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Variation in the Cost of Radiation Therapy Among Medicare Patients With Cancer

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Abstract

Purpose: Radiation therapy represents a major source of health care expenditure for patients with cancer. Understanding the sources of variability in the cost of radiation therapy is critical to evaluating the efficiency of the current reimbursement system and could shape future policy reform. This study defines the magnitude and sources of variation in the cost of radiation therapy for a large cohort of Medicare beneficiaries.

Patients and Methods: We identified 55,288 patients within the SEER database diagnosed with breast, lung, or prostate cancer between 2004 and 2009. The cost of radiation therapy was estimated from Medicare reimbursements. Multivariable linear regression models were used to assess the influence of patient, tumor, and radiation therapy provider characteristics on variation in cost of radiation therapy.

Results: For breast, lung, and prostate cancers, the median cost (interquartile range) of a course of radiation therapy was $8,600 ($7,300 to $10,300), $9,000 ($7,500 to $11,100), and $18,000 ($11,300 to $25,500), respectively. For all three cancer subtypes, patient- or tumor-related factors accounted for $< 3\%$ of the variation in cost. Factors unrelated to the patient, including practice type, geography, and individual radiation therapy provider, accounted for a substantial proportion of the variation in cost, ranging from 44% with breast, 43% with lung, and 61% with prostate cancer.

Conclusion: In this study, factors unrelated to the individual patient accounted for the majority of variation in the cost of radiation therapy, suggesting potential inefficiency in health care expenditure. Future research should determine whether this variability translates into improved patient outcomes for further evaluation of current reimbursement practices.

Introduction

Up to two thirds of patients with cancer receive radiation therapy.[1] The indications range from early-stage cancer treated with curative intent to metastatic cancer where palliative radiation therapy can improve or preserve quality of life. Radiotherapy is delivered as either external-beam radiation, consisting of daily outpatient treatments for several weeks, or brachytherapy, in which radioactive sources are surgically inserted into a patient's tumor. Advances in radiation technology aim to improve the ability to image, target, and safely target tumors but are often associated with increased costs and a tendency to percolate into clinical practice, without randomized evidence demonstrating their superiority over existing techniques. In fact, the relative increase in nationwide health care expenditure in radiation therapy has far outpaced that of other medical specialties.[2] This cost growth has drawn scrutiny and resulted in increased interest in the health economics of radiation oncology.

Analyses demonstrating the extent and sources of variability in the cost of radiation treatments are essential to understanding the economics of radiation therapy. Ideally, the cost of services should parallel patient case complexity or correlate with improved outcomes. A high degree of variability in expenditures represents inefficiency if these costs vary independently of patient-related factors or outcomes. The high cost of delivering radiation coupled with the broad use of this treatment modality raises the question of variability in the cost of radiation therapy. This study aims to define the magnitude and sources of variation of the cost of radiation therapy among Medicare patients with breast, lung, or prostate cancer.

Patients and Methods

Data Set

This study used the SEER-Medicare linked database. The SEER program, supervised by the National Cancer Institute, represents a collection of individual cancer registries spread across the United States covering 28% of the US population. This study used all available registries within SEER, which are listed in Table 1. The SEER-Medicare linkage includes Medicare claims data for Medicare beneficiaries within SEER. As a result, this population-based database allows investigators to track patterns of care, outcomes, and health care expenditures throughout a patient's disease course. The institutional review board of the University of California San Diego deemed this study exempt from review. We completed a data use agreement before analysis and obtained these data from Information Management Services (Calverton, MD).

Study Patients

This study focused on breast, prostate, and lung cancers, because these are the most common malignancies treated with radiotherapy in this patient population. Initial query of the

