line with other research on EHR adoption in underserved areas,[15,17,43] and suggests that PCPs in these counties may face challenges to EHR adoption that are not necessarily overcome by engagement with an REC, such as tight operating budgets, staff shortages, and limited capacity for integrating EHR training into the clinical workflow.[44,45] As the administrator of the REC program, ONC should consider collaborating with RECs to conduct comprehensive needs assessments among REC-enrolled PCPs located in HPSAs and high-minority areas and develop tailored strategies to address the specific barriers to EHR adoption faced by these provider groups.

Consistent with previous research on EHR adoption among FQHC providers,[46,47] FQHC presence in a county was positively associated with EHR adoption. This association may be due to the range of health IT-related resources that have been offered to FQHCs in recent years. For example, in addition to the technical support services offered by RECs, the Health

Resources Services Administration (HRSA) has been very instrumental in providing FQHCs with funding and other types of support to facilitate the adoption of health information technologies.[18]

Of note, EHR adoption rates were comparable across metropolitan and non-metropolitan areas, an encouraging finding that runs contrary to evidence from previous studies[15,17] and suggests that RECs and/or other HITECH initiatives are helping to address the longstanding urban-rural divide in EHR adoption.

Despite previous research documenting negative associations between EHR adoption and the proportion of poor and Medicaid patients treated at a facility,[15,16] the concentration of Medicaid enrollees in a county was positively associated with EHR adoption. This finding is likely attributed to the recent implementation of the Medicaid EHR Incentive Program which provides up to $63,750 to Medicaid eligible health professionals who have adopted and/or demonstrated meaningful use of a certified EHR system.[23] Rates of EHR adoption were particularly elevated in counties with the highest concentrations of Medicaid enrollment (>25.2%). Additional analyses also revealed no differences in EHR adoption according to county-level poverty concentration after accounting for Medicaid enrollment concentration in the county (data not shown). Thus, it appears that the Medicaid EHR Incentive Program has been successful in incentivizing and promoting EHR adoption among a group of providers that has historically been less likely to adopt health information technologies. Future research should continue to explore the role of other incentive-based programs in promoting diffusion of best practices and medical innovations among providers serving vulnerable patient populations and the impact of such programs on disparities.

The HITECH Act established both EHR adoption incentives and disincentives for Medicare providers. Medicare FFS eligible providers who fail to adopt and demonstrate meaningful use of EHRs by 2015 risk payment reductions proportional to the volume of Medicare patients they serve. As a result, providers based in counties with the highest

concentrations of Medicare FFS enrollment are more susceptible to such payment reductions. Interestingly, Medicare FFS enrollment concentration in counties was not associated with county-level EHR adoption among REC-enrolled PCPs; however, county-level Medicare Advantage enrollment was positively associated with adoption. It is unclear whether this association is explained by mechanisms related to the Medicare EHR Incentive Program or managed care presence in the market; although, past research indicates that providers located in markets with higher managed care penetration were more likely to adopt EHRs.[16]

Limitations

There are limitations to this study worth noting. First, this study focuses solely on REC-enrolled PCPs and not the general population of health providers; thus, it is unclear whether the findings from this study would generalize to other health professionals, such as specialist providers. Furthermore, it is possible that REC-enrolled providers differ from the general population of providers with respect to geographic location and their willingness to adopt EHRs. Additional information on the characteristics and geography of REC-enrolled providers and providers not enrolled with an REC would help shed light on whether this study's findings extend to the general population of health providers.

Second, for reasons related to data unavailability, this study does not consider the possible influence of EHR adoption rates among non-REC providers on REC-enrolled providers' adoption patterns. Because an EHR is a network good with a value that increases as the number of users increases, an REC-enrolled health provider based in a county with a higher concentration or "critical mass" of health providers with EHRs may be more likely to adopt an EHR than her counterpart located in a county that has yet to reach this "critical mass" state.[48]

Third, this study is a county-level analysis that does not account for provider- and practice-level factors that might contribute to variations in EHR adoption, such as provider age and openness to new technologies and practice size and staff composition. Lastly, it is unclear

from this study which REC-level factors may be associated with EHR adoption, such as organizational characteristics, partnerships, and outreach strategies of RECs; although, the observed REC effect on adoption patterns was modest.

