Radiotherapy Remains Underused in the Treatment of Soft-Tissue Sarcomas: Disparities in Practice Patterns in the United States

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ABSTRACT

Background: Practice patterns of radiation therapy (RT) use for soft-tissue sarcoma (STS) remain quite variable, despite clinical practice guidelines recommending the addition of RT to surgery for patients with high-grade STS, particularly for larger tumors. Using the National Cancer Database (NCDB), we assessed patterns of overall RT use, neoadjuvant versus adjuvant treatment, and specific RT modalities in this population. **Patients and Methods:** Patients aged ≥ 18 years with stage II/III STS in 2004 through 2015 were identified from the NCDB. Patterns of care were assessed using multivariable logistic regression analysis. **Results:** Of 27,426 total patients, 11,654 (42%) were treated with surgery alone versus 15,772 (58%) with RT in addition to surgery, with no overall increase in RT use over the study period. Notable clinical predictors of receipt of RT included tumor size (>5 cm), grade III, and tumors arising in the extremities. Conversely, female sex, older age (≥ 70 years), Black race, noncommercial insurance coverage, farther distance to treatment, and poor performance status were negative predictors of RT use. Of those receiving RT, 27% were treated with neoadjuvant RT and 73% with adjuvant RT. The proportion of those receiving neoadjuvant RT increased over time. Relevant factors associated with neoadjuvant RT included treatment at academic centers, larger tumor size, and extremity tumors. Of those who received RT with a modality specified as either intensity-modulated RT (IMRT) or 3D conformal RT (3DCRT), 61% were treated with IMRT and 39% with 3DCRT. The proportion of patients treated with IMRT increased over time. Relevant factors associated with IMRT use included treatment at academic centers, commercial insurance coverage, and larger and nonextremity tumors. **Conclusions:** Although use of neoadjuvant RT and IMRT has increased over time, a significant number of patients with STS are not receiving adjuvant or neoadjuvant RT. Our findings also note potential sociodemographic disparities and highlight the concern that not all patients with STS are being equally considered for RT.

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Background

Soft-tissue sarcomas (STS) constitute approximately 1% of all cancers diagnosed yearly in the United States and are a heterogeneous group of mesenchymal malignancies.¹ Their management is best achieved with multidisciplinary care involving surgery, radiation oncology, medical oncology, radiology, and pathology.² NCCN Clinical Practice Guidelines in Oncology (NCCN Guidelines) for STS recommend the addition of neoadjuvant or adjuvant radiation therapy (RT) to surgery for patients with high-grade STS,² particularly for larger tumors, given that randomized data have shown improvement in local control with the addition of RT.^{3–5} In addition, studies have shown that neoadjuvant RT may offer select benefits for patients with extremity STS treated with RT, including smaller treatment volume and lower dose, which translate to a lower risk of late radiation-induced complications, such as edema, fibrosis, and joint stiffness. However, neoadjuvant RT is associated with a higher risk of acute wound complications compared with adjuvant RT.⁶ Moreover, recent data have noted potential benefits in the use of intensity-modulated RT (IMRT).^{7,8} Yet, despite the benefits of RT in the management of high-grade sarcomas, there appears to be significant heterogeneity in its use, in addition to concern among providers regarding its potential underuse.^{9–11} The aim of this study was to better understand the patterns of multidisciplinary care and to quantify variations in practice, perioperative timing, and modality with respect to RT use in the management of patients with stage II/III STS using the National Cancer Database (NCDB).

Patients and Methods

Data Source

The study population was identified from the NCDB, a national cancer registry jointly sponsored by the American College of Surgeons and the American Cancer Society

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that draws on hospital registry data from >1,500 Commission on Cancer–accredited facilities in the United States.^{12,13} The dataset captures >70% of incident cancers and comprises >34 million unique cancer cases.^{12,13} Data are collected prospectively from Commission on Cancer–accredited program cancer registries with nationally standardized data-coding definitions.