Table 1. Patient Demographic and Clinical Characteristics by Cancer Site

Characteristic	Breast, No. (%)	Lung, No. (%)	Prostate, No. (%)
Total patients	18,100	7,172	30,016
Age at diagnosis, years			
66-69	4,881 (27)	1,505 (21)	7,533 (25)
70-74	5,280 (29)	1,970 (27)	11,145 (37)
75-79	4,330 (24)	1,849 (26)	8,069 (27)
80-84	2,685 (15)	1,228 (17)	2,805 (9.4)
≥ 85	924 (5.1)	620 (8.6)	464 (1.6)
Race			
White	16,244 (90)	6,264 (87)	24,789 (83)
Black	982 (5.4)	599 (8.4)	3,099 (10)
Other/unknown	874 (4.8)	309 (4.3)	2,128 (7.1)
Sex			
Male	—	3,667 (51)	30,016 (100)
Female	18,100 (100)	3,505 (49)	—
Marital status			
Married	9,190 (51)	3,778 (53)	21,640 (72)
Other	8,910 (49)	3,394 (47)	8,376 (28)
Income quintile			
Bottom	2,930 (16)	1,950 (27)	6,175 (21)
Second	3,439 (19)	1,700 (24)	5,914 (20)
Third	3,778 (21)	1,497 (21)	5,790 (19)
Fourth	3,846 (21)	1,240 (17)	5,969 (20)
Top	4,107 (23)	785 (11)	6,168 (21)
Charlson comorbidity score			
0	12,226 (68)	2,446 (34)	19,303 (64)
1	3,996 (22)	2,383 (33)	6,924 (23)
2	1,213 (6.7)	1,213 (17)	2,285 (7.6)
≥ 3	665 (3.7)	1,130 (16)	1,488 (5.0)
T stage			
T1	14,202 (78)	1,409 (20)	17,555 (58)
T2	3,426 (19)	2,516 (35)	11,439 (38)
T3	178 (1.0)	593 (8.3)	828 (2.8)
T4	72 (0.4)	2,087 (29)	109 (0.4)
T0/Tx	222 (1.2)	567 (7.9)	85 (0.3)
N stage			
N0/Nx	15,036 (83)	2,770 (39)	29,883 (100)
N1	2,543 (14)	613 (8.6)	133 (0.4)
N2	387 (2.1)	3,075 (43)	—
N3	134 (0.7)	714 (10.0)	—
Grade			
Well differentiated	5,066 (28)	200 (2.8)	156 (0.5)
Moderately differentiated	8,089 (45)	944 (13)	13,076 (44)
Poorly or undifferentiated	4,146 (23)	2,370 (33)	16,580 (55)
Unknown	799 (4.4)	3,658 (51)	204 (0.7)
Laterality			
Right	8,859 (49)	4,135 (58)	—
Left	> 9,230 (51)	2,970 (41)	—
Unknown	< 11 (< 0.1)	67 (0.9)	—
Year of diagnosis			
2004	2,761 (15)	1,130 (16)	4,733 (16)
2005	2,738 (15)	1,195 (17)	4,615 (15)
2006	2,892 (16)	1,137 (16)	5,268 (18)
2007	3,124 (17)	1,199 (17)	5,686 (19)
2008	3,241 (18)	1,276 (18)	5,071 (17)
2009	3,344 (18)	1,235 (17)	4,643 (15)
Geographic region			
Iowa	985 (5.4)	587 (8.2)	1,465 (4.9)
California	6,128 (34)	1,474 (21)	7,993 (27)
Connecticut	1,456 (8.0)	545 (7.6)	2,006 (6.7)
Georgia	1,429 (7.9)	731 (10)	3,185 (11)
Hawaii	211 (1.2)	53 (0.7)	474 (1.6)
Kentucky	1,011 (5.6)	888 (12)	1,797 (6.0)
Louisiana	906 (5.0)	776 (11)	2,182 (7.3)
Michigan (metropolitan Detroit)	1,157 (6.4)	702 (9.8)	2,411 (8.0)
New Jersey	2,831 (16)	839 (12)	5,385 (18)
New Mexico	340 (1.9)	91 (1.3)	541 (1.8)
Utah	501 (2.8)	45 (0.6)	892 (3.0)
Washington (western)	1,145 (6.3)	441 (6.2)	1,685 (5.6)
Metropolitan area			
Metro	15,839 (88)	5,743 (80)	25,340 (84)
Rural	2,261 (12)	1,429 (20)	4,676 (16)
Teaching hospital			
No	13,506 (75)	3,796 (53)	21,893 (73)
Yes	4,594 (25)	3,376 (47)	8,107 (27)
Radiation oncology clinic setting			
Hospital-associated outpatient clinic	10,568 (58)	4,289 (60)	10,052 (33)
Freestanding center	6,073 (34)	2,593 (36)	8,233 (27)
Hospital-associated outpatient clinic and freestanding center	1,459 (8.1)	290 (4.0)	11,731 (39)
Radiation therapy type			
External beam (non-IMRT)	13,686 (76)	5,963 (83)	1,703 (5.7)
IMRT	2,706 (15)	764 (11)	15,031 (50)
Brachytherapy alone	1,605 (8.9)	—	6,422 (21)
Brachytherapy and external beam	82 (0.5)	—	1,281 (4.3)
Brachytherapy and IMRT	21 (0.1)	—	4,697 (16)
Stereotactic radiation therapy	—	445 (6.2)	324 (1.1)
Proton therapy	—	—	558 (1.9)
Length of radiation, fractions			
15-24	1,054 (5.8)	1,166 (16)	1,043 (3.5)
25-34	12,692 (70)	3,433 (48)	4,587 (15)
≥ 35	2,749 (15)	2,128 (30)	17,082 (57)

