VOLUME 31 · NUMBER 1 · JANUARY 1 2013

JOURNAL OF CLINICAL ONCOLOGY

ORIGINAL REPORT

Use of Radiation Therapy in the Last 30 Days of Life Among a Large Population-Based Cohort of Elderly Patients in the United States

B. Ashleigh Guadagnolo, Kai-Ping Liao, Linda Elting, Sharon Giordano, Thomas A. Buchholz, and Ya-Chen Tina Shih

University of Texas MD Anderson Cancer Center, Houston, TX; and University of Chicago, Chicago, IL.

Published online ahead of print at www.jco.org on November 19, 2012.

Supported by Grant No. 1R21CA164449-01A1 from the National Cancer Institute (B.A.G.).

Presented at the 54th Annual Meeting of the American Society for Radiation Oncology, October 31, 2012, Boston, MA.

Authors' disclosures of potential conflicts of interest and author contributions are found at the end of this article.

Corresponding author: B. Ashleigh Guadagnolo, MD, MPH, Division of Radiation Oncology, The University of Texas MD Anderson Cancer Center, 1515 Holcombe Blvd, Unit 97, Houston, TX 77030; e-mail: aguadagn@mdanderson.org.

0732-183X/13/3101-80/$20.00

DOI: 10.1200/JCO.2012.45.0585

ABSTRACT

Purpose:
Our goal was to evaluate use and associated costs of radiation therapy (RT) in the last month of life among those dying of cancer.

Methods:
We used the Surveillance, Epidemiology, and End Results (SEER) -Medicare linked databases to analyze claims data for 202,299 patients dying as a result of lung, breast, prostate, colorectal, and pancreas cancers from 2000 to 2007. Logistic regression modeling was used to conduct adjusted analyses of potential impacts of demographic, health services, and treatment-related variables on receipt of RT and treatment with greater than 10 days of RT. Costs were calculated in 2009 dollars.

Results:
Among the 15,287 patients (7.6%) who received RT in the last month of life, its use was associated with nonclinical factors such as race, gender, income, and hospice care. Of these patients, 2,721 (17.8%) received more than 10 days of treatment. Nonclinical factors that were associated with greater likelihood of receiving more than 10 days of RT in the last 30 days of life included: non-Hispanic white race, no receipt of hospice care, and treatment in a freestanding, versus a hospital-associated facility. Hospice care was associated with 32% decrease in total costs of care in the last month of life among those receiving RT.

Conclusion:
Although utilization of RT overall was low, almost one in five of patients who received RT in their final 30 days of life spent more than 10 of those days receiving treatment. More research is needed into physician decision making regarding use of RT for patients with end-stage cancer.

J Clin Oncol 31:80-87. © 2012 by American Society of Clinical Oncology

INTRODUCTION

Investigators have identified quality of care indicators for cancer care at the end of life[1,2] and reported that overly aggressive cancer treatment at the end of life may be an indicator of poor-quality care.[3] These analyses have documented patterns of increasingly aggressive cancer care at the end of life since the mid-1990s.[2,4] However, none of these studies specifically addressed quality of care indicators with respect to the use of radiotherapy. In fact, few data exist regarding use of radiotherapy at the end of life.

Radiotherapy can be an effective tool for palliation of symptoms arising from cancer, such as pain from bone metastases or neurologic compromise from brain or spinal metastases. Some investigators have reported that there may be an underuse of radiotherapy for palliation.[5] However, radiotherapy can be delivered via various dosing regimens (eg, single fraction on one day versus multiple weeks), and investigators in Germany have reported that when radiotherapy is used at the end of life, half of patients spent more than 60% of their final 30 days undergoing radiation treatment.[6] Multiple studies have shown that shorter courses of radiotherapy are as effective as longer courses in palliating a variety of symptoms.[7-10]

The purpose of this study was to ascertain the proportion of patients who received radiotherapy in the last 30 days of life among Medicare beneficiaries who died as a result of the top five cancer causes of death between 2000 and 2007. We also sought to examine the influence of sociodemographic factors and health services characteristics associated with the use of radiotherapy at the end of life. We evaluated the duration of radiation therapy use, defined by the number of radiation treatment days, in the last 30 days of life, as well as costs.

Table 1. Univariate Analysis of Receipt of Radiation Therapy in the Last 30 Days of Life According to Sociodemographic, Disease, and Health Services Characteristics