Study Population

Inclusion criteria (see supplemental eFigure 1, available with this article at JNCCN.org) for the cohort consisted of patients aged ≥ 18 years with high-grade (stage II or III), nonmetastatic, nonretroperitoneal STS treated with surgery with or without perioperative RT (not including brachytherapy) in 2004 through 2015. Patients who underwent amputation were excluded because RT would not be indicated. Patients with STS arising in the head, neck, extremities, thorax, trunk, abdomen, and pelvis and those with the following common adult STS histologies were included: undifferentiated or unclassified histology, undifferentiated pleomorphic sarcoma, liposarcoma, leiomyosarcoma, fibrosarcoma/myxofibrosarcoma, synovial sarcoma, angiosarcoma, and malignant peripheral nerve sheath tumor.

Patient Cohorts and Variables

Covariates examined included age; sex; race/ethnicity; facility area (classified as metropolitan, urban, or rural based on data published by the US Department of Agriculture Economic Research Service); insurance; education level (defined as percentage of population in patient's zip code without a high school degree, which is derived from the US Census data); income level (defined as median income in patient's zip code); facility geographic location; facility type (nonacademic or academic, with "academic" referring to academic/research programs including NCI-designated Comprehensive Cancer Centers); distance to treatment facility (calculated as distance between patient's zip code center and hospital street address); Charlson-Deyo comorbidity index score¹⁴; primary tumor site; tumor histology, grade, and size; receipt of chemotherapy; and year of diagnosis.

Statistical Analysis

Baseline characteristics of the study cohorts were compared using Pearson's chi-square tests. Covariates achieving a threshold significance of $P < .1$ in univariate analysis were included in the multivariable logistic regression model. A multivariable logistic regression model was constructed using all baseline covariates to assess the independent effect of each covariate on the odds of being treated with RT, receiving neoadjuvant versus adjuvant RT, or receiving IMRT versus 3D conformal RT (3DCRT). A 2-tailed P value $< .05$ was considered statistically significant.

Statistical analyses were performed using Stata/SE, version 15.0 (StataCorp LLP).

Results

Baseline Clinical Characteristics

A total of 27,426 patients met the study inclusion criteria. Complete patient characteristics are shown in supplemental eTable 1. Notably, the median age of the patient cohort was 63 years (range, 18–90 years). Most patients were men (54%), of non-Hispanic White race/ethnicity (80%), and without significant comorbid illness (81%). It was less common for patients to receive treatment at a nonacademic facility (42%) and at a facility >40 miles from their residence (26%). In terms of disease characteristics, most patients had tumors arising in the extremities (58%), grade III disease (77%), and tumor size >5 cm (64%).

Overall, 58% of patients received RT. Of those with larger tumors (>5 cm), 62% were treated with perioperative RT. Of those who received RT, most received RT adjuvantly (73%) rather than neoadjuvantly (27%). Of those who received RT with modality specified as IMRT or 3DCRT, more were treated with IMRT (61%) than with 3DCRT (39%) (supplemental eFigure 1).

Factors Associated With Receipt of RT

Use of RT did not increase between 2004 and 2015 (Figure 1). Multivariable analysis revealed that sociodemographic factors associated with omission of RT were Black race, female sex, older age, noncommercial insurance coverage, and farther distance from treatment site. Notable clinical factors associated with decreased RT use were nonextremity tumors, smaller tumors (≤ 5 cm), lower-grade tumors (grade II vs III), and higher comorbidity score (Table 1). When specifically evaluating patients with larger tumors (>5 cm) (supplemental eTable 2) or abdominal/pelvic tumors (supplemental eTable 3), we found that similar demographic and clinical factors were associated with RT use.

Figure 1. Trends in receipt of surgery alone or surgery in addition to perioperative RT.

Abbreviation: RT, radiation therapy.

