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Persistent use of extended fractionation palliative radiotherapy for Medicare beneficiaries with metastatic breast cancer, 2011-2014

James B. Yu, MD^{1,2,3}, Craig E. Pollack, MD^{4,5}, Jeph Herrin, PhD^{3,6}, Weiwei Zhu, MPH^{3,7}, Pamela R. Soulos, MPH^{3,7}, Xiao Xu, PhD^{3,8}, and Cary P. Gross, MD^{2,3,7}

¹Department of Therapeutic Radiology, Yale School of Medicine, New Haven, CT.

²Yale Cancer Center, New Haven, CT.

³Cancer Outcomes, Public Policy, and Effectiveness Research (COPPER) Center at Yale, New Haven, CT.

⁴Johns Hopkins School of Medicine, Baltimore, MD.

⁵Johns Hopkins Bloomberg School of Public Health, Baltimore, MD.

⁶Section of Cardiology, Yale School of Medicine, New Haven, CT.

⁷Department of Internal Medicine, Section of General Internal Medicine, Yale School of Medicine, New Haven, CT.

⁸Department of Obstetrics, Gynecology, and Reproductive Sciences, Yale School of Medicine, New Haven, CT.

Abstract

Introduction—With no evidence to support extended radiation courses for the palliation of bone metastases, multiple guidelines were issued discouraging its use. We assessed contemporary use and cost of prolonged palliative radiotherapy in Medicare beneficiaries with bone metastases from breast cancer.

Methods—We conducted a retrospective, longitudinal study of palliative radiotherapy use among fee-for-service Medicare beneficiaries with bone metastasis from breast cancer who underwent palliative radiotherapy during 2011–2014. Patients were categorized according to the number of days (‘fractions’) on which they received palliative radiotherapy: 1, 2–10, 11–19, or 20–30. We examined the association of clinical, demographic, and provider characteristics with the use of extended (11 fractions) or very extended (20 fractions) fractionation with logistic regression models. We also compared the cost of different fractionation schemes from the payer perspective.

Corresponding author: James B. Yu MD MHS, Mailing address: Yale School of Medicine HRT 137, 333 Cedar St. New Haven, CT 06520, james.b.yu@yale.edu, Tel: 203-785-5703, Fax: 203-785-4622.

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Results—Of the 7,547 patients in the sample (mean age 71 years), 3,084 (40.8%) received extended fractionation. The proportion of patients receiving 11–19 (34.7% in 2011 and 28.1% in 2014, trend $p<.001$) and 20–30 treatments (10.3% in 2011 to 9.0% in 2014, trend $p=.07$) decreased modestly over time. Patients with comorbidities were less likely to undergo extended fractionation (34.4% for 3 comorbidities vs. 44.9% for 0 comorbidities; adjusted odds ratio [AOR] 0.67 [95% CI 0.58–0.76]). Patients treated at free-standing practices were more likely to undergo extended fractionation (47.9%) compared to those treated at hospital-based practices (37.3%, $p<.001$; AOR 1.49 [95% CI 1.35–1.65]). The mean cost of treatment varied from \$633 [standard deviation (SD) \$240] for single fraction treatment, to \$3,566 [SD \$1,349] for 11–19 fractions, to \$6,597 [SD \$2,893] for 20–30 fractions.

Conclusion—The use of prolonged courses of palliative radiotherapy among Medicare beneficiaries with breast cancer remained high in 2011–2014. The association between free-standing facility status and use of extended fractionation suggests that provider financial incentives may impact choice of treatment.