Characteristic	No.	% Treated With RT	*P*
Entire cohort	202,299	7.6	
Year of death			
2000	18,700	8.1	< .001
2001	22,664	8.5	
2002	25,212	8.1	
2003	26,978	7.7	
2004	27,320	7.6	
2005	27,962	7.0	
2006	27,261	7.0	
2007	26,202	6.9	
Age at death, years			
65-69	33,050	10.4	< .001
70-74	43,084	9.2	
75-79	48,612	8.2	
≥ 80	77,553	5.1	
Sex			
Male	104,053	8.3	< .001
Female	98,246	6.8	
Race/ethnicity			
Non-Hispanic white	167,126	7.7	< .001
Non-Hispanic black	18,462	6.2	
Hispanic	8073	7.3	
Other	8638	7.4	
Marital status			
Married	103,573	8.4	< .001
Unmarried	89,644	6.8	
Unknown	9082	6.5	
Cause of cancer death (tumor type)			
Breast	20,681	5.8	< .001
Colorectal	39,377	2.4	
Lung	103,421	11.2	
Pancreas	19,081	2.3	
Prostate	19,739	5.4	
Comorbidity index			
0	77,813	7.9	< .001
1	52,918	8.1	
≥ 2	46,346	7.5	
Unknown	25,222	5.5	
SEER registry region			
West/Hawaii	83,460	7.4	< .001
Northeast	44,318	7.2	
Midwest	37,611	7.0	
South	36,910	8.8	
Urban versus rural residence			
Urban	182,253	7.6	.677
Rural	20,026	7.4	
Median income in census tract			
Lowest quartile	43,245	7.8	< .001
Second quartile	43,210	8.0	
Third quartile	43,263	8.0	
Highest quartile	43,323	8.1	
Unknown	29,258	5.1	
Education level of census tract–% with <12 years of education			
First quartile (highest level)	48,090	7.3	.0067
Second quartile	48,012	7.6	
Third quartile	47,991	7.7	
Fourth quartile	47,768	7.8	
Unknown	10,438	7.1	

(continued in next column)

Table 1. Univariate Analysis of Receipt of Radiation Therapy in the Last 30 Days of Life According to Sociodemographic, Disease, and Health Services Characteristics (continued)

Characteristic	No.	% Treated With RT	*P*
No. of radiation oncologists in HSA/population of HSA *			
Lowest quartile (lowest density)	12,156	7.2	< .001
Second quartile	12,882	8.3	
Third quartile	61,032	8.0	
Highest quartile (highest density)	116,209	7.3	
Unknown	20	5.0	
Hospice			
Yes	118,807	6.1	< .001
No	83,492	9.6	

*Quartile in this category refers to the distribution of the density of providers not the proportion of patients.
Abbreviations: HSA, health service area; RT, radiation therapy.

METHODS

Data Source and Study Cohort Definition

We conducted this analysis using the Surveillance, Epidemiology, and End Results (SEER) -Medicare linked database, which links Medicare claims files with patients in the tumor registries in the SEER regions. The SEER program (a National Cancer Institute–supported database) includes tumor registries in 17 geographic areas covering approximately 25% of the US population.[11] The Medicare program provides payments for hospital, physician, and outpatient medical services for 97% of US citizens who are ≥ 65 years of age.[12,13] We used all available Medicare claims files to identify treatments and costs for patients in the linked SEER registries. All data were deidentified such that no protected health information could be linked to individual patients, and the University of Texas MD Anderson Cancer Center's institutional review board exempted this study.

The study cohort consisted of 202,299 patients ≥ 65 years of age who died as a result of lung, breast, prostate, colorectal, and pancreas cancers between January 1, 2000, and December 31, 2007. These cancers were chosen because they accounted for the top five most common causes of cancer deaths and comprised almost 60% of cancer deaths in 2010.[14] We initially identified 363,160 patients with these causes of death using the SEER cause of death recorded variable, which is based on the International Classification of Diseases ninth and 10th revision (ICD-9 and ICD-10) codes 153.XX, 154.0, 154.1, 154.8, C18-20 (colorectal); 174.XX, C50 (breast); 162.2 to 162.5, 162.8, 162.9, C34.0-C34.3, C34.8, C34.9 (lung); 157.XX, C25 (pancreas); and 185.XX, C61 (prostate). We excluded: 37,310 patients without pathologic confirmation of cancer, 10,839 patients whose cancer was diagnosed at death or autopsy, and 27,575 whose death occurred before age 65. We also excluded 85,137 patients who were not continuously enrolled in Medicare Part A and B, were enrolled with an HMO, or who had no claims data in their Medicare claims file during the 6 months before and throughout the study time period of interest, which was the final 30 days of life.

Dependent Variables

Radiotherapy use was identified using Current Procedural Terminology (CPT) codes 77400 to 77416, 77418, G0174, 0197T, and 77371 to 77373. We estimated the number of radiation treatment days by counting the number of days with one or more claims indicative of the receipt of radiotherapy. We quantified the duration of radiotherapy as a categorical variable to reflect recommended dosing regimens for palliative radiotherapy.[10,15,16] Costs of care were calculated from a payer's perspective (total amount reimbursed by Medicare) and included all costs incurred in the 30-day window before death. Costs were normalized to the 2009 dollar by using the Hospital Input Price Index[17] for Medicare Part A (inpatient services) and the Medicare Economic