(continued on next column)

Table 1. (continued)

NOTE. Dashes indicate not applicable.
Abbreviation: IMRT, intensity-modulated radiation therapy.

SEER-Medicare database identified 96,472 patients age ≥ 66 years diagnosed between 2004 and 2009 with nonmetastatic biopsy-proven cancer with Medicare claims for radiotherapy within 1 year of diagnosis. We included patients with breast cancer who underwent breast-conserving surgery and those with lung or prostate cancer receiving definitive radiotherapy without surgery. Patients with multiple primary tumors were excluded to avoid including costs incurred from other cancers. Patients were required to have continuous Medicare Part A and B coverage. Managed care organizations do not submit detailed claims data; therefore, patients enrolled in Medicare Part C were excluded. Additional inclusion criteria are discussed here, and the complete patient selection schema is provided in the Data Supplement.

Radiation Therapy

This study evaluated multiple different types of external-beam radiation therapy, including standard conformal radiation therapy, the more technically advanced intensity-modulated radiation therapy (IMRT), stereotactic body radiotherapy, and proton therapy. Additionally, we evaluated brachytherapy delivered with external-beam radiation or alone as definitive treatment. The delivery of a course of radiotherapy involves multiple steps, including imaging the patient before treatment (simulation), devising a radiation therapy plan (treatment planning), daily radiation treatments in the case of external-beam radiation therapy, and weekly management charges. Brachytherapy contains procedural codes related to implantation or insertion of a radiation source. Reimbursement for radiation therapy follows a fee-for-service billing structure that relies on a series of Healthcare Common Procedure Coding System (HCPCS; Data Supplement). For external-beam radiation therapy, an individual course of radiation therapy was defined as a cluster of radiation therapy claims. A break $\geq$ 30 days between claims for external-beam radiation therapy and $\geq$ 90 days for brachytherapy were assumed to indicate multiple courses of radiation therapy. For external-beam radiation therapy, only the first course was considered, because it was most likely delivered with definitive intent. Subsequent courses of radiation therapy were likely delivered in the setting of recurrent or metastatic disease. Additionally, patients treated with shorter courses of external-beam radiotherapy ($<$ 15 days or fractions) were excluded to reduce the risk of including patients with metastatic disease.

For each patient, radiation therapy billing claims were evaluated for the associated Unique Physician Identification Number (UPIN) or National Provider Index (NPI) number corresponding with the treating physician or clinical practice where radiation was delivered. In instances where $>$ one UPIN or NPI appeared during a patient's course of radiation therapy, the UPIN or NPI for the largest number of claims was selected. Patients who received radiation therapy at $>$ one treatment location, in states outside of SEER registries, or from unknown providers were excluded from evaluation. Providers or practices with fewer five patients treated per tumor site over the entire study period were also excluded. The final study cohort included 55,288 patients.