Despite these limitations, this study adds to the EHR adoption and diffusion literature by providing insight into EHR adoption patterns in the context of a large scale federally-funded program. It will be important for future research to assess the direct and indirect impact of RECs on EHR adoption across the entire population of health providers. Moreover, few studies have assessed the contribution of area-level factors to the diffusion of EHRs; thus, this study helps to fill an important gap in the research literature. Additional research is needed to determine whether these associations hold true for other provider groups.

Conclusion

Electronic health records have the potential to transform health care delivery by facilitating improvements in care quality, continuity, and efficiency. Recent legislative and programmatic efforts to help spur the adoption of EHRs in the US have demonstrated some early success; however, some geographic variations in EHR adoption indicate that greater attention needs to be paid to ensuring equitable uptake of this form of health information technology throughout the US.

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Appendix Table 4.1 Benjamini-Hochberg (B-H) Adjustment of Race-Associated Odd Ratios from Logistic Regression Models Predicting Receipt of Recommended Cancer Care and Survival

	Model 1† Black vs. White		**Model 2‡** Black vs. White		***p-value* for significance based on B-H Criterion**
Quality Measure	AOR	*p-value*	AOR	*p-value*	
Curative Surgery for Stage I or II Non-Small Cell Lung Cancer	**0.50***	<.0001	**0.52***	<.0001	0.0025
3-D CRT or IMRT for Prostate Cancer Patients Treated with EBRT	**0.53***	<.0001	**0.75***	0.0002	0.0050
Early Stage (Stage I/II vs. III/IV) at Presentation, Colon Cancer	**0.80***	<.0001	**0.78***	0.0001	0.0075
Curative Surgery for Stage I, II, or III Rectal Cancer	**0.57***	0.0004	**0.57***	0.0023	0.0100
Three-Year All Cause Survival for Colon Cancer ¶	**0.75***	0.0013	0.78*	0.0166	0.0125
Three-Year All Cause Survival for Rectal Cancer ¶	**0.61***	0.0074	0.66*	0.0495	0.0150
Use of Potent Antiemetics for Highly-Emetogenic Chemotherapy	**0.87***	0.0161	0.95	0.4771	0.0175
Adjuvant Chemotherapy for Stage III Colon Cancer	0.75*	0.0339	0.87	0.3709	0.0200
Curative Surgery for Stage I, II, or III Colon Cancer	0.76*	0.0367	0.82	0.2152	0.0225
Oral Anti-Androgen before Initiating GnRH Agonist Therapy for Metastatic Prostate Cancer	1.34*	0.0431	0.99	0.9750	0.0250
Chemotherapy and/or Radiation for Resected Stage IIIA Non-Small Cell Lung Cancer	1.67	0.1323	1.35	0.4684	0.0275
Mediastinal Evaluation for Stage I or II Non-Small Cell Lung Cancer	0.75	0.1329	0.92	0.7200	0.0300
Adjuvant Chemotherapy and Radiation Therapy for Stage II or III Rectal Cancer	1.49	0.1438	1.39	0.3104	0.0325
One-Year All Cause Survival for Non-Small Cell Lung Cancer	1.06	0.1731	1.05	0.2671	0.0350

Appendix Table 4.1 (Continued)

Early Stage (Stage I/II vs. III/IV) at Presentation, Rectal Cancer	0.87	0.2621	0.87	0.3248	0.0375
Androgen Ablation within 120 Days for Men with Stage IV Prostate Cancer	1.08	0.5587	0.99	0.9318	0.0400
Prescription of Narcotic Pain Medication for Advanced Cancer Patients in Pain	1.04	0.7250	1.04	0.7235	0.0425
One-Year All Cause Survival for Small Cell Lung Cancer	1.04	0.7330	1.07	0.6308	0.0450
Chemotherapy and Radiation for Limited-Stage Small Cell Lung Cancer	0.96	0.8299	0.80	0.3285	0.0475
Adjuvant Androgen Deprivation Therapy for High-Risk Cancers Treated with Radiation Therapy	1.01	0.8927	0.86	0.1220	0.0500