Table 2. Multivariate Results of Receipt of Any RT in the Last 30 Days of Life

Variable	Adjusted OR	95% CI	*P*
Year of death			
2000	1.00		
2001	1.00	0.93 to 1.08	.9332
2002	0.97	0.90 to 1.04	.3371
2003	0.91	0.85 to 0.98	.0119
2004	0.90	0.84 to 0.97	.0039
2005	0.83	0.78 to 0.90	< .001
2006	0.85	0.79 to 0.91	< .001
2007	0.84	0.78 to 0.90	< .001
Age, years			
65-69	1.00		
70-74	0.87	0.83 to 0.91	< .001
75-79	0.79	0.75 to 0.83	< .001
≥ 80	0.56	0.54 to 0.59	< .001
Sex			
Female	1.00		
Male	1.12	1.08 to 1.16	< .001
Race/ethnicity			
Non-Hispanic white	1.30	1.21 to 1.39	< .001
Non-Hispanic black	1.00		
Hispanic	1.32	1.18 to 1.47	< .001
Other	1.17	1.05 to 1.30	.0042
Marital status			
Married	1.00		
Unmarried	0.87	0.84 to 0.91	< .001
Unknown	0.79	0.73 to 0.87	< .001
Cancer type			
Breast	0.63	0.59 to 0.67	< .001
Colorectal	0.22	0.21 to 0.24	< .001
Lung	1.00		
Pancreas	0.20	0.18 to 0.22	< .001
Prostate	0.54	0.51 to 0.59	< .001
Comorbidity score			
0	1.00		
1	0.89	0.85 to 0.92	< .001
≥ 2	0.80	0.76 to 0.84	< .001
Unknown	0.67	0.63 to 0.71	< .001
SEER region			
Midwest	1.00		
Northeast	0.90	0.85 to 0.95	< .001
South	1.10	1.04 to 1.17	< .001
West/Hawaii	0.95	0.90 to 1.00	.0394
Urban versus rural residence			
Rural	1.00		
Urban	1.17	1.09 to 1.25	< .001
Median income in census tract			
Lowest quartile	1.00		
Second quartile	1.03	0.98 to 1.09	.2309
Third quartile	1.06	1.00 to 1.12	.0461
Highest quartile	1.12	1.06 to 1.18	< .0002
Unknown	0.83	0.77 to 0.89	< .001
No. of radiation oncologists in HSA/population of HSA			
Lowest quartile (lowest density)	1.00		
Second quartile	1.01	0.91 to 1.11	.9075
Third quartile	1.11	1.02 to 1.21	.0133
Highest quartile (highest density)	1.03	0.95 to 1.12	.4730
Hospice			
No	1.00		
Yes	0.64	0.62 to 0.67	< .001

(continued in next column)

Table 2. Multivariate Results of Receipt of Any RT in the Last 30 Days of Life (continued)

NOTE. Independent variables were included in a stepwise model with criteria of $P < .05$ for significance for entrance into the model. Educational level did not reach significance in the adjusted model and thus is not shown here.

Abbreviations: HSA, health service area; OR, odds ratio; RT, radiation therapy.

Index[18] for Medicare Part B (outpatient services). Costs were also adjusted for geographic variation by using the geographic adjustment factor for Part A claims and the geographic practice index for Part B claims.

Independent Variables

Independent variables in our analyses included year of death (2000-2007), age at death, sex, race/ethnicity, cancer type, marital status, SEER geographic region, and urban versus rural residence. We linked the SEER-Medicare database to the Area Resource File[19] via state and county codes to ascertain the number of radiation oncologists (per 100,000) practicing within each patient's health service area. Neighborhood education and income variables were measured at the census tract level (categorized in quartiles). Comorbidity was constructed by using Klabunde's algorithm; this algorithm calculates a modified Charlson comorbidity score[20] on the basis of inpatient and outpatient claims within a 12-month window before cancer diagnosis.[21-23] Because cancer diagnoses occurred many years antecedent to death for some patients, those with missing data were designated Charlson status "unknown" to avoid excluding a large number of patients from the analysis, which may limit interpretation of this variable. Hospice care was identified as any hospice admission and/or service date in the hospice claims file during the last 30 days of life.

We limited analyses of the duration of radiotherapy to the subset of patients who received radiotherapy at the end of life. In addition to the independent variables above, we added type of radiotherapy facility to these analyses because reimbursement for providers can be higher in freestanding facilities compared with hospital-associated centers, as providers in freestanding facilities can potentially receive both technical and professional fees for services provided. Using an algorithm developed by other investigators,[24] we considered that patients had their radiotherapy at a hospital-associated facility if their claims for radiotherapy were only present in the outpatient claims files. Those whose radiotherapy claims were present in the carrier claims file were considered to have had their treatments in a freestanding facility.

Statistical Analyses

Statistical analyses were conducted with the SAS Systems software for Windows (Version 9.2) and STATA (version 12.0). The unadjusted association of each potential explanatory variable with the outcome of radiation treatment in the last 30 days of life was assessed with χ^2 tests for binary and categorical variables. We performed a Cochran-Armitage test for trend to assess change in the proportion of patients who received radiotherapy in the last 30 days of life from 2000 to 2007. Logistic regression models were used to examine the independent association between each explanatory variable and the use of radiotherapy as well as the intensity of radiotherapy use. Final results are presented as odds ratios with 95% confidence intervals. Cost data were analyzed with the extended estimating equations method.[25]

RESULTS

Receipt of Radiation Therapy in the Last 30 Days of Life

Of the 202,299 patients included in this study, 15,287 (7.6%) received radiotherapy in the last 30 days of life. Characteristics of the

Table 3. Univariate Analysis of Length of Treatment Course in Last 30 Days of Life