Introduction

Palliative radiotherapy attempts to ease pain and discomfort for patients with cancer that has metastasized to bone. It can be as short as a single treatment or as lengthy as several weeks or more of daily treatment. Clinical evidence from randomized trials reported in the mid-2000s supported shorter courses of treatment, showing equivalent pain relief and palliation of symptoms compared to longer courses of treatment^{1–3}. Furthermore, though there is evidence that there are lower rates of retreatment with 10 fractions versus 1 fraction¹, there is no evidence to support the use of >10 treatments vs. 10 fractions. Based on these findings, as well as ethical considerations for minimizing treatment time and cost for patients with metastatic disease, professional societies recommended against the use of prolonged courses of palliative therapy in 2011^{4, 5}. In 2013, the American Society of Radiation Oncology (ASTRO) released their Choosing Wisely guidelines, recommending against the use of extended fractionation (>10 treatments) for a course of palliative radiotherapy^{4, 6–8}. They noted that “strong consideration should be given to a single 8 Gy fraction for patients with a limited prognosis or with transportation difficulties”⁶.

Despite the body of evidence showing limited benefit, prior studies have found relatively high rates of extended fractionation use in clinical practice. For example, for patients with prostate cancer metastatic to the bone, estimates of the use of more than 10 fractions in the palliative setting ranged from 37.1% in a cohort of National Cancer Database patients treated in 2004–2012⁹, to 50.3% in a sample of Medicare patients during 2006–2009¹⁰. Schreiber et al also noted that 6.3% of patients with prostate cancer bone metastases underwent treatment with 20 or more fractions. Because these studies analyzed data that predated the Choosing Wisely guidelines, it is possible that utilization of prolonged fractionation schemes has declined in the years since the release of these guidelines.

In addition to rates of extended fractionation, it would be important to identify non-clinical factors associated with its use. Skewed incentives in a fee-for-service reimbursement structure could also impact palliative radiotherapy decision-making¹⁰. For example, it has

been shown that physicians at free-standing radiation oncology practices – who are more likely to own their own radiation machines - are more likely to treat with more expensive forms of radiotherapy compared to physicians at hospital-based practices^{11,12}. Hence, it is plausible that physicians at free-standing practices may be more likely to use longer treatment courses, given the higher reimbursement for longer treatment and associated financial benefit with machine ownership. It is also unclear whether practice structure interacts with physician's ability to more rapidly adopt shorter fractionation courses – perhaps free-standing practices are more nimble and able to make whole sale changes to practice, or perhaps they are more reluctant to adopt shorter courses of treatment resulting in a slower rate of adoption. Additionally, healthcare market factors may play a role: a geographic region where there is greater competition between providers may incentivize providers to “maximize” reimbursement received from each patient by increasing the length of treatment.

In the current study, we sought to address the knowledge gaps regarding the contemporary patterns of care in the years surrounding the ASTRO Choosing Wisely guidelines, as well as the clinical and non-clinical factors associated with use of longer course palliative radiotherapy for breast cancer metastatic to bone. We assessed utilization patterns of short versus extended fractionation courses in patients with breast cancer enrolled in the Medicare fee-for-service program who underwent palliative radiotherapy for bone metastases during 2011–2014. Furthermore, we analyzed the relation between practice structure and competition on the use of prolonged fractionation, as well as whether practice structure interacted with year to year differences in the use of prolonged fractionation. Finally, we assessed differences in cost based on length of treatment.

Methods

Data source and Study Design

We conducted a retrospective, longitudinal study using the Chronic Conditions Data Warehouse (CCW) obtained from the Centers for Medicare and Medicaid Services. The CCW data includes 100% of claims for breast cancer patients enrolled in fee-for-service Medicare.

Patient selection

We identified women with a first occurrence of breast cancer who had bone metastasis, defined based on an International Classification of Diseases, 9th revision (ICD-9) diagnosis code 174.x during 2008–2014 in conjunction with an ICD-9 diagnosis code 198.5 during 2010–2014. We further limited the sample to women who received palliative radiotherapy based on Healthcare Common Procedure Coding System procedure codes. Patients were included in the final analytic sample (Appendix B) if they met all of the following criteria: 1) had 2 ICD-9 diagnosis codes for bone metastasis during 2010–2014, 2) had continuous enrollment in fee-for-service Medicare Parts A and B from 6 months before radiotherapy initiation through the end of study period, 3) initiated radiotherapy in the 5 days before through 1 year after the first metastasis diagnosis code, 4) did not have radiotherapy claims in the 30 days prior to their first palliative treatment (which would indicate they had possibly

