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The Adoption of New Adjuvant Radiotherapy Modalities among Medicare Beneficiaries with Breast Cancer: Clinical Correlates and Cost Implications

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Abstract

Purpose—New radiotherapy modalities have broadened treatment options for older women with breast cancer, but it is unclear how clinical factors, geographic region, and physician preference affect the choice of radiotherapy modality.

Methods and Materials—We used SEER-Medicare to identify women diagnosed with stage I–III breast cancer from 1998–2007 who underwent breast-conserving surgery. We assessed temporal trends in and costs of the adoption of intensity modulated radiotherapy (IMRT) and brachytherapy. Using hierarchical logistic regression, we evaluated the relationship between use of these new modalities and patient and regional characteristics.

Results—Of 35,060 patients, 69.9% received conventional external beam radiotherapy (EBRT). While overall radiotherapy usage remained constant, use of IMRT increased from 0.0% to 12.6% from 1998–2007, while brachytherapy increased from 0.7% to 9.0%. The statistical variation in brachytherapy use attributable to the radiation oncologist and geographic region was 41.4% and 9.5%, respectively (for IMRT: 23.8% and 22.1%, respectively). Women undergoing treatment at a free-standing radiation facility were significantly more likely to receive IMRT than women treated at a hospital-based facility (odds ratio for IMRT vs. EBRT: 3.89 [95% CI, 2.78–5.45]). No association was seen for brachytherapy. The median radiotherapy cost per treated patient increased from \$5,389 in 2001 to \$8,539 in 2007.

Conclusions—IMRT and brachytherapy usage increased substantially from 1998–2007; overall, radiotherapy costs increased by more than 50%. Radiation oncologists played an important role in

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treatment choice for both types of radiotherapy, while geographic region played a bigger role in use of IMRT than brachytherapy.

Introduction

For women with early stage breast cancer, breast-conserving surgery (BCS) followed by conventional whole breast external beam radiotherapy (EBRT) has been a cornerstone of local therapy in women wishing to avoid mastectomy.(1) A robust body of evidence indicates that adjuvant EBRT results in improved local control and overall survival compared with BCS alone.(2) Clinical decision-making concerning radiotherapy has become more complex in recent years, as the number of radiotherapy options has increased. In particular, intensity modulated radiotherapy (IMRT) and brachytherapy have displaced EBRT, even before phase III trials have established their benefit.(3, 4) IMRT, as a specialized form of EBRT, improves radiation dose homogeneity with reduction in acute skin reactions and possibly later breast fibrosis.(5) In brachytherapy, several techniques are available, but the dominant form involves high dose rate delivery of radiation via a balloon catheter surgically implanted within the tumor bed, thought to be the area at highest risk for local recurrence, thereby reducing the time of treatment to one week compared to 5-7 weeks for a typical course of EBRT or IMRT.

Understanding the diffusion of radiotherapy modalities in older patients is particularly important, as the incidence of breast cancer increases with age.(6) Because older patients are frequently excluded from clinical trials, the generalizability of evidenced-based medical practice may be tenuous, making decisions more susceptible to physician biases and market-based factors.(7) Although other investigators have evaluated the early adoption of IMRT or brachytherapy among older patients in isolation, it is important to further our understanding of various health system factors in the use of radiotherapy by incorporating all potential treatment modalities in a single study, using more recent data.(3, 4) Levels of reimbursement, ownership of treatment facilities, and Certificate of Need (CON) regulations, which require states to demonstrate need before constructing new radiotherapy facilities or purchasing equipment, have complex interactions with clinical decision-making at patient and regional levels, yet their relation to the adoption of new modalities in the Medicare population is unclear. Furthermore, while overall Medicare expenditures vary by region, it is unclear whether there is an association between higher spending and the adoption of new cancer therapies. We hypothesized that patients residing in higher-spending areas would be more likely to receive newer, more expensive radiotherapy modalities, while those residing in states with radiotherapy CON regulations would be less likely.

Technological advances in medicine are often accompanied by increased costs, and radiotherapy is no exception. Given the lack of clarity about whether the new modalities provide clinical benefits, and heightened concerns about increases in overall Medicare expenditures, it is critical to understand the clinical and health system correlates as well as the cost implications of incorporating radiotherapy innovations into the care of older women with breast cancer. To address these knowledge gaps, we assessed temporal trends in the use of standard and new radiotherapy modalities among Medicare beneficiaries with breast cancer and determined whether the adoption of IMRT or brachytherapy was associated with a higher overall use of radiotherapy, or whether these modalities replaced the existing EBRT approach. We also assessed the degree to which the use of the newer modalities varied across regions and by radiation oncologist and surgeon. Finally, we estimated the costs of new radiotherapy modalities.