Study Covariates

Patient- and tumor-related variables obtained from SEER included age at diagnosis, sex, race, marital status, geographic location, tumor stage, nodal stage, primary tumor laterality (for breast and lung cancers), and median household income determined from 2000 US Census tract data. Pre-existing comorbidity was assessed using the Deyo adaptation of the Charlson comorbidity index, which uses Medicare claims data in the inpatient and outpatient settings from the year before cancer diagnosis.[3] Care in a teaching hospital was defined as any indirect medical education payment during a hospitalization after the patient's diagnosis of cancer. Patients were assumed to have received radiation therapy in a freestanding center if their radiation therapy claims were present only in the Physician/Supplier Part B (National Claims History) file; if present only in the Medicare Outpatient file, they were classified as having received treatment in a hospital-associated outpatient clinic.[4] Patient characteristics stratified by cancer are listed in Table 1.

Cost of Radiation Therapy

The cost of a course of radiation therapy for each individual patient was defined as the summation of Medicare reimbursements from radiation therapy–related claims using previously described methods.[5,6] Medicare reimbursements were used as a proxy for health care costs.[5] Radiation delivered in the inpatient setting was not included, because of the inability to separate reimbursement for inpatient radiation therapy from other charges incurred during a hospitalization. The Geographic Practice Cost Index[7] was used to adjust costs for regional variation in Medicare payments, and the Medicare Economic Index[8] was used to adjust for inflation, with all dollar estimates reported in 2009 US dollars. Reported costs were rounded to the nearest hundred dollars.

Statistical Analysis

The cost of radiation therapy was expected to differ by tumor site, and therefore, separate analyses were conducted for each cancer. The primary goal of this project was to determine the drivers of variability in the cost of radiation therapy. Potential predictors of cost included patient-related factors, such as patient demographics and tumor characteristics, and non–patient-related factors, such as year of diagnosis, geography, radiation oncology provider, and practice setting. We assumed that the type of radiation delivered and the duration of a course of radiation therapy would substantially affect the cost of treatment; therefore, we included this as a separate category. The duration of a course of external-beam radiation therapy was estimated from the number of distinct days with a Medicare claim indicating radiation treatment, which was a proxy for number of radiation fractions.

The impact of these factors on cost was determined with the ω^2 statistic from a linear regression with cost as the dependent covariate.[9] For example, if a group of explanatory variables in a regression had an ω^2 value of 0.05, this would indicate that 5% of the variation in cost was explained by these variables. We determined the ω^2 statistic from sequentially constructed multivariable linear regression models to determine the impact of covariates on variation in the cost of radiation therapy. The appropriateness of the regression models was examined using residual plots. All included covariates were defined a priori based on factors that we hypothesized could affect treatment complexity and cost. Because of the high degree of correlation between radiation therapy provider and other covariates, such as state, region, and radiation therapy clinic type, the multivariable models did not include all of these covariates in any single model. The effect size of each variable was derived from a separate multivariable linear regression with cost as the dependent covariate. All statistical tests were two sided, and $P < .05$ was considered statistically significant. Analyses were conducted using SAS software (version 9.4; SAS Institute, Cary, NC).

Results

The total cost of radiation therapy across all 55,288 patients in this study was estimated to be $831,275,000. The median cost of a course of radiation therapy (interquartile range) per patient was $8,600 ($7,300 to $10,300) for breast cancer, $9,000 ($7,500 to $11,100) for lung cancer, and $18,000 ($11,300 to $25,500) for prostate cancer. Breast and lung cancers had normal distributions for cost, whereas prostate cancer had a more dispersed distribution (Data Supplement).

Factors associated with the patient or patient's tumor accounted for < 3% of the total variation in the cost of radiation therapy for breast, lung, and prostate cancers (Appendix Table A1, online only). Factors unrelated to the patient, including year of diagnosis, location of treatment, and individual provider, accounted for a substantial proportion of the variation, ranging from 44% with breast and 43% with lung to 61% with prostate cancer. The type of radiation therapy a patient received accounted for a large portion of the variation of cost, ranging from 15% with prostate to 27% with breast and 30% with lung cancer.

Regional differences were also noted with respect to variability in cost (Figure 1). For breast, lung, and prostate cancers, < 5% of the variation in cost was explained by patient or tumor characteristics in most all SEER regions. Factors not attributable to the patient accounted for > 20% of the cost variability in all SEER regions with all three cancers. In prostate cancer specifically, factors not attributable to the patient accounted for > 50% of the cost variability in most all SEER regions. The type of radiation therapy accounted for ≥ 10% of the cost variation in all SEER regions and had a greater impact on the variability in cost in breast and lung cancers than in prostate cancer.