been in the midst of a course of adjuvant treatment), 5) did not receive breast surgery within 3 months prior to the initiation of radiotherapy in an attempt to exclude patients who may have received adjuvant breast radiation, and 6) received their last palliative treatment prior to December 21, 2014 (because we did not have 2015 claims and thus could not ascertain whether additional fractions were received). Because radiotherapy codes do not specify whether treatment was performed for palliative purposes, we made the assumption that any RT received in the 5 days before through 1 year after the first occurrence of a diagnosis code indicative of metastatic disease among patients who had not received breast surgery in the prior 3 months were receiving palliative treatment.

We excluded patients if they died within 10 days of their last palliative treatment, since we were unable to differentiate short courses of radiation from those who had an incomplete course of treatment due to death. We also excluded patients who received >30 days of radiation treatment, as this length of treatment was thought to be so excessively prolonged that it was unlikely palliative and more likely to be a misclassification of an adjuvant treatment regimen.

Construction of variables

Palliative radiation therapy for bony metastases was identified by searching for Healthcare Common Procedure Coding System procedure codes indicative of radiation therapy delivery^{10,13,15}. Because billing codes do not allow for differentiation of multiple fractions on a single day, we defined fractionation scheme based on the number of unique days on which patients received radiotherapy. To define a continuous course of therapy, we required that radiation treatment delivery codes had a maximum of 10 days between consecutive treatment delivery dates. Consecutive radiation treatment delivery codes that had a >10 day gap were considered to be part of two separate courses. If a patient received multiple courses of palliative radiation therapy, only the first course was considered for this analysis. Patients were then categorized according to the number of days on which they received palliative radiotherapy: 1, 2–10, 11–19, or 20–30. We defined “extended fractionation” according to the Choosing Wisely guidelines as more than 10 days. We defined “very extended fractionation” as 20 or more days.

We calculated the cost of radiation treatment for each patient by summing the costs associated with all radiation planning, simulation, delivery, and management claims for the course of radiation (Appendix A). We estimated the mean and median cost per course of radiation treatment stratified by fractionation scheme. All cost estimates were adjusted to 2016 U.S. dollars using the all items Consumer Price Index.

Patient characteristics used in the analysis included age, race, comorbidity, metropolitan area residence, median household income at the zip code level, and US Census division. Year in which palliative radiotherapy was initiated was recorded based on Medicare claim dates. Comorbidity was assessed in the 6 months prior to starting palliative radiotherapy using a modified version of the Elixhauser index¹⁴. Consistent with prior work¹⁵, we only included conditions that were previously found to be associated with mortality in a sample of non-cancer patients.

Treatment was categorized as occurring at a hospital-based versus free-standing center. Patients whose radiotherapy delivery was billed solely through the Carrier claims were assumed to have received treatment at a free-standing center, while those who had any radiotherapy delivery billed via the Outpatient facility claims were assumed to have received treatment at a hospital-based center¹⁶.

We constructed two measures reflecting competition in the Hospital Referral Region (HRR)¹⁷. The first measure was the proportion of patients within an HRR who were treated at free-standing centers, as opposed to hospital-based centers. The second measure was the Herfindahl Index for radiation oncologist competition within the HRR. The Herfindahl Index was calculated by summing the squares of the market share for each radiation oncologist within an HRR,¹⁸ where market share was defined as proportion of patients in our sample treated by each radiation oncologist. A larger index value indicates less competition within the HRR. Both measures were HRR-level metrics and were categorized using quintiles to allow for non-linearities in their association with treatment as well as ease of interpretation.