Characteristic	No.	% With RT Course of Specified Duration				*P*
		1 Day	2-5 Days	6-10 Days	≥ 11 Days	
Total	15,287	9.5	36.8	35.9	17.8	
Year of death						
2000-2003	7,555	9.3	36.1	36.2	18.5	.074
2004-2007	7,732	9.8	37.5	35.6	17.2	
Age at death, years						
65-69	3,430	9.2	36.2	36.9	17.7	.466
70-74	3,981	9.3	37.1	36.3	17.3	
75-79	3,963	9.3	36.5	35.8	18.5	
≥ 80	3,913	10.4	37.2	34.7	17.8	
Sex						
Male	8,642	9.6	36.6	35.9	18.0	.903
Female	6,645	9.5	37.1	35.9	17.6	
Race/ethnicity						
Non-Hispanic white	12,926	9.4	36.4	36.3	18.0	.135
Non-Hispanic black	1,135	10.8	40.1	33.3	15.9	
Hispanic	589	10.5	38.4	34.3	16.8	
Other	637	10.1	37.4	34.9	17.7	
Marital status						
Married	8,647	9.5	36.2	36.2	18.1	.720
Unmarried	6,054	9.5	37.6	35.4	17.5	
Unknown	586	9.7	37.0	36.0	17.2	
Cancer type/cause of death						
Breast	1,206	12.1	36.7	36.7	14.6	< .001
Colorectal	960	9.2	32.2	35.3	23.3	
Lung	11,609	9.0	37.0	36.0	18.0	
Pancreas	447	10.7	39.4	29.5	20.4	
Prostate	1,065	12.0	37.8	36.8	13.3	
Comorbidity score						
0	6,148	8.9	36.4	36.6	18.2	< .001
1	4,310	9.5	35.7	36.2	18.7	
≥ 2	3,453	9.7	39.1	34.2	17.1	
Unknown	1,376	12.1	36.1	36.6	15.3	
SEER region						
West/Hawaii	6,199	9.7	36.2	35.4	18.8	.039
Midwest	2,632	8.8	36.3	36.7	18.3	
Northeast	3,202	9.8	38.0	36.5	15.7	
South	3,254	9.6	37.2	35.6	17.7	
Urban/rural residence						
Urban	13,800	9.5	37.0	35.8	17.7	.458
Rural	1,486	9.7	34.5	37.2	18.7	
Neighborhood income						
Lowest quartile	3,365	9.1	37.8	35.1	18.0	.055
Second quartile	3,458	9.5	36.4	35.7	18.3	
Third quartile	3,473	9.2	36.0	35.8	19.1	
Highest quartile	3,488	9.6	36.4	37.1	16.9	
Unknown	1,503	11.2	37.9	35.5	15.4	
Neighborhood % < 12 years education						
Lowest quartile	3,486	9.5	37.1	36.8	16.7	.798
Second quartile	3,660	10.0	35.8	36.1	18.2	
Third quartile	3,701	9.3	37.2	35.2	18.3	
Highest quartile	3,700	9.4	37.2	35.5	17.9	
Unknown	740	9.5	35.4	37.0	18.1	
Radiation oncologist density						
Lowest quartile	880	8.2	36.8	35.7	19.3	.658
Second quartile	1,065	9.6	34.5	37.8	18.2	
Third quartile	4,878	9.3	37.4	35.4	17.9	
Highest quartile	8,463	9.8	36.7	36.0	17.6	

(continued on following page)

Table 3. Univariate Analysis of Length of Treatment Course in Last 30 Days of Life (continued)

Characteristic	No.	% With RT Course of Specified Duration				P
		1 Day	2-5 Days	6-10 Days	≥ 11 Days	
Type of RT facility						
Hospital associated	9,975	9.9	37.6	36.2	16.3	< .001
Freestanding	5,312	8.9	35.2	35.3	20.6	
Hospice						
No	8,007	8.8	34.0	35.1	22.1	< .001
Yes	7,280	10.3	39.9	36.7	13.1	

Abbrevation: RT, radiation therapy.

entire cohort and the univariate analyses are shown in Table 1. There was a decrease in the proportion of patients who received radiotherapy from 2000 to 2007 ($P < .001$). There was a higher proportion of patients who elected hospice care in later years, with 51% of patients electing hospice in the years from 2004 to 2007 compared with 44% electing hospice care in the earlier period of 2000 to 2003 ($P < .001$). Multivariate analysis (Table 2) revealed that, after adjusting for other characteristics, the likelihood of receiving radiotherapy was significantly greater with the following: earlier year of death; lung cancer cause of death; younger age; male sex; non-Hispanic white, Hispanic, or other race (versus non-Hispanic black); married status; Charlson comorbidity index of 0; southern SEER region; urban residence; neighborhood income level in the highest quartiles; and no receipt of hospice care.

Days of Treatment Among Those Who Received Radiotherapy in the Last 30 Days of Life

Table 3 shows the length of the radiation treatment course in days for patients who received radiotherapy in the last 30 days of life as categorized by typical palliative treatment course lengths[15] for various characteristics. Of the patients who received radiotherapy, 2,734 (17.8%) received > 10 days of treatment, and more than half (53.7%) of patients received > 5 days of treatment. Treatment-related characteristics that were significantly associated with a higher proportion of patients receiving > 10 days of radiotherapy included treatment at a freestanding radiation facility and absence of hospice care. Multivariate analysis confirmed that these factors remained significant when adjusting for other characteristics (Table 4) and showed that non-Hispanic white patients were also more likely to receive > 10 days of radiotherapy. In this model, we analyzed the influence of sequencing of hospice and radiotherapy on receipt of > 10 days of radiotherapy. Of those who enrolled in hospice and received radiotherapy, 97% completed their radiotherapy before hospice enrollment. Patients who received hospice care were less likely to receive > 10 days of radiotherapy, and this was true whether the patient enrolled in hospice care before or after radiotherapy was completed.