Methods

Study design and data source

Using the National Cancer Institute's Surveillance, Epidemiology, and End Results (SEER)-Medicare linked database, we assessed temporal trends in the use of EBRT, IMRT, and brachytherapy in women undergoing BCS for invasive, non-metastatic breast cancer. SEER is a compilation of clinical and demographic data from 17 high-quality tumor registries that cover approximately 28% of the U.S. population.(8) In addition, we calculated the costs of each modality over time. We used hierarchical generalized linear models to account for the clustering of patients by provider (radiation oncologist or surgeon) and hospital referral region (HRR). Incorporating these two levels of clustering allowed us to assess the degree to which variation in adoption of each radiotherapy modality was attributable to patient, physician, or HRR-level factors. We constructed separate models for each new radiotherapy modality using EBRT as the reference group. The Yale Human Investigation Committee determined that this study did not constitute human subjects research.

Study sample

We selected female patients diagnosed with stage I-III, non-metastatic, invasive breast cancer during the years 1998-2007 (Appendix 1). Inclusion criteria were as follows: age 67-94, first or only tumor diagnosis, histology consistent with epithelial origin, known month of diagnosis and tumor laterality, diagnosis not reported from autopsy or death certificate, received BCS and did not receive mastectomy within nine months of diagnosis, and did not receive a second non-breast cancer diagnosis during the time period from initial diagnosis through 12 months post-BCS. In order to ensure that patients were likely to have complete Medicare claims, we only included patients with continuous enrollment in fee-for-service Medicare Parts A and B from 24 months prior to diagnosis through 12 months post-BCS (or death if patient died within 12 months of BCS). Receipt of BCS was assessed using Medicare claims (Appendix 2).

Construction of variables

Receipt and type of radiotherapy were ascertained using Healthcare Common Procedure Coding System codes (HCPCS, Appendix 2). We considered a patient to have received radiotherapy if the treatment was initiated within nine months of BCS and if she had any treatment delivery codes for brachytherapy or at least four treatment delivery codes for EBRT or IMRT. We employed the four-treatment restriction in order to increase the likelihood that patients actually received a full course of radiotherapy. Only 0.3% of the sample had 1-3 treatments, so reclassifying them as having received radiotherapy would not have affected our results.

Sociodemographic characteristics included age, race, marital status, median household income based on zip code or census tract estimates, and metropolitan residence. Clinical characteristics included cancer stage, tumor laterality, hormone receptor status, and receipt of chemotherapy. To assess comorbidity, we searched for International Classification of Disease, 9th revision (ICD-9), diagnosis codes in the 24 through three months prior to diagnosis that appeared on any inpatient claims or at least 2 outpatient/physician claims more than 30 days apart.(9) We identified the conditions suggested by Elixhauser et al. (10) that we had previously determined were significantly associated with mortality among a sample of non-cancer patients (Appendix 3). We identified each patient's radiation oncologist and surgeon using the Unique Physician Identification Number (UPIN).

Patient zip code of residence was used to assign each patient to an HRR.(11) Because some radiation oncologists and surgeons treated patients from multiple HRRs, and because of the

challenges of modeling multiple HRRs per provider, we reassigned patients to the HRR from which their radiation oncologist or surgeon treated the plurality of patients. Regional characteristics included state CON status and selected Dartmouth Atlas of Healthcare HRR-level variables, including radiation oncologists and primary care physicians per 100,000 population, total Medicare reimbursement, and adjusted mortality rate of Medicare beneficiaries with fee-for-service coverage.(12) Patient's state was used to assess if CON policies controlling radiation oncology services were in place during the study period. We assumed that patients who had any radiotherapy claims billed in the outpatient claims file received radiotherapy at a hospital-based center, while patients who only had radiotherapy claims billed in the physician claims file received radiotherapy at a free-standing center. To adjust for secular trends, all models also included year of diagnosis (measured as elapsed year since 1998) and year squared.