Statistical analysis

The frequency and percentage of patients undergoing each fractionation scheme was calculated for each year in 2011–2014. A one-sided Cochrane-Armitage trend test was performed for each fractionation group to assess potential decreasing trend over the years in 2011–2014. We used descriptive statistics (mean, standard deviation, median, and interquartile range) to characterize the costs associated with the different fractionation schemes. Given the non-normal distribution of costs, the median costs of treatment for different length courses were compared using the Wilcoxon rank-sum test.

Logistic regression models were used to assess the association of patient clinical and demographic characteristics, as well as market competition characteristics, with receipt of extended fractionation. We first estimated a series of bivariate models to identify factors for the final model. Factors were retained if either the overall Wald p-value or any individual coefficient p-value were less than 0.05. Retained factors were included in a single model; covariates that were statistically significant in this adjusted analysis using the same criteria as above were retained in a final model. Year of radiotherapy was also included in the final model in the adjusted model in order to evaluate temporal trends. As we were interested in whether the type of radiotherapy center (freestanding vs. hospital based) influenced the temporal trends in patterns of treatment, we tested the interaction between year of diagnosis and type of radiotherapy center. As a secondary analysis, we repeated the logistic regression using very extended fractionation (>20) as the outcome.

Results

Overall, 7,547 patients were identified as having undergone palliative radiotherapy for bone metastases in 2011–2014 (Table 1). During this study period, 40.9% of women received a treatment course with >10 fractions while 4.0% received a single fraction. When examined by year, only 3.5% of patients received a single-fraction in 2011, and the use remained persistently low through 2014 (4.7%). Meanwhile, the proportion of patients undergoing 11–

19 treatments remained relatively high (34.7% in 2011 and 28.1% in 2014). Similarly, the proportion of patients undergoing 20 or more treatments remained high (10.3% in 2011 and 9.0% in 2014 (Figure 1)). There was a significant decreasing trend in the use of 11–19 fractions over time ($p<.001$). The decline in the use of 20–30 fractions, however, was not statistically significant ($p=.07$).

The mean and median costs of treatment were much higher for extended courses of treatment versus single fraction (Table 2). The median cost of very extended fractionation was nearly 10-fold more than single fraction (\$5,530 [Interquartile Range (IQR) \$4,644–\$7,731] vs. \$630 [IQR \$470–\$754], $p<.0001$). The median cost of extended fractionation was nearly 5-fold more than single fraction (\$3,259 [IQR \$2,759–\$4,026], $p<.0001$ vs. single fraction).

Patient related factors associated with a lower likelihood of undergoing extended fractionation (>10 treatments) included older age (adjusted odds ratio (AOR) for age 85 vs. 65–69: 0.79 [95% confidence interval (CI) 0.66–0.95]), and having comorbid conditions (3 vs. 0 conditions AOR: 0.67 [95% CI 0.58–0.76]) (Table 3). There was a significantly lower likelihood of extended fractionation use in more recent years (AOR for 2013 and 2014 vs. 2011: 0.82 [95% CI 0.72–0.93] and 0.73 [95% CI 0.64–0.83]). Patient-related factors associated with a greater likelihood of very extended fractionation were similar; however, there was no statistically significant difference in the use of very extended fractionation in later years compared to 2011.

Practice setting was significantly associated with use of extended fractionation. Patients treated at a free-standing practice were more likely than those treated at hospital-based practices to undergo extended (>10 treatments) fractionation (47.9% vs. 37.3%, AOR 1.49 [95% CI 1.35–1.65]) as well as very extended (≥ 20) treatment courses (11.1% vs. 9.0%, AOR 1.22 [95% CI 1.04–1.43]). Of note, the interaction between year of radiotherapy and type of radiotherapy center (free-standing vs. hospital-based) was not statistically significant (data not shown) and so was excluded from the final multivariable models.