Resource Use and Costs of Care Analyses

The proportion of patients who were admitted to the hospital during the last 30 days of life was higher among those who received radiotherapy (71% *v* 49%, $P < .001$) compared with those who did not received radiation therapy, as was the proportion with an intensive care unit stay (17% *v* 14%, $P < .001$). Among those, 32% were hospitalized before the initiation of radiotherapy, and 68% were hospitalized after radiotherapy began ($P < .001$). A higher proportion of patients who received radiotherapy had an emergency room (ER) visit in the last 30 days of life (55% *v* 37%, $P < .001$). Among those, 24% had their ER visit before the initiation of radiotherapy, and 76% initiated radiotherapy before any ER visit. The mean length of stay (LOS) as an inpatient, defined as any date with a claim for ER visit, hospitalization, or intensive care unit, was longer for patients who received radiotherapy (7.2 days; 95% CI, 7.1 to 7.4 days) than for those who did not receive radiotherapy (5.3 days; 95% CI, 5.2 to 5.3 days). The adjusted mean total costs of care in the last 30 days of life (Table 5) were higher among those who received radiotherapy and was highest among the group of patients who received radiotherapy but no hospice care. Notably, among those who received radiotherapy in the last

Table 4. Multivariate Analysis of Receipt of > 10 days of RT in the Last 30 Days of Life

Variable	Adjusted OR	95% CI	P
Race/ethnicity			
Non-Hispanic white	1.22	1.03 to 1.44	.0220
Non-Hispanic black	1.00		
Hispanic	1.03	0.78 to 1.36	.8209
Other	1.02	0.78 to 1.34	.8762
Cancer cause of death			
Breast	0.82	0.69 to 0.97	.0182
Colorectal	1.43	1.22 to 1.68	< .001
Lung	1.00		
Pancreas	1.24	0.97 to 1.57	.0824
Prostate	0.72	0.60 to 0.87	< .001
SEER region			
Midwest	1.00		
Northeast	0.79	0.69 to 0.91	.0013
South	0.89	0.78 to 1.02	.1032
West/Hawaii	0.98	0.87 to 1.11	.7478
Type of RT facility			
Hospital associated		1.00	
Free standing	1.31	1.20 to 1.43	< .001
Hospice			
No	1.00		
Hospice before RT completion	0.40	0.25 to 0.64	< .001
RT completion before hospice	0.53	0.48 to 0.58	< .001

Independent variables were included in a stepwise model with criteria of $P < .05$ for significance for entrance into the model. Variables tested but not significant included year of treatment, age, comorbidity, sex, marital status, urban/rural residence, income, educational level, and radiation oncologist density.

Abreviations: OR, odds ratio; RT, radiation therapy.

Table 5. Cost and Length of Stay for Inpatient Care, Comparison Between RT and No-RT Cohort (N = 202,299)

Model	Radiation	Hospice		Mean	Cost Difference (ref-covariable)			
					Unadjusted		Adjusted*	
					Difference	95% CI	Difference	95% CI
Total cost (CMS pay)†	Yes	Yes		$12,822	−$3,594	−$4,002 to −$3185	$787	$591 to $984
	Yes	No		$18,898	$2,483	$2,092 to $2874	$3,453	$3,176 to $3,730
	No	Yes		$8,333	−$8,082	−$8,239 to −$7,925	−$2675	−$2,811 to −$2,538
	No	No	(Ref.)	$16,416				
LOS, days‡	Yes	Yes		5.03	−3.58	−3.80 to −3.35	−2.49	−2.63 to −2.36
	Yes	No		9.25	0.65	0.43 to 0.86	0.63	0.47 to 0.80
	No	Yes		3.00	−5.61	−5.69 to −5.52	−5.06	−5.15 to −4.98
	No	No	(Ref.)	8.61				

NOTE. Independent variables included: age at death, sex, ethnicity, SEER region, rural/urban, income, Charlson omorbidity index, radiation oncologist density, hospice, radiation, cause of death, and interaction of radiation use and hospice. Goodness-of-fit: $P = .2985$ for cost model and $P = .8696$ for LOS model.
Abbreviations: CMS, Centers for Medicare & Medicaid Services; LOS, length of stay; Ref., reference; RT, radiation therapy.
*Estimates derived based on extended generalized linear model.[25]
†CMS reimbursements were adjusted by using 2009 adjusters.
‡LOS includes all emergency room, hospital, and intensive care unit days.

month of life, hospice care was associated with a 32% decrease in mean total cost of care (Table 5), and this decrease was similar whether patients received radiotherapy before hospice care or after enrollment in hospice care (Table 6).

DISCUSSION

This investigation offers the first US population–based assessment of the use of radiotherapy in the end-of-life setting. The proportion of patients who received radiotherapy in the last 30 days of life overall was low; however, the receipt of radiotherapy varied by multiple nonclinical factors. We observed that almost one in five of patients who received radiotherapy in the final 30 days of life spent more than 10 of those days receiving radiotherapy. The costs of care were significantly higher for patients who received radiotherapy in the last 30 days of life compared with those who did not. Election of Medicare's hospice benefit was associated with significantly fewer days of radiation treatment and lower costs of care among those who received radiotherapy in the final month of life.