We then assessed the magnitude of the impact of each covariate on the cost of radiation therapy using multivariable regression for each disease site (Figure 2). Among all patients, various patient- or tumor-related factors were significant predictors of cost, although the absolute impact on cost was relatively small. No patient- or tumor-related factor affected the cost of radiation therapy by > $1,000. Multiple non–patient-related factors substantially influenced the cost of radiation therapy. The cost of radiation therapy increased from 2004 through 2007, decreased uniformly across all disease sites between 2007 and 2008, and resumed an upward trend again in 2009. The geographic region of treatment delivery affected the cost of radiation therapy, with the lowest cost in Hawaii and the highest cost in Washington state. The type and length of radiation delivered influenced cost, with longer courses of radiation therapy, IMRT, stereotactic radiation therapy, and proton therapy all increasing cost compared with standard conformal radiation therapy. Proton therapy for prostate cancer increased cost by $24,400 compared with standard conformal radiotherapy ($P < .001$) and by $11,000 compared with 35 daily fractions of IMRT. Finally, radiation oncology clinic setting affected cost for all tumor sites, particularly prostate cancer, where treatment in freestanding radiation oncology clinics resulted in an additional $11,800 in Medicare reimbursement compared with hospital-associated clinics ($P < .001$). The Data Supplement shows the complete results of this multivariable analysis.

Finally, the number of distinct combinations of HCPCS Medicare billing claims used during a course of radiation therapy was evaluated for each disease site. This analysis revealed that 94.5% of patients with breast, 99.4% of patients with lung, and 93.6% of patients with prostate cancer had unique combinations of HCPCS codes over their course of radiation therapy.

Discussion

In an efficient payment system, reimbursement of health care services should vary based on factors related to the patient, disease, or patient case complexity. The key finding of this study—that variability in Medicare reimbursement for radiotherapy does not depend on patient- or disease-related factors—suggests substantial inefficiency within the current Medicare reimbursement framework for radiation therapy. Between 2003 and 2008, radiation oncology outpaced all medical specialties, with the largest relative increase in Medicare expenditure.[2] Given that the magnitude of this problem will likely increase with further deployment of newer high-cost technologies, radiation oncology will likely be a focus of future reimbursement reform.

This study found that the largest drivers of cost variation were factors unrelated to the patient, namely location of care and individual provider. This finding parallels other research examining drivers of variation in nationwide Medicare reimbursement. For example, researchers from Dartmouth reported substantial geographic variation across all of Medicare, with reimbursement ranging from $6,900 per beneficiary in the lowest spending region to > $13,000 in the highest spending region.[10] Additionally, a report by the Institute of Medicine found that providers accounted for 73% of variation in post–acute care costs, such as long-term care hospitals.[11] Reimbursement patterns that vary by geography or hinge on individual providers suggest either suboptimal health care delivery or inefficient reimbursement practices.

Beyond the location of care and radiation therapy provider, the specific type of radiation delivered represented a major component of cost variability. Our study, in addition to previous research, found that IMRT and proton therapy add substantial cost to a course of radiation therapy.[4,12] Although improved patient outcomes would justify the use of these technologies, unfortunately, the field of radiation oncology largely lacks