HRR level radiation oncologist competition was also associated with extended fractionation use. Receiving care in an area with moderately low levels of competition (quintile 4) was associated with greater use of extended hypofractionation (vs. treatment in the most competitive HRRs: AOR 1.21 [95% CI 1.03–1.43]). However, there were no significant associations between other quintiles of competition and use of extended hypofractionation, nor was there an obvious trend seen. HRR-level radiation oncologist competition was not associated with very extended fractionation.

Discussion

Despite guidelines recommending against routine use of extended fractionation for the palliation of bone metastases⁶, almost half of all breast cancer patients with bone metastases underwent extended courses of radiation therapy during 2011–2014 and the use of single fraction radiotherapy was low. Although there was a small but statistically significant decrease in the use of extended fractionation from 2011–2014, rates of extended therapy

remained much higher than single fraction treatment. Moreover, use of extended fractionation was associated with type of practice setting, with patients treated at free-standing facilities more often receiving extended and very extended fractionation when compared with those treated at hospital-based facilities. These results underscore the need to consider the impact of financial incentives on clinical decision making in the setting of palliative radiotherapy.

The results of our study extend prior literature and demonstrate a continued high utilization rate of extended courses of palliative treatment. For example, only 3.3% of Medicare beneficiaries who underwent radiotherapy for prostate cancer bone metastasis underwent single fraction radiotherapy in the years 2006–2009, compared to 50.3% who received more than 10 fractions¹⁰. Our prior work investigating the National Cancer Database (NCDB) for multiple cancer types indicated that single fraction regimens were underutilized through 2011, with the proportion of patients receiving single fraction radiation ranging from 3.1% in 2006 to 7.5% in 2011¹⁹. Furthermore, in this prior work, only 2.3% of breast cancer patients underwent single fraction regimens¹⁹. The results of the present study suggest that single fraction treatment for breast cancer patients in the Medicare population was lower than in the NCDB data, with a more modest rise over time.

Our work suggests that reimbursement and market factors may play an important role in the continued and inappropriate use of extended course palliative radiotherapy. Specifically, the type of practice at which the patient was treated was strongly associated with the likelihood of prolonged fractionation. This is concerning given that treatment decisions regarding patients' palliative radiotherapy should be independent of the practice type and competition. We are unable to identify the mechanisms underlying this variation in our study which may include lack of physician knowledge of the guidelines and misaligned incentives. Our study, however, does indicate that prolonged fractionation was an order of magnitude more expensive than single fraction treatment, pointing towards the potential role of financial incentives in decision-making. These findings could also reflect relatively greater challenges that free-standing centers face compared to hospital-based providers due to less reliable referral patterns. Regardless, both providers at free-standing and hospital based centers had unsatisfactory rates of extended treatment courses, and both types of providers likely face fiscal incentives to prolong treatment courses.

The continued use of unnecessarily extended (>10 fraction) courses of radiotherapy is a clear example of a low-value medical practice that persists despite overwhelming evidence and expert consensus against it. Inefficient medical practice is a key problem of the US healthcare system at large. Similar to other inefficient medical practices, palliative radiotherapy could be an opportunity for episode-based reimbursement that could encourage single fraction treatment, incentivize physicians toward efficient practice, and potentially lower costs overall. Given the multiple well-publicized guidelines arguing against the use of extended fractionation schema, it is unclear whether further intensification of traditional modes of physician education will impact the adoption of shorter courses of radiotherapy. Without alternative reimbursement structures, the greater than 10-fold difference in current reimbursement between a very extended course of radiation and single fraction radiation may make adoption of short course radiation unlikely. Simple changes to per-treatment

reimbursement may work at cross purposes, incentivizing providers to deliver more fractions per treatment to maintain current levels of overall payment. However, before firm conclusions can be made, more data is needed as to the impact of bundled payments on changes to radiation oncology practice.