Our finding of a low proportion of patients receiving radiotherapy may suggest underutilization of this palliative modality in end-of-life cancer care. Lutz et al[5] found that 3% of patients in hospice care received radiotherapy. We found a decreasing use of radiotherapy in the last 30 days of life from 2000 to 2007, which corresponded to an increasing trend in hospice enrollment. Explanation for variation in use of radiotherapy by nonclinical variables is beyond the scope of these data. However, our findings may reflect barriers to access to palliative radiotherapy among some groups of patients, such as black patients, who have been shown to have significantly lower rates of receiving recommended cancer therapies than white patients.[26,27] Other investigators have also identified that receipt of palliative radiotherapy varies by nonclinical factors such as sex, household income, nursing home residence, and travel time to a treatment facility.[28,29] Our finding of geographic variation in radiotherapy use is consistent

Table 6. Cost Model for Those Receiving Radiation Therapy in the Last 30 Days of Life (N = 15,287)

Treatment sequence	Mean Cost	Unadjusted		Adjusted	
		Difference	95% CI	Difference	95% CI
RT/hospice sequence					
No hospice (Ref.)	$18,898				
Hospice before RT completion	$10,461	−$8,437	−$10,402 to −$6472	−$1,817	−$3,187 to −$447
RT completion before hospice	$12,885	−$6,013	−$6,449 to −$5,578	−$2,011	−$2,352 to −$1,671
RT/ER sequence					
No ER (Ref.)	$12,104				
ER visit before RT initiation	$23,370	$11,266	$10,606 to $11,925	$2,617	$2,021 to $3,213
RT initiation before ER visit	$17,889	$5,784	$5,332 to $6,237	$1,774	$1,292 to $2,255
RT/hospitalization sequence					
No hospitalization (Ref.)	$5443				
Hospitalization before RT initiation	$23,721	$18,278	$17,772 to $18,784	$82,678	−$52,268 to $217,624
RT initiation before hospitalization	$18,586	$13,143	$12,718 to $13,568	$44,397	−$57,829 to $146,623

NOTE. (1) CMS reimbursements were adjusted by using 2009 adjusters. (2) Estimates was derived on the basis of extended generalized linear model.[25] (3) Other independent variables included: age at death, sex, ethnicity, SEER region, rural/urban, income, Charlson comorbidity index, and radiation oncologist density. (4) Goodness-of-fit: $P = .9314$.
Abbreviations: CMS, Centers for Medicare & Medicaid Services; ER, emergency room; Ref., reference; RT, radiation therapy.

with other studies' showing that use of radiotherapy in various clinical scenarios varied with SEER geographic location.[26,30]

It is beyond the scope of this study to determine whether the percentage of patients who received > 10 days of radiotherapy treatment is appropriate. Kapadia et al[31] also showed that 17% of patients with lung cancer who received radiotherapy within 14 days of death received > 10 treatments. Gripp et al determined that radiation dosing schedules resulting in > 10 treatments (2-3 Gy per fraction) for patients at the end of life represented poorly tailored end-of-life care.[6] The American Society for Radiation Oncology (ASTRO) has issued evidence-based guidelines establishing that treatment courses of one, five, six, or 10 treatments all provide adequate and equivalent symptom control with minimal toxicity in the palliative setting for bone metastases, and that more than 10 fractions of radiotherapy unlikely provide any additional benefit.[15] For palliation of brain metastases, a typical course of palliative whole-brain radiotherapy is [lte] 10 treatments,[10] and courses of ≥ 10 treatments have been determined to offer no greater clinical benefit than shorter courses for palliation of spinal cord compression among patients with limited life expectancy.[16] Similar guidelines for palliation of thoracic lesions support use of regimens of 10 fractions or fewer for patients with limited life expectancy.[32,33] Quality indicators reflecting these recommended palliative radiation dosing schedules could be derived from these guidelines, which would offer metrics for future study of palliative radiotherapy practice. Future administrative data research efforts could be aided by incorporation of diagnosis and claims codes that specifically included codes for anatomic sites of metastases as well as palliative radiotherapy procedures (eg, whole-brain radiation therapy) in the International Classification of Disease-10 and Common Procedural Terminology code repertoires. A combination of clear quality indicator metrics and specific codes for metastatic cancer sites and palliative procedures would allow clearer tracking of patterns of care and opportunities for radiation oncology care improvement.

We found that the costs of care for patients who received radiotherapy at the end of life were higher than for those patients who did not. Any debate about the costs of radiotherapy at the end of life must include acknowledgment of the palliative benefits to patients, such as decreased pain or improved neurologic functioning potentially offered through a course of conventional short-course radiotherapy. Also, increased costs could be due to complications of cancer that resulted in hospitalizations and need for radiotherapy, rather than radiotherapy itself.