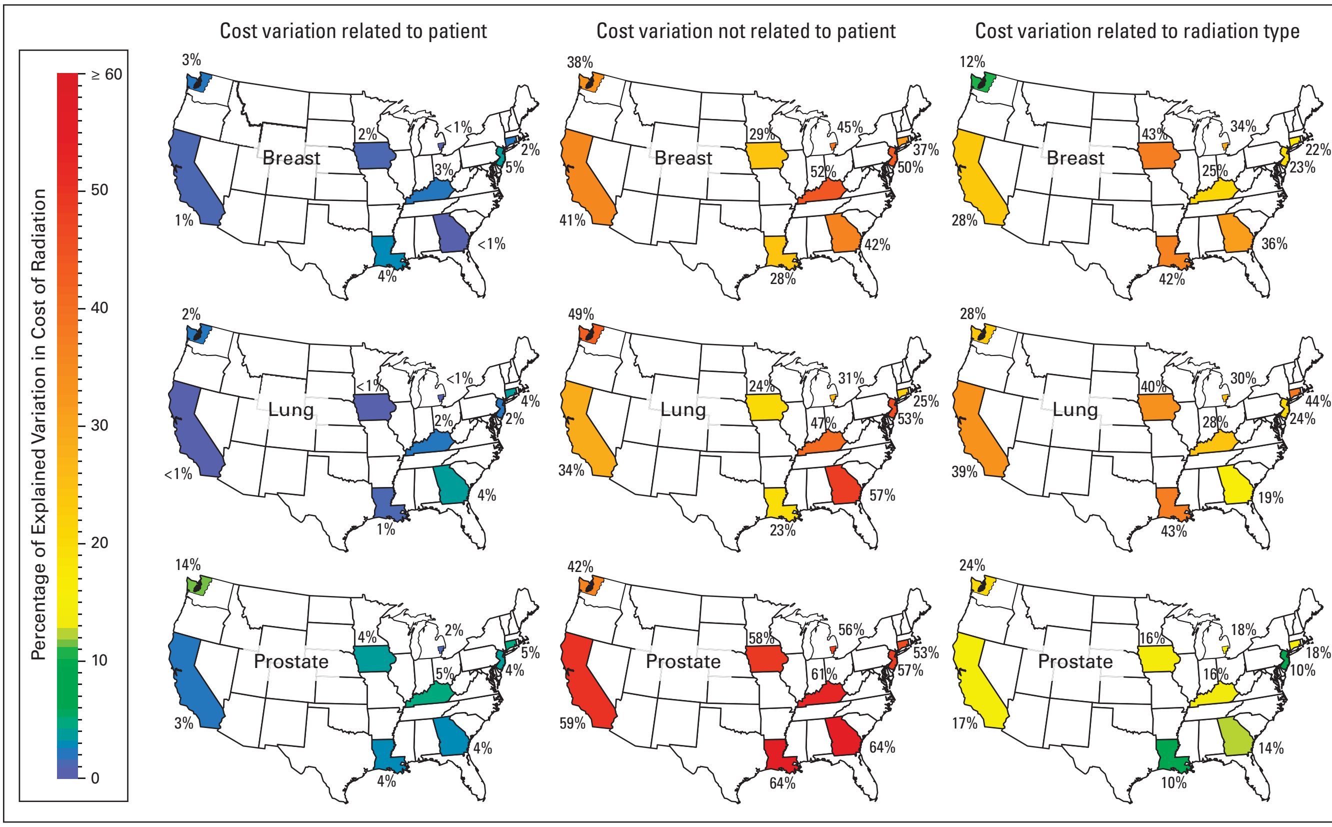

Figure 1. Sources of variation in cost of course of radiation therapy for patients with breast, lung, or prostate cancer, stratified by state. Fraction of explained variance comes from ω^2 statistic in multivariable analysis. Cost variation related to patient comes from ω^2 in linear regression that included patient-related covariates (patient age, race, sex, income level, T stage, N stage, tumor grade, laterality, and type of primary surgery). Cost variation unrelated to patient comes from change in ω^2 when adding radiation therapy course length to previous multivariable model. Cost variation not related to patient comes from change in ω^2 when adding care in teaching hospital and provider to previous multivariable model. Utah, New Mexico, and Hawaii were excluded from this analysis because of small patient numbers.

randomized evidence comparing newer more expensive technologies with existing standard technologies. Furthermore, outcomes from nonrandomized trials or retrospective series have not always demonstrated a clinically meaningful impact for newer technologies. For example, population-based studies of proton therapy in prostate cancer have not shown a clear clinical benefit compared with standard radiation therapy.[12,13] However, stereotactic radiation therapy in lung cancer has substantially improved outcomes compared with standard radiation techniques,[14] providing clear justification for the increased cost.[15] Carefully conducted comparative-effectiveness and cost-effectiveness research is critical to defining the value of new medical technology.