To determine the cost of radiotherapy, we summed the total amount paid by Medicare for inpatient, outpatient, and physician services in the 12 months following diagnosis using HPCPS codes that were specific for radiotherapy. Due to changes in the way costs were reported on Medicare claims, we restricted this portion of the analysis to patients diagnosed in 2001 and later. All costs were adjusted to 2009 dollars using the Consumer Price Index. To estimate the total number of Medicare fee-for-service beneficiaries diagnosed with early stage breast cancer annually, we applied SEER stage and age-specific incidence rates to the total number of female beneficiaries with fee-for-service coverage who were aged 65 years.(13, 14) To estimate the number of women receiving BCS and radiotherapy, we applied recent data regarding the use of BCS among Medicare beneficiaries with early stage breast cancer (59% of women received BCS) to our estimate of the radiotherapy treatment patterns and costs.(15) To estimate the additional costs associated with the use of new radiotherapy modalities, we estimated the total national costs using the same distribution of modalities we observed in 2007 and subtracted the cost that would have resulted if all women had received EBRT.

Statistical Methods

We summarized the distribution of all covariates for the entire sample and separately for the four treatment groups (no radiotherapy, EBRT, IMRT, and brachytherapy). To assess the independent effects of each covariate on radiotherapy modality, we estimated two hierarchical generalized linear models. The first model compared patients who received IMRT with those who received EBRT; the second model compared patients who received brachytherapy with those who received EBRT. We used EBRT as the reference group for both models as it was the dominant and traditional treatment choice. Each model included error terms at the radiation oncologist and HRR level; these 3-level models allowed us to account for non-independence of treatment selection among patients of the same radiation oncologist and HRR. For each model we calculated the proportion of variance explained by the model, the patient, the radiation oncologist, and the HRR under the assumptions of the model.(16) In a secondary analysis, we estimated analogous models clustering patients by their surgeon rather than radiation oncologist.

All analyses were performed using SAS version 9.2 (SAS Institute Inc, Cary, NC) and Stata version 12.0 (StataCorp, College Station, TX). The hierarchical logistic models were estimated using Stata's *xtmelogit* routine.

Results

Of the 35,060 patients who met inclusion criteria, 27,728 patients (79.1%) received some form of radiotherapy: 24,496 (69.9%) received EBRT; 1,983 (5.7%) received IMRT; and 1,249 (3.6%) received brachytherapy. The patients who did not receive radiotherapy were

older and had higher comorbidity compared to patients who received radiotherapy (Table 1). One-third of the patients who did not receive radiotherapy were 85 years, while only 10.9% of the overall sample fell in this age range. Similarly, 22.4% of the patients who did not receive radiotherapy had 3 comorbidities, compared to only 13.5% of the entire sample.

There was substantial change over time in the use of the radiotherapy modalities from 1998-2007 (Figure 1). The overall proportion of patients receiving radiotherapy of any type remained relatively constant, at approximately 80%. The use of EBRT decreased during the study period, from 77.3% in 1998 to 57.2% in 2007. There was a corresponding increase in the use of IMRT and brachytherapy, from 0% and 0.5% in 1998 to 12.6% and 9.0% in 2007, respectively.

In the model comparing IMRT to EBRT, the oldest patients were significantly less likely to receive IMRT than the youngest patients (Table 2; odds ratio (OR) 0.63 [95% confidence interval (CI), 0.43-0.90], as were the least healthy patients (OR for 3 vs. 0 conditions, 0.78 [95% CI, 0.63-0.98]). Patients who had left-sided tumors were significantly more likely to receive IMRT (OR 1.75 [95% CI, 1.52-2.01]). There was no association between IMRT and race, metro status, cancer stage, hormone receptor status, or receipt of chemotherapy. Receipt of treatment at a free-standing facility was the only health system factor that was associated with a higher likelihood of IMRT use (OR 3.89 [95% CI, 2.78-5.45]). There was no association between living in a state with CON regulation for radiotherapy facilities, radiation oncologist or primary care physician density or total Medicare expenditures per capita and IMRT.

Patients with a higher comorbidity burden were more likely to receive brachytherapy than EBRT (OR for 3 vs. 0 conditions, 1.29 [95% CI, 1.03-1.63]). Patients with stage II disease or who received chemotherapy were less likely to receive brachytherapy (OR for stage II vs. I, 0.39 [95% CI, 0.32-0.48]; OR for chemotherapy, 0.55 [95% CI, 0.42-0.72]). There was no association between age, hormone receptor status, or type of radiotherapy facility. None of the health system factors was associated with brachytherapy.