Hospice care was associated not only with a decreased use of radiotherapy, but also with a decrease in the number of radiation treatment days a patient was likely to undergo. There are few studies specifically exploring the relationship between hospice participation and receipt of radiotherapy, but Lutz et al[5] did note that the cost of even a single fraction of radiotherapy outpaces the capitated daily amount reimbursed by Medicare for patients who elect the hospice benefit, thus serving as a disincentive to use radiotherapy after hospice care election.[5] Our analysis showing a 32% reduction in costs among those who received radiotherapy while on hospice care is commensurate with previously noted cost decreases of 25% to 40% associated with hospice in the last month of life.[34]

Chief among the inherent limitations of our claims-based study is that we were unable to obtain information regarding the reason or intent of radiotherapy (ie, whether the intent was palliative *v* curative). However, by restricting the study window to 30 days before death as a result of cancer, we assumed that the vast majority of patients were treated with palliative intent, reflecting a similar cohort definition strategy as that of other researchers who examined chemotherapy use at the end of life.[3] Although it is possible that some patients had disease and performance status such that they were treated with curative intent and subsequently died while being treated aggressively for their cancer, it is rare for patients to die as a result of or during definitive radiotherapy. In fact, for some cancers, medically inoperable cases are referred for definitive radiotherapy because of the negligible short-term mortality risks associated with radiotherapy.[35] Thus, the proportion of patients who were not treated with palliative intent was likely small and of negligible impact on the results. We are also unable to obtain radiation dose information nor accurately determine receipt of multiple sequential radiotherapy courses from these data, thus limiting our ability to interpret the appropriateness of the number of days of treatment.

Radiotherapy can provide needed palliation for patients with advanced cancer. It is possible, on the basis of overall low percentage of patients who received radiotherapy in the last 30 days of life, that there is underuse of this modality in end-stage cancer care. However, dosing regimens that require dying patients to spend a significant proportion of their final days visiting a radiation therapy suite likely counters the overall aim of palliative care. Recently published guidelines[15] regarding dosing for palliative regimens may facilitate concordance between the number of radiation treatments patients receive in their final days and the number they need for effective palliation, and this deserves further study. The use of hospice significantly influenced use and costs of radiotherapy in our study. This may be related to the capitated nature of hospice care reimbursement and its role as a disincentive for intensive and costly treatments at the end of life. Further research is needed into quality of care, physician incentives, and costs for radiotherapy in end-of-life cancer care.

AUTHORS' DISCLOSURES OF POTENTIAL CONFLICTS OF INTEREST

Although all authors completed the disclosure declaration, the following author(s) and/or an author's immediate family member(s) indicated a financial or other interest that is relevant to the subject matter under consideration in this article. Certain relationships marked with a "U" are those for which no compensation was received; those relationships marked with a "C" were compensated. For a detailed description of the disclosure categories, or for more information about ASCO's conflict of interest policy, please refer to the Author Disclosure Declaration and the Disclosures of Potential Conflicts of Interest section in Information for Contributors.
Employment or Leadership Position: None **Consultant or Advisory Role:** None **Stock Ownership:** None **Honoraria:** None **Research Funding:** Linda Elting, Helsinn **Expert Testimony:** None **Other Remuneration:** None

AUTHOR CONTRIBUTIONS

Conception and design: B. Ashleigh Guadagnolo, Ya-Chen Tina Shih
Financial support: Thomas A. Buchholz
Administrative support: B. Ashleigh Guadagnolo, Thomas A. Buchholz
Provision of study materials or patients: Sharon Giordano, Thomas A. Buchholz
Collection and assembly of data: B. Ashleigh Guadagnolo, Kai-Ping Liao
Data analysis and interpretation: All authors
Manuscript writing: All authors
Final approval of manuscript: All authors

REFERENCES

1. Earle CC, Park ER, Lai B, et al: Identifying potential indicators of the quality of end-of-life cancer care from administrative data. J Clin Oncol 21:1133-1138, 2003

2. Earle CC, Landrum MB, Souza JM, et al: Aggressiveness of cancer care near the end of life: Is it a quality-of-care issue? J Clin Oncol 26:3860-3866, 2008

3. Earle CC, Neville BA, Landrum MB, et al: Evaluating claims-based indicators of the intensity of end-of-life cancer care. Int J Qual Health Care 17: 505-509, 2005

4. Earle CC, Neville BA, Landrum MB, et al: Trends in the aggressiveness of cancer care near the end of life. J Clin Oncol 22:315-321, 2004

5. Lutz S, Spence C, Chow E, et al: Survey on use of palliative radiotherapy in hospice care. J Clin Oncol 22:3581-3586, 2004

6. Gripp S, Mjartan S, Boelke E, et al: Palliative radiotherapy tailored to life expectancy in end-stage cancer patients: Reality or myth? Cancer 116:3251-3256, 2010

7. Hartsell WF, Scott CB, Bruner DW, et al: Randomized trial of short- versus long-course radiotherapy for palliation of painful bone metastases. J Natl Cancer Inst 97:798-804, 2005

8. Chow E, Harris K, Fan G, et al: Palliative radiotherapy trials for bone metastases: A systematic review. J Clin Oncol 25:1423-1436, 2007

9. Rades D, Dahm-Daphi J, Rudat V, et al: Is short-course radiotherapy with high doses per fraction the appropriate regimen for metastatic spinal cord compression in colorectal cancer patients? Strahlenther Onkol 182:708-712, 2006

10. Rades D, Lohynska R, Veninga T, al: Evaluation of 2 whole-brain radiotherapy schedules and prognostic factors for brain metastases in breast cancer patients. Cancer 110:2587-2592, 2007