AOR – Adjusted Odds Ratio
GnRH – Gonadotropin Releasing Hormone
3-D CRT – 3-Dimensional Conformal Radiation Therapy
IMRT – Intensity Modulated Radiation Therapy
EBRT – External Beam Radiation Therapy
† Model 1 corresponds to adjusted logistic regression models *excluding* hospital fixed effects
‡ Model 2 corresponds to adjusted logistic regression models *including* hospital fixed effects
All models adjusted for age, sex (except prostate cancer models), marital status, prior cancer history, Charlson comorbidity score, and year of diagnosis. Lung cancer models also included chronic obstructive pulmonary disease (COPD) as a covariate, and for this group the Charlson score was calculated without COPD. Treatment and survival models adjusted for tumor grade and stage, and survival models also adjusted for tumor size. Palliative/supportive care models adjusted for cancer type.
***** indicates AOR is statistically significant at p<.05
Boldface* indicates AOR is statistically significant after applying Benjamini-Hochberg multiple comparisons adjustment
¶ Three-year survival for colon and rectal cancers captures patients diagnosed during 2001 & 2002

Appendix Table 4.2 Adjusted (*including Socioeconomic Status*) Race-Associated Odd Ratios from Logistic Regression Models Predicting Receipt of Recommended Cancer Care and Survival

Quality Measure	Model [1†] Black vs. White AOR [95% CI]	Model 2[‡] Black vs. White AOR [95% CI]
Colon Cancer		
Early Stage (Stage I/II vs. III/IV) at Presentation, Colon Cancer	**0.80 [0.71, 0.90]***	**0.78 [0.69, 0.89]***
Early Stage (Stage I/II vs. III/IV) at Presentation, Rectal Cancer	0.86 [0.67, 1.11]	0.85 [0.64, 1.13]
Curative Surgery for Stage I, II, or III Colon Cancer	0.72 [0.54, 0.95]*	0.76 [0.55, 1.06]
Curative Surgery for Stage I, II, or III Rectal Cancer	**0.62 [0.44, 0.88]***	0.61 [0.41, 0.89]*
Adjuvant Chemotherapy for Stage III Colon Cancer	0.83 [0.63, 1.11]	0.93 [0.68, 1.28]
Adjuvant Chemotherapy and Radiation Therapy for Stage II or III Rectal Cancer	1.59 [0.91, 2.78]	1.53 [0.79, 2.96]
Three-Year All Cause Survival for Colon Cancer ¶	**0.77 [0.63, 0.93]***	0.79 [0.64, 0.98]*
Three-Year All Cause Survival for Rectal Cancer ¶	0.64 [0.43, 0.93]*	0.69 [0.45, 1.07]
Lung Cancer		
Curative Surgery for Stage I or II Non-Small Cell Lung Cancer	**0.57 [0.47, 0.70]***	**0.57 [0.45, 0.72]***
Mediastinal Evaluation for Stage I or II Non-Small Cell Lung Cancer	0.77 [0.52, 1.15]	0.91 [0.57, 1.45]
Chemotherapy and/or Radiation for Resected Stage IIIA Non-Small Cell Lung Cancer	1.56 [0.77, 3.16]	1.16 [0.48, 2.79]
Chemotherapy and Radiation for Limited-Stage Small Cell Lung Cancer	1.11 [0.74, 1.67]	0.87 [0.54, 1.39]
One-Year All Cause Survival for Non-Small Cell Lung Cancer	**1.16 [1.03, 1.22]***	1.09 [0.99, 1.19]
One-Year All Cause Survival for Small Cell Lung Cancer	1.13 [0.87, 1.47]	1.12 [0.85, 1.47]

Appendix Table 4.2 (Continued)

Prostate Cancer		
Androgen Ablation within 120 Days for Men with Stage IV Prostate Cancer	1.08 [0.82, 1.41]	1.01 [0.73, 1.41]
Oral Anti-Androgen before Initiating GnRH Agonist Therapy for Metastatic Prostate Cancer	1.13 [0.83, 1.54]	0.82 [0.56, 1.18]
Adjuvant Androgen Deprivation Therapy for High-Risk Cancers Treated with Radiation Therapy	1.02 [0.87, 1.20]	0.89 [0.73, 1.08]
3-D CRT or IMRT for Prostate Cancer Patients Treated with EBRT	**0.54 [0.48, 0.61]***	**0.78 [0.67, 0.91]***
Palliative/Supportive Care		
Use of Potent Antiemetics for Highly-Emetogenic Chemotherapy	0.90 [0.80, 1.00]	0.95 [0.82, 1.10]
Prescription of Narcotic Pain Medication for Advanced Cancer Patients in Pain	1.03 [0.84, 1.27]	1.06 [0.84, 1.34]