Table 1. Factors Associated With Receipt of Radiotherapy

Factor	Univariate Analysis		Multivariate Analysis	
	OR (95% CI)	P Value	OR (95% CI)	P Value
Age				
<70 y	Ref		Ref	
≥70 y	0.85 (0.81–0.90)	<.001	0.88 (0.82–0.94)	<.001
Sex				
Male	Ref		Ref	
Female	0.81 (0.78–0.86)	<.001	0.83 (0.79–0.88)	<.001
Race/Ethnicity				
Non-Hispanic White	Ref		Ref	
Non-Hispanic Black	0.90 (0.83–0.98)	.017	0.87 (0.80–0.96)	.004
Hispanic	0.90 (0.82–0.99)	.045	0.90 (0.80–1.01)	.063
Other	0.95 (0.85–1.06)	.371	0.93 (0.83–1.05)	.251
Facility area				
Metropolitan	Ref		—	—
Urban	1.03 (0.96–1.11)	.383	—	—
Rural	1.08 (0.89–1.31)	.437	—	—
Unknown	1.01 (0.88–1.15)	.935	—	—
Facility location				
East	Ref		Ref	
South	1.03 (0.96–1.11)	.339	1.08 (1.00–1.17)	.057
Central	1.26 (1.17–1.36)	<.001	1.36 (1.25–1.47)	<.001
West	1.10 (1.01–1.19)	.022	1.12 (1.03–1.22)	.011
Unknown	1.02 (0.94–1.11)	.645	0.91 (0.81–1.01)	.089
Facility type				
Nonacademic	Ref		Ref	
Academic	1.03 (0.98–1.09)	.216	1.01 (0.95–1.07)	.784
Insurance				
Commercial	Ref		Ref	
Medicare	0.82 (0.78–0.87)	<.001	0.89 (0.83–0.96)	.001
Medicaid	0.87 (0.78–0.97)	.013	0.91 (0.81–1.02)	.100
Uninsured	0.76 (0.66–0.87)	<.001	0.76 (0.66–0.88)	<.001
Other	0.97 (0.84–1.11)	.627	0.98 (0.85–1.14)	.829
Distance to treatment facility				
≤40 miles	Ref		Ref	
>40 miles	0.85 (0.80–0.90)	<.001	0.75 (0.70–0.79)	<.001
Unknown/Missing	0.76 (0.60–0.95)	.018	1.26 (0.53–2.98)	.601
Zip code education level				
≥21%	Ref		Ref	
13%–20.9%	1.03 (0.95–1.12)	.445	1.03 (0.94–1.12)	.561
7%–12.9%	1.05 (0.97–1.13)	.233	1.00 (0.91–1.10)	.954
<7%	1.07 (0.99–1.15)	.108	1.00 (0.90–1.12)	.961
Unknown	0.79 (0.62–0.99)	.050	0.60 (0.17–2.06)	.416

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Table 1. Factors Associated With Receipt of Radiotherapy (cont.)