We identified several patient factors associated with a lower likelihood of extended and very extended fractionation. In particular, patients with greater comorbidity and older age—who are likely to have an even shorter life expectancy and greater difficulty in coming to a radiation facility for repeated treatments—were less likely to receive prolonged fractionation. This is mirrored in the NCDB, where patients with more comorbid disease were more likely to undergo single fraction treatment¹⁹. It is possible that, in the context of shorter life expectancy or greater difficulty with longer courses of treatment, physicians and patients may have placed a greater emphasis on patient convenience, making shorter fractionation preferred. Providers may erroneously wish to use extended fractionation in patients with better life expectancies (for example, those with fewer comorbidities²⁰) given a desire to reduce re-treatment. At the same time, we recognize that it is reasonable to use a 10 fraction regimen in treating patients with longer expected survival or for treatment of weight-bearing areas such as the spine or femurs for which regrowth of metastatic tumor would be especially problematic.

Our study has several limitations. It is restricted to patients enrolled in fee-for-service Medicare. It is possible that patients with other forms of insurance had different patterns of palliative radiation fractionation. However, we find this unlikely as our findings are consistent with analyses conducted using the NCDB¹⁹, which includes all patients from Commission on Cancer-accredited facilities. It is also possible that limiting our patients to Medicare enrollees unfairly painted free-standing centers as being more costly. There is evidence that hospital-based practices may charge higher prices to private insurers, in essence trading one efficiency (lower utilization of Medicare) for an inefficiency (higher prices to the privately insured)²¹. Future research in other patient populations will help validate our findings and inform generalizability. Another limitation is our use of radiotherapy days as a proxy for number of fractions received, resulting in patients who received multiple fractions per day being incorrectly classified. However, hyperfractionated (multiple treatments per day) radiotherapy for the palliation of bone metastases is expected to be exceedingly rare or nonexistent. Furthermore, if there are patients receiving multiple treatments per day, our estimates of the use of unnecessarily large numbers of treatments are likely to be conservative. Another limitation is that simply calculating the cost of treatment may not fully encompass the financial implications of longer vs. shorter radiation treatment. Expenses and serious financial burden may harm the patient. In addition, work days lost, transport costs, and co-insurance costs may reflect further burden than a simple accounting of costs²². Finally, our study is limited to the years 2011–2014 and we cannot conclude that these treatment patterns have persisted to the present day. However, as an assessment of physician response to professional society guidelines, our results can still inform ongoing efforts to reduce unnecessary treatments.

In conclusion, the use of extended fractionation persisted in the years 2011 through 2014, despite multiple clinical guidelines arguing against its routine use. The continued use of

extended fractionation was associated with both clinical and non-clinical factors such as practice type, underscoring the need to encourage and incentivize physicians to avoid prolonged courses of radiation, and to incorporate patients into the decision-making process in a more robust way.

Supplementary Material

Refer to Web version on PubMed Central for supplementary material.

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Figure 1: Percentage of patients treated with radiation courses involving 1, 2–10, 11–19, and 20–30 fractions, respectively, for bone metastases from breast cancer in 2011–2014.

Table 1 –

Patient Characteristics (Overall sample column contains column percent; all other percentages are row percent)