After adjusting for specific covariates, we found that radiation oncologist and HRR contributed equally to the variation in IMRT use, with 23.8% attributable to the radiation oncologist and 22.1% attributable to HRR. There was a much stronger relation between the radiation oncologist and use of brachytherapy: 41.4% of the variation in brachytherapy use was attributable to the radiation oncologist and 9.5% to HRR. When we statistically clustered on the surgeon rather than radiation oncologist, the variance in IMRT and brachytherapy use ascribed to the surgeon was 11.0% and 32.8%, respectively, indicating that the surgeon had a stronger impact on use of brachytherapy than IMRT, relative to the radiation oncologist.

For patients diagnosed in 2001-2007 the median cost of EBRT, IMRT, and brachytherapy was \$6,104 (interquartile range [IQR], \$5,105-\$6,999); \$12,375 (IQR, \$10,131-\$18,750); and \$13,667 (IQR, \$10,583-\$16,246), respectively. In aggregate, the costs associated with radiotherapy treatment rose from \$5,389 per treated patient in 2001 to \$8,539 in 2007 (Figure 2). At the national level, we estimated that 31,371 Medicare fee-for-service beneficiaries would have undergone BCS in 2007; 80% of these (about 25,000) would have received adjuvant radiotherapy. (14, 15, 17) Using our estimates of treatment patterns (12.6% receiving IMRT; 9.0% receiving brachytherapy), the total estimated costs to Medicare for adjuvant radiotherapy were approximately \$213.4 Million. However, if all of the women who received adjuvant radiotherapy had received EBRT, the total costs would be approximately \$160.5 Million. Hence, the additional cost to the Medicare fee-for-service

program due to the use of new breast cancer radiotherapy modalities in 2007 was approximately \$53 Million.

Discussion

Among Medicare beneficiaries undergoing BCS for early stage breast cancer, we observed a remarkable shift in radiotherapy practice patterns towards new, more expensive radiotherapy modalities from 1998 to 2007. Our statistical modeling showed a striking influence by individual physicians in prescribing these new modalities. By 2007, nearly one in four women receiving adjuvant radiotherapy was treated with IMRT or brachytherapy, resulting in a 57% increase in per capita cost of radiotherapy. The diffusion of new technology was not associated with an increase in the proportion of women receiving adjuvant radiotherapy, but rather replaced EBRT in a “zero sum game.” Moreover, these escalating costs are unlikely to be accompanied by improved cure rates while any toxicity or quality of life benefits are arguably minimal.

Our analysis builds upon prior patterns of care studies in important ways, including an empirical assessment of the relative importance of the radiation oncologist, surgeon, and geographic region on the adoption of new radiotherapy modalities. Specialist physicians had a much stronger impact on brachytherapy than IMRT, while geographic region had a stronger effect on IMRT use. Thus, clinical decisions to use brachytherapy seem to be significantly influenced by both the surgeon, who may implant the brachytherapy balloon, and the radiation oncologist. We also found that patients with left-sided tumors were more likely to receive IMRT. The ability of IMRT to reduce cardiac exposures sufficiently to reduce toxicity is speculative and is highly dependent on the technique used.(18, 19) This association is also likely due to the fact that many Medicare reimbursement policies in certain jurisdictions only allow IMRT for left-sided breast cancers.(3)

Brachytherapy was more common in patients with stage I tumors and greater comorbidity. These findings should be considered in light of the CALGB 9343 study, published in 2004, which defined a group of elderly patients with favorable tumor characteristics who might not require adjuvant radiotherapy.(20, 21) That is, brachytherapy may be used particularly among women for whom the trial suggested radiotherapy may not be necessary. It is possible that patients and their physicians may have been uncomfortable with forgoing radiotherapy and instead opted for brachytherapy.

State CON regulations for radiotherapy facilities did not have an impact on the use of either IMRT or brachytherapy, suggesting that CONs may not be an effective tool for decreasing radiation oncology costs. Consistent with prior findings, women undergoing radiotherapy at a free-standing facility were more likely to receive IMRT.(3) Free-standing facilities, which bill globally for technical and professional services, are more likely than hospital-based facilities to be owned by physicians. Since the more lucrative aspects of IMRT are the technical rather than the professional reimbursements, equity ownership in the free-standing setting may be a powerful financial incentive.