Factor	Univariate Analysis		Multivariate Analysis	
	OR (95% CI)	P Value	OR (95% CI)	P Value
Zip code income level, USD				
<\$38,000	Ref		Ref	
\$38,000–\$47,999	1.04 (0.96–1.13)	.326	1.01 (0.92–1.10)	.912
\$48,000–\$62,999	1.09 (1.01–1.18)	.023	1.03 (0.94–1.14)	.473
≥\$63,000	1.07 (1.00–1.15)	.066	0.99 (0.89–1.10)	.899
Unknown	0.83 (0.66–1.04)	.102	0.87 (0.36–2.11)	.762
CCI score				
0	Ref		Ref	
1	0.87 (0.81–0.93)	<.001	0.90 (0.83–0.96)	.002
2	0.77 (0.67–0.89)	<.001	0.80 (0.69–0.93)	.004
≥3	0.73 (0.57–0.93)	.010	0.77 (0.60–0.99)	.047
Primary tumor site				
Extremity	Ref		Ref	
Head and neck	0.55 (0.50–0.61)	<.001	0.69 (0.62–0.77)	<.001
Thorax	0.53 (0.49–0.58)	<.001	0.52 (0.47–0.56)	<.001
Abdomen/Pelvis	0.44 (0.41–0.47)	<.001	0.42 (0.39–0.44)	<.001
Other/NOS	0.50 (0.43–0.58)	<.001	0.54 (0.46–0.63)	<.001
Histology				
Unclassified	Ref		Ref	
Undifferentiated pleomorphic sarcoma	1.16 (1.06–1.25)	.001	1.13 (1.03–1.23)	.007
Fibrosarcoma/Myxofibrosarcoma	0.89 (0.82–0.97)	.005	1.01 (0.93–1.09)	.884
Liposarcoma	0.97 (0.90–1.05)	.416	1.01 (0.93–1.10)	.786
Leiomyosarcoma	0.54 (0.50–0.58)	<.001	0.68 (0.62–0.73)	<.001
Synovial sarcoma	1.42 (1.25–1.61)	<.001	1.45 (1.26–1.66)	<.001
Angiosarcoma	0.42 (0.37–0.49)	<.001	0.55 (0.48–0.64)	<.001
MPNST	0.94 (0.83–1.06)	.295	1.07 (0.93–1.22)	.341
Tumor size				
≤5 cm	Ref		Ref	
5.1–10 cm	1.81 (1.71–1.92)	<.001	1.81 (1.71–1.93)	<.001
10.1–15 cm	1.90 (1.76–2.04)	<.001	1.86 (1.72–2.01)	<.001
>15 cm	1.44 (1.33–1.56)	<.001	1.46 (1.34–1.59)	<.001
Tumor grade				
2	Ref		Ref	
3	1.64 (1.55–1.73)	<.001	1.50 (1.41–1.60)	<.001
Receipt of chemotherapy				
No	Ref		Ref	
Yes	1.69 (1.58–1.80)	<.001	1.39 (1.29–1.49)	<.001
Unknown	0.75 (0.65–0.87)	<.001	0.71 (0.61–0.82)	<.001
Year of diagnosis				
2004–2007	Ref		—	—
2008–2011	1.03 (0.97–1.10)	.286	—	—
2012–2015	1.03 (0.97–1.09)	.384	—	—

Abbreviations: CCI, Charlson-Deyo comorbidity index; MPNST, malignant peripheral nerve sheath tumor; NOS, not otherwise specified; OR, odds ratio.

Factors Associated With Receipt of Neoadjuvant Versus Adjuvant RT

Use of neoadjuvant RT increased over the study period, whereas use of adjuvant RT declined (Figure 2). Multivariable analysis revealed that notable factors associated with use of neoadjuvant RT included treatment at academic centers, larger tumor size (>5 cm), and tumors arising in the extremities (Table 2).

Factors Associated With RT Modality

Use of IMRT increased over the study period compared with 3DCRT (Figure 3). Multivariable analysis showed that important factors associated with IMRT use included treatment at academic centers, more recent diagnosis, larger tumor size (>5 cm), tumors arising in nonextremity locations (head and neck, thorax, and abdomen/pelvis), and commercial insurance coverage (Table 3).

Discussion

We used a national cancer registry to evaluate patterns of care in the treatment of high-grade STS. To our knowledge, this is the most comprehensive study to examine patterns of care regarding the use of RT in patients with high-grade STS using a real-world patient cohort. Given that randomized data have shown improvement in local control with the addition of RT,^{3–5} NCCN Guidelines for STS recommend the addition of neoadjuvant or adjuvant RT to surgery for patients with high-grade STS, particularly for larger tumors.² However, our study shows that RT is potentially underused, with 42% of patients not receiving RT for stage II/III sarcomas. Even when we evaluated only patients with larger tumors (>5 cm), 38% did not receive RT. Importantly, use of RT did not change over the study period. Interestingly, a prior SEER analysis of a similar cohort of patients with STS noted overall RT use of 47%, although the study included lower-grade histologies.¹⁵