In addition to demonstrating variability in cost, this study highlights the complicated fee-for-service reimbursement structure within the specialty of radiation oncology. Our finding that the vast majority of patients had a unique combination of radiation therapy billing codes emphasizes the complexity of the current system. Fee-for-service reimbursement in general suffers from misaligned incentives, where providers are rewarded for doing more rather than reimbursed for quality of care.[7] Many potential alternative payment models exist, such as blended payment models, bundled payments, or accountable care organizations.[16] Regardless of the specific model, the ideal system should strive to provide value-based reimbursement that accounts for underlying patint case complexity and patient preference. The findings of our study strongly suggest that changes are needed to meet this goal.

This study has limitations warranting discussion. SEER-Medicare data do not contain information regarding patient anatomy, body habitus, or other physical examination findings. We could also only superficially evaluate documented clinical factors and therefore did not have insight into the technical complexity of each patient case. These factors could influence the delivery of radiation and explain a portion of the cost variation. Another limitation relates to the selectivity of our study cohort; our analysis does not fully represent the entire Medicare population or the remainder of the US population. The data set we used does not include younger patients or those with managed care plans or private insurance; therefore, our results may not be generalizable outside of our study cohort. Despite this drawback, we suspect that broader inclusion criteria would only increase the variability in cost. In addition, both treatment guidelines and reimbursement codes have changed since completion of this study. These changes will affect radiation therapy cost variation. However, the extent of this impact cannot yet be assessed with currently available SEER-Medicare data. A final but important limitation relates to our lack of understanding of