11. National Cancer Institute: Surveillance Epidemiology and End Results. http://seer.cancer.gov/index.html

12. Potosky AL, Riley GF, Lubitz JD, et al: Potential for cancer related health services research using a linked Medicare-tumor registry database. Med Care 31:732-748, 1993

13. Warren JL, Klabunde CN, Schrag D, et al: Overview of the SEER-Medicare data: Content, research applications, and generalizability to the United States elderly population. Med Care 40:IV-3-18, 2002 (suppl)

14. Jemal A, Siegel R, Xu J, et al: Cancer statistics, 2010. CA Cancer J Clin 60:277-300

15. Lutz S, Berk L, Chang E, et al: Palliative radiotherapy for bone metastases: An ASTRO evidence-based guideline. Int J Radiat Oncol Biol Phys 79:965-976, 2011

16. Prewett S, Venkitaraman R: Metastatic spinal cord compression: Review of the evidence for a radiotherapy dose fractionation schedule. Clin Oncol 22:222-230, 2010

17. Centers for Medicare & Medicaid Services: Quarterly index levels in the CMS Prospective Payment System (IPPS) hospital 2006 input price index using IHS Global Insight Inc. (IGI) forecast assumptions, by expense category: 1996-2021. https://www.cms.gov/MedicareProgramRatesStats/downloads/mktbskt-pps-hospital-2006.pdf

18. Centers for Medicare & Medicaid Services: Quarterly Index Levels in the CMS Medicare Economic Index using IHS Global Insight Inc. (IGI) Forecast Assumptions, by Expense Category: 1996-2021 https://www.cms.gov/MedicareProgramRatesStats/downloads/mktbskt-economic-index.pdf

19. US Department of Health and Human Services, Health Resources and Services Administration, Bureau of Health Professions: Area Resource File (ARF), 2009-2010. www.arf.hrsa.gov

20. Charlson ME, Pompei P, Ales KL, et al: A new method of classifying prognostic comorbidity in longitudinal studies: Development and validation. J Chronic Dis 40:373-383, 1987

21. Klabunde CN, Potosky AL, Legler JM, et al: Development of a comorbidity index using physician claims data. J Clin Epidemiol 53:1258-1267, 2000

22. Klabunde CN, Harlan LC, Warren JL: Data sources for measuring comorbidity: A comparison of hospital records and Medicare claims for cancer patients. Med Care 44:921-928, 2006

23. Klabunde CN, Legler JM, Warren JL, et al: A refined comorbidity measurement algorithm for claims-based studies of breast, prostate, colorectal, and lung cancer patients. Ann Epidemiol 17:584-590, 2007

24. Smith BD, Pan IW, Shih YC, et al: Adoption of intensity-modulated radiation therapy for breast cancer in the United States. J Natl Cancer Inst 103:798-809, 2011

25. Basu A, Rathouz PJ: Estimating marginal and incremental effects on health outcomes using flexible link and variance function models. Biostatistics 6:93-109, 2005

26. Tuttle TM, Jarosek S, Habermann EB, et al: Omission of radiation therapy after breast-conserving surgery in the United States: A population-based analysis of clinicopathologic factors. Cancer, 2011 http://www.ncbi.nlm.nih.gov/pubmed/21952948

27. Steele CB, Pisu M, Richardson LC: Urban/rural patterns in receipt of treatment for non-small cell lung cancer among black and white Medicare beneficiaries, 2000-2003. J Natl Med Assoc 103: 711-718, 2011

28. Johnston GM, Boyd CJ, Joseph P, et al: Variation in delivery of palliative radiotherapy to persons dying of cancer in Nova Scotia, 1994 to 1998. J Clin Oncol 19:3323-3332, 2001

29. Lavergne MR, Johnston GM, Gao J, et al: Variation in the use of palliative radiotherapy at end of life: Examining demographic, clinical, health service, and geographic factors in a population-based study. Palliat Med 25:101-110, 2011

30. Guadagnolo BA, Liu CC, Cormier JN, et al: Evaluation of trends in the use of intensity-modulated radiotherapy for head and neck cancer from 2000 through 2005: Socioeconomic disparity and geographic variation in a large population-based cohort. Cancer 116:3505-3512, 2010

31. Kapadia NS, Mamet R, Zornosa C, et al: Radiation therapy at the end of life in patients with incurable nonsmall cell lung cancer. Cancer 118: 4339-4345, 2012

32. Rodrigues G, Videtic GMM, Sur R, et al: Palliative thoracic radiotherapy in lung cancer: An American Society for Radiation Oncology evidence-based clinical practice guideline. Pract Radiat Oncol 1:60-71, 2011

33. Rodrigues G, Macbeth F, Burmeister B, et al: Consensus statement on palliative lung radiotherapy: Third International Consensus Workshop on Palliative Radiotherapy and Symptom Control. Clin Lung Cancer 13:1-5, 2012

34. Emanuel EJ: Cost savings at the end of life. What do the data show? JAMA 275:1907-1914, 1996

35. Das M, Abdelmaksoud MH, Loo BW Jr, et al: Alternatives to surgery for early stage non-small cell lung cancer-ready for prime time? Curr Treat Options Oncol 11:24-35, 2010