Moreover, concern remains that not all patients are equally considered for available therapies, given that we identified particular disparities in RT use among certain populations. In our study, we noted that Black patients, women, older patients, those with noncommercial insurance, and those with farther distance to treatment were less likely to receive RT, suggesting that these populations may also be vulnerable to omission of RT. Perhaps the most striking disparities we identified concerned the potential underuse of RT among patients who were Black and female, for which further investigation is warranted. Our study is consistent with several others that have noted disparities in the receipt of guideline-concordant cancer care and overall outcomes

Figure 2. Trends in receipt of neoadjuvant or adjuvant RT. Abbreviation: RT, radiation therapy.

among Black patients due to a number of patient- and provider-driven factors.^{16–23} In addition, our study is consistent with several others that have revealed undertreatment of female patients compared with their male counterparts with respect to other disease sites and modalities of cancer care.²⁴ We have previously shown that older populations are less likely to receive perioperative RT¹¹ due to a number of potential factors that others have investigated, including physician-based factors such as hesitancy to recommend more-intensive treatment due to preconceived biases regarding patient frailty, and patient-related factors such as prioritization of immediate convenience and quality of life over long-term outcomes and survival.^{25–27}

Patients with noncommercial insurance may encounter delays in obtaining medical attention or experience provider discrimination because of their insurance status, and several prior studies of other malignancies have shown that patients with noncommercial insurance such as Medicaid or who are uninsured are less likely to receive guideline-recommended care and frequently experience worse outcomes.^{28–31} It is possible that those with longer travel to their treatment facility may correspondingly undergo treatment in underresourced facilities where RT may not be easily incorporated into their treatment course. Moreover, given that some providers may not consider RT for patients with smaller tumors (≤ 5 cm), we specifically assessed whether these disparities persisted when only including patients with larger tumors (>5 cm) (supplemental eTable 2). Concordant with the larger cohort, in this subset, Black patients, women, older populations, those with noncommercial insurance, and those with farther distance to treatment remained less likely to receive RT. We identified that Hispanic patients were also less likely to receive RT. In addition, when specifically examining those with abdominal/pelvic tumors, we noted that similar demographic and

Table 2. Factors Associated With Receipt of Neoadjuvant Versus Adjuvant Radiotherapy

Factor	Univariate Analysis		Multivariate Analysis	
	OR (95% CI)	P Value	OR (95% CI)	P Value
Age				
<70 y	Ref		Ref	
≥70 y	0.83 (0.77–0.90)	<.001	0.95 (0.85–1.06)	.355
Sex				
Male	Ref		—	—
Female	0.99 (0.92–1.07)	.844	—	—
Race/Ethnicity				
Non-Hispanic White	Ref		Ref	
Non-Hispanic Black	1.13 (1.00–1.27)	.055	0.95 (0.83–1.09)	.501
Hispanic	0.76 (0.65–0.89)	.001	0.78 (0.65–0.93)	.007
Other	0.90 (0.76–1.06)	.214	0.93 (0.77–1.12)	.454
Facility area				
Metropolitan	Ref		Ref	
Urban	1.17 (1.06–1.30)	.002	0.87 (0.77–0.98)	.024
Rural	1.26 (0.97–1.66)	.089	0.90 (0.66–1.22)	.497
Unknown	1.26 (1.04–1.52)	.018	1.12 (0.89–1.42)	.329
Facility location				
East	Ref		Ref	
South	1.40 (1.26–1.55)	<.001	1.42 (1.26–1.60)	<.001
Central	1.02 (0.91–1.14)	.789	1.02 (0.90–1.15)	.790
West	0.77 (0.67–0.87)	<.001	0.76 (0.66–0.87)	<.001
Unknown	1.04 (0.91–1.19)	.582	1.22 (1.02–1.44)	.026
Facility type				
Nonacademic	Ref		Ref	
Academic	1.78 (1.64–1.92)	<.001	1.43 (1.31–1.56)	<.001
Insurance				
Commercial	Ref		Ref	
Medicare	0.88 (0.82–0.95)	.001	0.96 (0.86–1.07)	.470
Medicaid	0.84 (0.71–0.99)	.042	0.79 (0.66–0.95)	.012
Uninsured	1.03 (0.84–1.26)	.788	0.95 (0.75–1.19)	.643
Other	1.46 (1.20–1.76)	<.001	1.30 (1.05–1.61)	.015
Distance to treatment facility				
≤40 miles	Ref		Ref	
>40 miles	2.16 (2.00–2.34)	<.001	1.96 (1.78–2.16)	<.001
Unknown/Missing	1.49 (1.05–2.12)	.024	1.63 (0.68–3.95)	.276
Zip code education level				
≥21%	Ref		—	—
13%–20.9%	1.10 (0.98–1.24)	.111	—	—
7%–12.9%	1.08 (0.97–1.21)	.161	—	—
<7%	1.08 (0.96–1.21)	.216	—	—
Unknown	1.33 (0.93–1.91)	.122	—	—