	Fractionation scheme (number of radiotherapy treatments)										P-value*
	Overall sample		1 treatment		2–10 treatments		11–19 treatments		20–30 treatments		
	N (Column%)		N	Row%	N	Row%	N	Row%	N	Row%	
Total	7547		305	4.0	4158	55.1	2350	31.1	734	9.7	
Age											<.001
64	1166	(15.5)	54	4.6	668	57.3	351	30.1	93	8.0	
65–69	2241	(29.7)	85	3.8	1213	54.1	699	31.2	244	10.9	
70–74	1551	(20.6)	50	3.2	800	51.6	521	33.6	180	11.6	
75–79	1127	(14.9)	39	3.5	645	57.2	346	30.7	97	8.6	
80–84	794	(10.5)	35	4.4	450	56.7	245	30.9	64	8.1	
85	668	(8.9)	42	6.3	382	57.2	188	28.1	56	8.4	
Race											.15
White	6430	(85.2)	261	4.1	3499	54.4	2041	31.7	629	9.8	
Black	829	(11.0)	32	3.9	487	58.7	234	28.2	76	9.2	
Other	288	(3.8)	12	4.2	172	59.7	75	26.0	29	10.1	
Comorbidities											<.001
0	3080	(40.8)	84	2.7	1615	52.4	1037	33.7	344	11.2	
1–2	3090	(40.9)	147	4.8	1714	55.5	942	30.5	287	9.3	
3	1377	(18.3)	74	5.4	829	60.2	371	26.9	103	7.5	
Metro status											.91
Metro	5905	(78.2)	238	4.0	3243	54.9	1851	31.3	573	9.7	
Non-metro**	1642	(21.8)	67	4.1	915	55.7	499	30.4	161	9.8	
Income quintile***											.78
Q1 (lowest)	1488	(19.7)	61	4.1	821	55.2	450	30.2	156	10.5	
Q2	1458	(19.3)	59	4.0	797	54.7	456	31.3	146	10.0	
Q3	1464	(19.4)	56	3.8	783	53.5	491	33.5	134	9.2	
Q4	1509	(20.0)	65	4.3	860	57.0	449	29.8	135	8.9	
Q5 (highest)**	1628	(21.6)	64	4.3	897	60.4	504	34.0	153	10.3	
US Census division											<.001
New England	393	(5.2)	16	4.1	252	64.1	100	25.4	25	6.4	
Middle Atlantic	1117	(14.8)	40	3.6	647	57.9	320	28.6	110	9.8	
South Atlantic	1630	(21.6)	68	4.2	895	54.9	508	31.2	159	9.8	
East North Central	1221	(16.2)	55	4.5	662	54.2	398	32.6	106	8.7	
East South Central	545	(7.2)	23	4.2	291	53.4	172	31.6	59	10.8	
West North Central	497	(6.6)	15	3.0	297	59.8	147	29.6	38	7.6	
West South Central	874	(11.6)	22	2.5	452	51.7	319	36.5	81	9.3	
Mountain	450	(6.0)	33	7.3	239	53.1	128	28.4	50	11.1	
Pacific	820	(10.9)	33	4.0	423	51.6	258	31.5	106	12.9	

	Fractionation scheme (number of radiotherapy treatments)										P-value*
	Overall sample		1 treatment		2–10 treatments		11–19 treatments		20–30 treatments		
	N (Column%)		N	Row%	N	Row%	N	Row%	N	Row%	
Type of RT center											<.001
Hospital-based	5003	(66.3)	229	4.6	2909	58.1	1414	28.3	451	9.0	
Free-standing	2544	(33.7)	76	3.0	1249	49.1	936	36.8	283	11.1	
HRR-level percentage of patients treated at free-standing center											<.001
Q1 (7.1%)	1025	(13.6)	55	5.4	592	57.8	288	28.1	90	8.8	
Q2 (7.2–21.6%)	1763	(23.4)	70	4.0	1021	57.9	521	29.6	151	8.6	
Q3 (21.7–37.2%)	1806	(23.9)	81	4.5	1008	55.8	542	30.0	175	9.7	
Q4 (37.3–63.0%)	1807	(23.9)	70	3.9	979	54.2	573	31.7	185	10.2	
Q5 (63.1%)	1146	(15.2)	29	2.5	558	48.7	426	37.2	133	11.6	
HRR-level Herfindahl Index quintile for radiation oncologist competition											.14
Q1 (most competitive)	3675	(48.7)	156	4.2	2078	56.5	1097	29.9	344	9.4	
Q2	1594	(21.1)	70	4.4	853	53.5	520	32.6	151	9.5	
Q3	1104	(14.6)	39	3.5	616	55.8	335	30.3	114	10.3	
Q4	727	(9.6)	28	3.9	374	51.4	252	34.7	73	10.0	
Q5 (least competitive)	447	(5.9)	12	2.7	237	53.0	146	32.7	52	11.6	