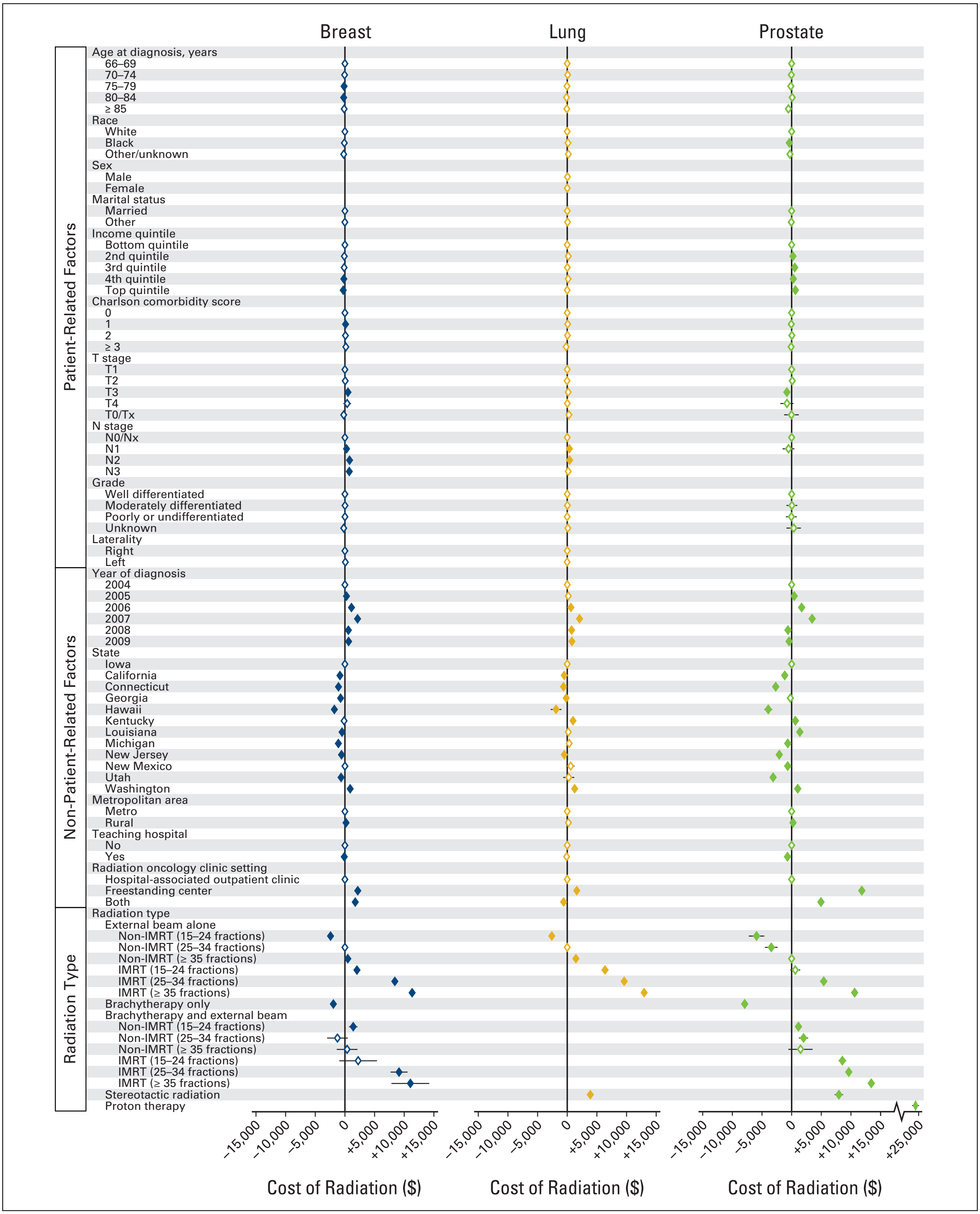

Figure 2. Full multivariable model to determine predictors of cost of radiotherapy among patients with breast, lung, or prostate cancer stratified by provider. Diamonds represent effect size, with vertical lines indicating 95% CIs. Diamonds to right of vertical lines represent covariates that increase cost of radiation therapy, whereas diamonds to left represent covariates that decrease cost. Solid diamonds indicate $P < .05$. IMRT, intensity-modulated radiation therapy.

the relationship between the cost of treatment and patient-related outcomes. For example, if more expensive radiation therapy were to reduce toxicity or improve disease control, the existing payment model would achieve the goal of providing value-based reimbursement. In fact, such an effect has been described for IMRT relative to less expensive conventional radiation modalities in both prostate and head and neck cancers.[13,17] However, further research in this area is warranted for other disease sites.

In summary, using a large cohort of Medicare patients with breast, lung, or prostate cancer, this study demonstrates that factors unrelated to the patient or disease account for the largest share of variation in the cost of radiation therapy. Patient- and disease-related factors, serving as a proxy for patient case complexity, had nearly no correlation with cost variation, suggesting inefficiency in the current fee-for-service reimbursement paradigm.

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AUTHORS' DISCLOSURES OF POTENTIAL CONFLICTS OF INTEREST

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No relationship to disclose

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No relationship to disclose

Appendix

Table A1. Sources of Cost Variation by Cancer Type

Multivariable Regression Model	Breast, ω^2 (95% CI)	Lung, ω^2 (95% CI)	Prostate, ω^2 (95% CI)
Model 1: patient characteristics	0.012 (0.009 to 0.015)	0.001 (0.000 to 0.004)	0.005 (0.003 to 0.006)
Model 2: model 1 plus tumor characteristics	0.018 (0.014 to 0.022)	0.003 (0.003 to 0.003)	0.027 (0.027 to 0.027)
Model 3: model 2 plus year of diagnosis	0.09 (0.08 to 0.10)	0.09 (0.08 to 0.10)	0.11 (0.10 to 0.11)
Model 4: model 3 plus location of treatment	0.20 (0.19 to 0.21)	0.15 (0.13 to 0.16)	0.32 (0.31 to 0.32)
Model 5: model 4 plus radiation therapy provider	0.46 (0.45 to 0.47)	0.43 (0.41 to 0.45)	0.63 (0.63 to 0.64)
Model 6: model 5 plus type of radiation therapy	0.73 (0.72 to 0.73)	0.73 (0.72 to 0.73)	0.78 (0.77 to 0.78)

NOTE. Table summarizes results of sequentially constructed multivariable linear regression analyses predicting cost of course of radiation therapy. ω^2 statistic comes from multivariable linear regressions and represents the fraction of variance explained by covariates in each model. Patient characteristics include age, sex (lung cancer only), race, marital status, median income, and Charlson comorbidity score. Tumor characteristics include T stage, N stage, tumor grade, and laterality (breast and lung cancers). Location of treatment includes geographic region, population density, radiation therapy clinic setting, and whether care was received in a teaching hospital.