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Table 2. Factors Associated With Receipt of Neoadjuvant Versus Adjuvant Radiotherapy (cont.)

Factor	Univariate Analysis		Multivariate Analysis	
	OR (95% CI)	P Value	OR (95% CI)	P Value
Zip code income level, USD				
<\$38,000	Ref		Ref	
\$38,000–\$47,999	0.95 (0.85–1.07)	.383	1.03 (0.90–1.17)	.697
\$48,000–\$62,999	0.92 (0.83–1.03)	.169	1.09 (0.96–1.24)	.179
≥\$63,000	0.87 (0.78–0.96)	.009	1.12 (0.98–1.27)	.099
Unknown	1.10 (0.77–1.55)	.606	0.84 (0.35–1.98)	.689
CCI score				
0	Ref		—	—
1	1.03 (0.93–1.14)	.594	—	—
2	0.99 (0.80–1.24)	.960	—	—
≥3	1.14 (0.79–1.66)	.486	—	—
Primary tumor site				
Extremity	Ref		Ref	
Head and neck	0.18 (0.14–0.23)	<.001	0.26 (0.20–0.35)	<.001
Thorax	0.44 (0.38–0.51)	<.001	0.45 (0.39–0.53)	<.001
Abdomen/Pelvis	0.58 (0.52–0.64)	<.001	0.55 (0.49–0.61)	<.001
Other/NOS	0.55 (0.42–0.72)	<.001	0.64 (0.48–0.86)	.003
Histology				
Unclassified	Ref		Ref	
Undifferentiated pleomorphic sarcoma	0.47 (0.41–0.53)	<.001	0.58 (0.51–0.66)	<.001
Fibrosarcoma/Myxofibrosarcoma	0.59 (0.53–0.67)	<.001	0.62 (0.55–0.70)	<.001
Liposarcoma	0.70 (0.63–0.78)	<.001	0.59 (0.52–0.66)	<.001
Leiomyosarcoma	0.53 (0.47–0.60)	<.001	0.67 (0.59–0.76)	<.001
Synovial sarcoma	0.91 (0.78–1.06)	.227	0.99 (0.83–1.18)	.901
Angiosarcoma	0.21 (0.14–0.29)	<.001	0.40 (0.27–0.58)	<.001
MPNST	0.34 (0.28–0.43)	<.001	0.40 (0.31–0.50)	<.001
Tumor size				
≤5 cm	Ref		Ref	
5.1–10 cm	2.53 (2.29–2.80)	<.001	2.41 (2.16–2.68)	<.001
10.1–15 cm	4.19 (3.74–4.70)	<.001	3.86 (3.41–4.37)	<.001
>15 cm	5.33 (4.72–6.01)	<.001	4.69 (4.11–5.35)	<.001
Tumor grade				
2	Ref		Ref	
3	1.22 (1.11–1.34)	<.001	0.98 (0.88–1.08)	.647
Receipt of chemotherapy				
No	Ref		Ref	
Yes	1.93 (1.78–2.09)	<.001	1.53 (1.39–1.68)	<.001
Unknown	1.12 (0.88–1.42)	.350	1.18 (0.91–1.53)	.207
Year of diagnosis				
2004–2007	Ref		Ref	
2008–2011	1.47 (1.34–1.61)	<.001	1.48 (1.34–1.64)	<.001
2012–2015	1.93 (1.77–2.11)	<.001	1.84 (1.67–2.04)	<.001