* Chi-squared test

** Category includes patients with unknown metro status

*** Income group quintiles: Q1 \$38,505, Q2 = \$38,506–\$46,254, Q3 = \$46,290–\$56,013, Q4 = \$56,046–\$72,531, Q5 \$72,551; Q5 includes patients with unknown income

Table 2 -

Radiotherapy related costs by fractionation group, adjusted to 2016 US dollars

	Cost per course			
# fractions days	Mean (SD)	Median (Q1 – Q3)	P value (pairwise comparison vs. 1 fraction)*	P value (pairwise comparison vs. 2–9 fractions)*
1	\$633 (\$240)	\$630 (\$470-\$754)	Ref	
2–10	\$2,074 (\$902)	\$2,039 (\$1,496-\$2,483)	<0.001	Ref
11–19	\$3,566 (\$1,349)	\$3,259 (\$2,759-\$4,026)	<0.001	<0.001
20	\$6,597 (\$2,893)	\$5,530 (\$4,644-\$7,731)	<0.001	<0.001

* Wilcoxon rank-sum test

Table 3 –

Adjusted association between patient characteristics and receipt of extended fractionation (>10 treatments) and very extended fractionation (≤ 20 treatments)

	Extended fractionation			Very extended fractionation		
	Odds Ratio	95% CI	P-value	Odds Ratio	95% CI	P-value
Age			<.001			.005
64	0.87	0.75 1.01		0.74	0.57 0.95	
65–69	1.00	-- --		1.00	-- --	
70–74	1.12	0.98 1.28		1.08	0.88 1.32	
75–79	0.89	0.77 1.03		0.78	0.61 1.00	
80–84	0.88	0.74 1.04		0.73	0.55 0.97	
85	0.79	0.66 0.95		0.76	0.56 1.04	
Comorbidities			<.001			.002
0	1.00	-- --		1.00	-- --	
1–2	0.84	0.75 0.93		0.84	0.71 0.99	
3	0.67	0.58 0.76		0.67	0.54 0.85	
US Census division			.04			.03
New England	1.00	-- --		1.00	-- --	
Middle Atlantic	1.30	1.02 1.67		1.59	1.01 2.50	
South Atlantic	1.32	1.04 1.67		1.50	0.97 2.33	
East North Central	1.45	1.14 1.85		1.39	0.88 2.19	
East South Central	1.41	1.07 1.86		1.72	1.05 2.80	
West North Central	1.14	0.86 1.52		1.17	0.69 1.98	
West South Central	1.46	1.13 1.90		1.36	0.85 2.17	
Mountain	1.21	0.91 1.63		1.73	1.05 2.85	
Pacific	1.45	1.12 1.88		2.01	1.27 3.17	
Year of RT			<.001			.51
2011	1.00	-- --		1.00	-- --	
2012	0.91	0.79 1.04		1.00	0.80 1.25	
2013	0.82	0.72 0.93		0.91	0.74 1.14	
2014	0.73	0.64 0.83		0.87	0.70 1.08	
Type of RT center			<.001			.02
Hospital-based	1.00	-- --		1.00	-- --	
Free-standing	1.49	1.35 1.65		1.22	1.04 1.43	
HRR-level Herfindahl Index for radiation oncologist competition			.17			
Q1 (most competitive)	1.00	-- --				
Q2	1.08	0.96 1.23				
Q3	1.03	0.89 1.18				
Q4	1.21	1.03 1.43				
Q5 (least competitive)	1.14	0.93 1.39				

* Race, metro status, income group, and HRR-level concentration of patients treated at a free-standing center not included in multivariable model as they were not significantly associated with receipt of extended fractionation.

** Race, metro status, income group, as well as all HRR-level measures of competition not included in multivariable model as they were not significantly associated with receipt of very extended fractionation.

Unadjusted analysis shown in Appendix B.

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