There are important limitations to our study to consider. While we included many of the variables we believed could affect patterns of care, there remain important variables that we could not measure due to the use of an administrative database, such as quality of life and patient preference. Additionally, our study sample was restricted to women 67 years-old who had Medicare fee-for-service coverage, so our results may not be generalizable to younger patients or those with other insurance.

In conclusion, over 20% of patients diagnosed in 2007 were treated with a new radiotherapy modality, and our data suggest that the trajectory is increasing. With IMRT and

brachytherapy costing twice as much as EBRT, this shift to newer modalities resulted in an increase in the median radiotherapy cost per treated patient of over 50%. At a time of unsustainable health care costs, any increased costs from medical innovation must be commensurate with tangible clinical benefit. Clearly, more study of the comparative effectiveness of new technologies is needed so that financial incentives in our imperfect medical marketplace may be better aligned with optimal patient care.

Supplementary Material

Refer to Web version on PubMed Central for supplementary material.

Acknowledgments

This study used the linked Surveillance, Epidemiology, and End Results (SEER)-Medicare database. The interpretation and reporting of these data are the sole responsibility of the authors. We acknowledge the efforts of the Applied Research Program, NCI; the Office of Research, Development and Information, CMS; Information Management Services, Inc.; and the SEER Program tumor registries in the creation of the SEER-Medicare database.

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Appendix 1. Sample selection figure

Appendix 2. Procedure codes used in analysis

	Receipt of radiotherapy		Costs of radiotherapy
	Healthcare Common Procedure Coding System	International Classification of Diseases, 9 th revision	
Treatment			
Breast-conserving surgery	19110, 19120, 19125, 19126, 19160, 19162, 19301, 19302	85.20, 85.21, 85.22, 85.23, 85.25,	
External beam radiotherapy	77402, 77403, 77404, 77406, 77407, 77408, 77409, 77411, 77412, 77413, 77414, 77416,		77261-77799, 0182T, 19296, 19297, 19298, C9714, C9715, 0073T, G0174, C1715, C1717, C1718, C1719, C1720, C9726, G0178, Q3001, 76965
Intensity modulated radiotherapy	77301 *, 77418, 0073T, G0174		
Brachytherapy	77761, 77762, 77763, 77776, 77777, 77778, 77781, 77782, 77783, 77784, 77799, 0182T, 19296, 19297, 19298, C9714, C9715		

* Code 77301 (intensity modulated radiotherapy plan) was not used to identify whether a patient received radiotherapy. If a patient had code 77301 in addition to delivery codes for external beam radiation therapy, she was assigned to the intensity modulated radiotherapy group. If this code appeared without any delivery codes, she was assigned to the no radiotherapy group.

Appendix 3. Elixhauser conditions included in comorbidity index

Appendix 3. Elixhauser conditions included in comorbidity index.

Condition
Congestive Heart Failure
Cardiac Arrhythmia
Valvular Disease
Pulmonary Circulation Disorders
Peripheral Vascular Disorders
Paralysis
Other Neurological Disorders
Chronic Pulmonary Disease
Diabetes Uncomplicated
Diabetes Complicated
Renal Failure
Liver Disease
AIDS/HIV
Rheumatoid Arthritis/collagen
Coagulopathy
Weight Loss
Fluid and Electrolyte Disorders

Condition
Deficiency Anemia
Alcohol Abuse
Drug Abuse
Psychoses
Depression

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Summary

We used a population-based sample to study patterns in the use of radiotherapy modalities among women diagnosed with breast cancer from 1998-2007. Although the proportion of women receiving radiotherapy remained stable during this period, there was a substantial increase in the use of intensity modulated radiotherapy and brachytherapy, with a corresponding decrease in the use of traditional external beam radiotherapy. This shift resulted in a 50% increase in the average cost of radiotherapy from 1998-2007.

Figure 1.
Percent of patients receiving each radiotherapy modality by year.

Figure 2. Proportion of breast cancer patients receiving adjuvant radiotherapy and radiotherapy-specific costs over time.

Table 1

Patient and health system characteristics by radiotherapy modality.