Abbreviations: CCI, Charlson-Deyo comorbidity index; MPNST, malignant peripheral nerve sheath tumor; NOS, not otherwise specified; OR, odds ratio.

clinical factors were associated with RT use (supplemental eTable 3). It is important to note that the present study did not include retroperitoneal sarcomas, because the management of these tumors differs from STS of other anatomic subsites and it would be difficult to conclude that omission of RT in their management was a deviation from guideline-recommended treatment. Indeed, the role of RT in the management of retroperitoneal sarcomas remains controversial,^{32–36} especially in light of recent data from the STRASS trial showing overall no benefit of neoadjuvant RT.³⁷

Treatment with neoadjuvant RT is often preferred, given the lower dose and smaller treatment volumes, which reduce the risk of long-term RT toxicity, such as fibrosis, edema, and joint issues, at the expense, however, of a higher risk of postsurgical wound complications.⁶ We examined practice patterns regarding timing of RT and found that, over the study period, there was an increase in neoadjuvant RT use, whereas use of adjuvant RT declined. This was especially pronounced in patients with larger tumors (>5 cm), more recent diagnosis, and treatment at academic centers. The observation that those with larger tumors are more likely to receive preoperative treatment is consistent with the ability to achieve a lower dose and smaller treatment fields with neoadjuvant RT. Moreover, our results showing that patients treated at academic medical centers and those with more recent diagnoses are more likely to receive neoadjuvant RT may be due to the tendency of academic institutions to incorporate into practice the recent randomized data showing a potentially favorable adverse effect profile for neoadjuvant treatment. All of this information is consistent with a shift in treatment paradigm regarding the timing of RT with respect to surgery for STS.

IMRT can offer a number of potential benefits, including favorable dosimetric characteristics that allow preferential sparing of bone, skin, soft tissues, and other organs at risk. Given the recent data highlighting the benefits of using IMRT in patients who receive RT,^{7,8} we sought to determine whether its use has been increasing in patients receiving RT in addition to surgery. Our study shows that, over the study period, there was an increase in IMRT use compared with 3DCRT. Notable predictors of receipt of IMRT included larger tumor size (>5 cm), tumors arising in nonextremity locations, more recent diagnosis, treatment at academic centers, and commercial insurance coverage. It is possible that patients with larger tumor sizes are more likely to receive IMRT because of the potentially favorable dosimetric profile and outcomes of IMRT, particularly when used for nonextremity locations.^{8,38} Moreover, patients were

Figure 3. Trends in receipt of IMRT versus 3DCRT, by year.

Abbreviations: 3DCRT, 3D conformal radiotherapy; IMRT, intensity-modulated radiotherapy.

more likely to receive IMRT at academic centers, which may tend to adopt changes in modality sooner than nonacademic centers, show increased comfort with use of IMRT, and benefit from more experience with regard to obtaining insurance approval for IMRT. Interestingly, lack of commercial insurance coverage was a negative predictor of receipt of IMRT, which can often be a more resource-intensive and expensive treatment course, though potentially more cost-effective.³⁹

Strengths of the present study include a large, modern cohort of >27,000 patients treated for STS, adjustment for a range of patient- and facility-level variables, and inclusion of patients treated with both neoadjuvant and adjuvant RT and numerous modalities. Our study has several notable limitations, given its retrospective design and reliance on the content and accuracy of information included in the NCDB. In addition, there is inherent selection bias associated with the retrospective nature of this analysis. It is also possible that we were unable to account for several unmeasured confounders, such as patient preferences, physician attitudes, referral patterns, and quality of care received, which may have impacted patient selection and management.