AOR – Adjusted Odds Ratio
GnRH – Gonadotropin Releasing Hormone
3-D CRT – 3-Dimensional Conformal Radiation Therapy
IMRT – Intensity Modulated Radiation Therapy
EBRT – External Beam Radiation Therapy
† Model 1 corresponds to adjusted logistic regression models *excluding* hospital fixed effects
‡ Model 2 corresponds to adjusted logistic regression models *including* hospital fixed effects
All models adjusted for age, sex (except prostate cancer models), marital status, area-level socioeconomic status based on the zip code of the patient's residence (median household income, the percentage of college graduates, and the percentage of persons living below the poverty level), prior cancer history, Charlson comorbidity score, and year of diagnosis. Lung cancer models also included chronic obstructive pulmonary disease (COPD) as a covariate, and for this group the Charlson score was calculated without COPD. Treatment and survival models adjusted for tumor grade and stage, and survival models also adjusted for tumor size. Palliative/supportive care models adjusted for cancer type.
***** indicates AOR is statistically significant at p<.05
Boldface* indicates AOR is statistically significant after applying Benjamini-Hochberg multiple comparisons adjustment
¶ Three-year survival for colon and rectal cancers captures patients diagnosed during 2001 & 2002

Appendix Table 4.3 Types of Composite Measure Scoring Techniques

Method	Description
All-or-None Process Measures	Performance is defined by the proportion of patients receiving all of the specified care processes for which they were eligible. No credit is given for patients who receive some but not all required items.
Any-or-None	Similar to-all-or none but is used for events that should not occur. A patient is counted as failing if he or she experiences at least 1 adverse outcome from a list of 2 or more adverse outcomes.
Linear Combinations	Can be simple average or weighted average of individual measure scores.
Regression-Based Composites	If a certain outcome is regarded as a gold standard, the weighting of individual items may be determined empirically by optimizing the predictability of gold standard end-point.
Opportunity Scoring	This approach counts the number of times a given care process was actually performed (numerator) divided by the number of chances a provider had to give this care correctly (denominator). Unlike simple averaging, each item is implicitly weighted in proportion to the percentage of eligible patients, which may vary from provider to provider.

Source: Centers for Medicare and Medicaid Services, 2012

Appendix Table 4.4 Electronic Health Record Meaningful Use Criteria

Stage 1 (2011-2012) Data Capture and Sharing	Stage 2 (2014) Advance Clinical Processes	Stage 3 (2016) Improved Outcomes
Electronically capturing health information in a standardized format	More rigorous health information exchange (HIE)	Improving quality, safety, and efficiency, leading to improved health outcomes
Using that information to track key clinical conditions	Increased requirements for e-prescribing and incorporating lab results	Decision support for national high-priority conditions
Communicating that information for care coordination processes	Electronic transmission of patient care summaries across multiple settings	Patient access to self-management tools
Initiating the reporting of clinical quality measures and public health information	More patient-controlled data	Access to comprehensive patient data through patient-centered HIE
Using information to engage patients and their families in their care		Improving population health