	Radiotherapy modality				All
	None	External beam	Intensity modulated	Brachytherapy	
	N (%)	N (%)	N (%)	N (%)	N (%)
N	7,332 (100.0)	24,496 (100.0)	1,983 (100.0)	1,249 (100.0)	35,060 (100.0)
<i>Patient Characteristics</i>					
<i>Age at Diagnosis</i>					
67-69	606 (8.3)	4,696 (19.2)	400 (20.2)	237 (19.0)	5,939 (16.9)
70-74	1,100 (15.0)	7,838 (32.0)	614 (31.0)	360 (28.8)	9,912 (28.3)
75-79	1,499 (20.4)	6,891 (28.1)	547 (27.6)	337 (27.0)	9,274 (26.5)
80-84	1,767 (24.1)	3,784 (15.4)	339 (17.1)	224 (17.9)	6,114 (17.4)
85-94	2,360 (32.2)	1,287 (5.3)	83 (4.2)	91 (7.3)	3,821 (10.9)
<i>Race</i>					
White	6,647 (90.7)	22,513 (91.9)	1,808 (91.2)	1,151 (92.2)	32,119 (91.6)
Black	453 (6.2)	1,069 (4.4)	127 (6.4)	52 (4.2)	1,701 (4.9)
Other	232 (3.2)	914 (3.7)	48 (2.4)	46 (3.7)	1,240 (3.5)
<i>Marital Status</i>					
Married	2,226 (30.4)	12,135 (49.5)	949 (47.9)	594 (47.6)	5,904 (45.4)
Not married	4,758 (64.9)	11,645 (47.5)	899 (45.3)	593 (47.5)	7,895 (51.0)
Unknown	348 (4.7)	716 (2.9)	135 (6.8)	62 (5.0)	1,261 (3.6)
<i>Median Household Income</i>					
\$32,999	1,443 (19.7)	3,688 (15.1)	302 (15.2)	186 (14.9)	5,619 (16.0)
\$33,007-\$39,970	951 (13.0)	3,308 (13.5)	198 (10.0)	142 (11.4)	4,599 (13.1)
\$40,007-\$49,987	1,606 (21.9)	5,028 (20.5)	416 (21.0)	257 (20.6)	7,307 (20.8)
\$50,007-\$62,983	1,430 (19.5)	5,257 (21.5)	465 (23.4)	259 (20.7)	7,411 (21.1)
\$63,002*	1,902 (25.9)	7,215 (29.5)	602 (30.4)	405 (32.4)	10,124 (28.9)
<i>Residence in Metro County</i>					
No	1,004 (13.7)	3,065 (12.5)	156 (7.9)	90 (7.2)	4,315 (12.3)
Yes	6,328 (86.3)	21,431 (87.5)	1,827 (92.1)	1,159 (92.8)	30,745 (87.7)

	Radiotherapy modality				All
	None	External beam	Intensity modulated	Brachytherapy	
Cancer Stage					
I	4,901 (66.8)	17,064 (69.7)	1,366 (68.9)	1,058 (84.7)	24,389 (69.6)
II	2,103 (28.7)	6,911 (28.2)	549 (27.7)	191 (15.3)	9,754 (27.8)
III	328 (4.5)	521 (2.1)	68 (3.4)	0 (0.0)	917 (2.6)
Comorbid Conditions					
No conditions	2,765 (37.7)	12,569 (51.3)	966 (48.7)	578 (46.3)	16,878 (48.1)
1-2 conditions	2,924 (39.9)	9,261 (37.8)	788 (39.7)	490 (39.2)	13,463 (38.4)
3 conditions	1,643 (22.4)	2,666 (10.9)	229 (11.5)	181 (14.5)	4,719 (13.5)
Tumor Laterality					
Right-sided	3,513 (47.9)	12,200 (49.8)	852 (43.0)	622 (49.8)	7,187 (49.0)
Left-sided	3,819 (52.1)	12,296 (50.2)	1,131 (57.0)	627 (50.2)	17,873 (51.0)
Hormone Receptor Status					
Negative	697 (9.5)	2,587 (10.6)	260 (13.1)	112 (9.0)	3,656 (10.4)
Positive	5,534 (75.5)	19,612 (80.1)	1,592 (80.3)	1,045 (83.7)	27,783 (79.2)
Unknown	1,101 (15.0)	2,297 (9.4)	131 (6.6)	92 (7.4)	3,621 (10.3)
Chemotherapy					
No	6,579 (89.7)	20,326 (83.0)	1,584 (79.9)	1,134 (90.8)	29,623 (84.5)
Yes	753 (10.3)	4,170 (17.0)	399 (20.1)	115 (9.2)	5,437 (15.5)
Health System Characteristics					
Type of Radiotherapy Facility					
Hospital-based	n/a (0.0)	17,740 (72.4)	1,113 (56.1)	950 (76.1)	19,803 (56.5)
Free-standing	n/a (0.0)	6,756 (27.6)	870 (43.9)	282 (22.6)	7,908 (22.6)
Missing/not applicable	7,332 (100.0)	0 (0.0)	0 (0.0)	17 (1.4)	7,349 (21.0)

* Category also includes patients with unknown income who were combined with patients in the highest income quintile due to privacy regulations

Table 2

Adjusted* odds ratios for receipt of intensity modulated radiotherapy or brachytherapy versus external beam radiotherapy.

	Intensity modulated vs. external beam radiotherapy		Brachytherapy vs. external beam radiotherapy	
	Odds ratio (95% CI)	P-value [†]	Odds ratio (95% CI)	P-value [†]
<i>Patient Characteristics</i>				
Age at Diagnosis		.04		.29
67-69	ref		ref	
70-74	0.91 (0.75-1.12)		1.00 (0.81-1.24)	
75-79	1.06 (0.86-1.30)		1.05 (0.84-1.31)	
80-84	1.00 (0.79-1.28)		1.19 (0.93-1.53)	
85-94	0.63 (0.43-0.90)		1.35 (0.96-1.91)	
Race		.22		.61
White	ref		ref	
Black	1.33 (0.95-1.86)		0.83 (0.56-1.23)	
Other	0.91 (0.55-1.50)		0.92 (0.59-1.42)	
Marital Status		.004		.90
Married	ref		ref	
Not married	0.98 (0.85-1.14)		1.02 (0.87-1.19)	
Unknown	0.56 (0.39-0.79)		1.09 (0.73-1.64)	
Residence in Metro County		.30		.46
No	ref		ref	
Yes	1.21 (0.84-1.75)		1.15 (0.79-1.66)	
Cancer Stage		.30		<.001
I	ref		ref	
II	0.88 (0.74-1.04)		0.39 (0.32-0.48)	
III	0.98 (0.65-1.48)			
Comorbid Conditions		.09		.09
0	ref		ref	
1-2	0.92 (0.79-1.07)		1.03 (0.88-1.21)	
3	0.78 (0.63-0.98)		1.29 (1.03-1.63)	
Tumor Laterality		<.001		.29
Right-sided	ref		ref	
Left-sided	1.75 (1.52-2.01)		1.08 (0.94-1.26)	
Hormone Receptor Status		.82		.59
Negative	ref		ref	
Positive	0.93 (0.75-1.17)		1.12 (0.86-1.46)	
Unknown	0.92 (0.66-1.29)		1.21 (0.83-1.78)	
Chemotherapy		.11		<.001

	Intensity modulated vs. external beam radiotherapy		Brachytherapy vs. external beam radiotherapy	
	Odds ratio (95% CI)	P-value [†]	Odds ratio (95% CI)	P-value [†]
No	ref		ref	
Yes	1.18 (0.96-1.45)		0.55 (0.42-0.72)	
Health System Characteristics				
Type of Radiotherapy Facility		<.001		.09
Hospital-based	ref		ref	
Free-standing	3.89 (2.78-5.45)		0.78 (0.58-1.04)	
State Certificate of Need for Radiotherapy Facilities		.11		.07
No	ref		ref	
Yes	2.06 (0.85-5.04)		0.55 (0.29-1.05)	
Primary Care Physicians (per 100,000 population)	0.97 (0.89-1.06)		0.96 (0.89-1.03)	
Radiation Oncologists (per 100,000 population)	0.93 (0.52-1.66)		1.22 (0.71-2.10)	
Total Medicare Reimbursement per enrollee (Part A and B)	1.05 (0.90-1.23)		1.01 (0.87-1.17)	

Abbreviations: CI = confidence interval

* Both models also adjusted for HRR-level age-sex-race adjusted mortality among Medicare enrollees with fee-for-service coverage, year of diagnosis, and year of diagnosis squared.

[†]Wald p-value