Source: Office of the National Coordinator for Health IT

Appendix Table 4.5 List of Regional Extension Centers and Funding

Regional Extension Center Grantee	State	Federal Share	Additional Funding in 2011
Alabama Regional Extension Center	AL	$7,519,969	$404,806
Alaska eHealth Network	AK	$3,632,357	$604,446
Altarum Institute	MI	$19,619,990	
Arizona Health e-Connection (AzHeC)	AZ	$10,791,644	$403,131
Arkansas Foundation for Medical Care, Inc.	AR	$7,400,000	$404,775
California Regional Extension Center (North)	CA	$17,286,081	$600,227
California Regional Extension Center (South)	CA	$13,961,339	$672,913
CalOptima Foundation	CA	$4,662,426	$1,187,574
Chesapeake Regional Information System for Our Patients	MD	$5,535,423	$869,352
Chicago Health Information Technology Regional Extension Center (CHITREC)	IL	$7,649,533	$621,719
CIMRO of Nebraska	NE	$6,647,371	$402,404
Colorado Regional Health Information Organization (CORHIO)	CO	$12,475,000	$404,775
Community Health Centers Alliance, Inc.*	FL	$11,078,879	$262,934
Dakota State University	SD	$5,687,168	$568,142
Dallas-Fort Worth Hospital Council Education and Research Foundation	TX	$8,488,513	$406,262
eHealth Connecticut	CT	$5,749,309	$695,601
eHealth DC	DC	$5,488,437	$854,623
eQHealth Solutions, Inc.	MS	$4,289,613	$954,585
Greater Cincinnati Health Bridge	OH, KY, IN	$9,738,000	$361,775
Health Choice Network of Florida, Inc.*	FL	$12,998,040	$404,775
Health Information Exchange	HI and Pacific Territories	$5,859,716	$545,059
HealthInfoNet	ME	$4,777,483	$836,275
HealthInsight	UT, NV	$6,917,783	$151,217
HITEC-LA	CA	$15,625,910	$778,865
IFMC	IA	$5,508,019	
Kansas Foundation for Medical Care, Inc. (KFMC)	KS	$7,000,000	$404,775

Appendix Table 4.5 (Continued)

Louisiana Health Care Quality Forum	LA	$6,207,802	$406,973
Lovelace Clinic Foundation-LCF Research	NM	$6,175,000	$404,775
Massachusetts eHealth Collaborative, Inc.	NH	$5,105,495	$1,211,814
Massachusetts Technology Park Corporation	MA	$13,433,107	$406,668
MetaStar, Inc.	WI	$9,125,000	$404,775
Morehouse School of Medicine	GA	$19,521,542	$89,012
Mountain-Pacific Quality Health Foundation (MPQHF)	MT, WY	$5,020,754	$1,384,021
National Indian Health Board (NIHB)	DC, Serving Nationwide Indian Country	$15,625,910	$403,865
New Jersey Institute of Technology (NJIT)	NJ	$23,048,351	$765,241
New York eHealth Collaborative (NYeC)	NY	$26,534,999	$404,776
Northern Illinois University	IL	$7,546,000	$358,775
NYC REACH	NY	$21,754,010	$179,700
OCHIN, Inc.	OR	$13,201,499	
Ohio Health Information Partnership (OHIP)	OH	$28,500,000	
Oklahoma Foundation for Medical Quality, Inc. (OFMQ)	OK	$5,331,685	$667,547
PaperFree Florida	FL	$5,884,132	$520,643
Ponce School of Medicine	PR	$19,280,796	$2,259,154
Purdue University	IN	$12,000,000	$404,775
Qsource	TN	$7,256,155	$328,283
Qualis Health	WA, ID	$12,846,482	
Quality Insights of Delaware	DE	$5,859,716	$260,891
Quality Insights of Pennsylvania, Inc. (Eastern)	PA	$28,810,271	$1,094,504
Quality Insights of Pennsylvania, Inc. (Western)	PA	$15,625,910	$778,865
Rhode Island Quality Institute (RIQI)	RI	$6,000,000	$404,775
South Carolina Research Foundation	SC	$5,581,407	$823,368
Stratis Health	MN, ND	$19,000,000	$289,040
Texas Tech University Health Sciences Center	TX	$6,666,296	$403,479
The Curators of the University of Missouri	MO	$6,836,335	$403,440

Appendix Table 4.5 (Continued)

The TAMUS Health Science Center Research Foundation	TX	$5,279,970	$1,124,805
University of Central Florida	FL	$7,669,328	$207,731
University of Kentucky Research Foundation	KY	$6,005,467	$399,308
University of North Carolina AHEC REC	NC	$13,569,169	
University of Texas Health Science Center at Houston	TX	$15,274,327	$405,448
Vermont Information Technology Leaders, Inc.	VT	$6,762,080	$142,695
VHQC (Virginia Health Quality Center)	VA	$12,425,000	$404,775
West Virginia Health Improvement Institute, Inc.	WV	$6,000,000	$404,775

Source: Office of the National Coordinator for Health IT