Conclusions

Our findings show that RT for patients with high-grade STS remains potentially underused, despite national guidelines recommending the addition of RT to surgery. Moreover, our analysis also reflects that certain subgroups may be particularly vulnerable to omission of treatment, which could adversely impact outcomes. However, despite these findings, patients receiving RT were more likely to receive neoadjuvant RT and IMRT when treated, reflecting practice pattern change in line with emerging data suggesting the beneficial adverse effect profile of each. Given that treatment at academic and high-volume centers is associated

Table 3. Factors Associated With Receipt of Intensity-Modulated Radiotherapy

Factor	Univariate Analysis		Multivariate Analysis	
	OR (95% CI)	P Value	OR (95% CI)	P Value
Age				
<70 y	Ref		Ref	
≥70 y	0.80 (0.71–0.91)	.001	0.93 (0.78–1.11)	.433
Sex				
Male	Ref		—	—
Female	1.01 (0.90–1.13)	.869	—	—
Race/Ethnicity				
Non-Hispanic White	Ref		Ref	
Non-Hispanic Black	1.06 (0.87–1.29)	.582	1.01 (0.81–1.27)	.905
Hispanic	1.46 (1.12–1.90)	.005	1.53 (1.14–2.04)	.004
Other	1.66 (1.22–2.25)	.001	1.91 (1.38–2.65)	<.001
Facility area				
Metropolitan	Ref		—	—
Urban	0.87 (0.73–1.03)	.111	—	—
Rural	0.84 (0.51–1.36)	.469	—	—
Unknown	1.07 (0.76–1.52)	.696	—	—
Facility location				
East	Ref		Ref	
South	0.94 (0.79–1.12)	.505	1.03 (0.85–1.24)	.756
Central	0.64 (0.54–0.76)	<.001	0.65 (0.54–0.79)	<.001
West	0.61 (0.50–0.75)	<.001	0.61 (0.49–0.75)	<.001
Unknown	0.98 (0.79–1.22)	.868	1.04 (0.80–1.36)	.754
Facility type				
Nonacademic	Ref		Ref	
Academic	1.57 (1.39–1.78)	<.001	1.41 (1.22–1.61)	<.001
Insurance				
Commercial	Ref		Ref	
Medicare	0.79 (0.70–0.89)	<.001	0.84 (0.71–0.99)	.049
Medicaid	0.92 (0.71–1.20)	.552	0.77 (0.58–1.01)	.061
Uninsured	0.74 (0.52–1.05)	.089	0.56 (0.39–0.82)	.003
Other	0.95 (0.66–1.38)	.790	0.92 (0.62–1.36)	.676
Distance to treatment facility				
≤40 miles	Ref		Ref	
>40 miles	1.32 (1.15–1.52)	<.001	1.22 (1.04–1.43)	.017
Unknown/Missing	1.14 (0.52–2.51)	.737	2.09 (0.15–29.44)	.585
Zip code education level				
≥21%	Ref		—	—
13%–20.9%	1.22 (1.00–1.49)	.051	—	—
7%–12.9%	1.08 (0.90–1.30)	.396	—	—
<7%	1.05 (0.87–1.27)	.596	—	—
Unknown	1.17 (0.53–2.61)	.692	—	—

(continued on next page)

Table 3. Factors Associated With Receipt of Intensity-Modulated Radiotherapy (cont.)

Factor	Univariate Analysis		Multivariate Analysis	
	OR (95% CI)	P Value	OR (95% CI)	P Value
Zip code income level, USD				
<\$38,000	Ref		Ref	
\$38,000–\$47,999	1.10 (0.90–1.33)	.349	1.19 (0.97–1.47)	.098
\$48,000–\$62,999	1.07 (0.89–1.29)	.485	1.18 (0.96–1.44)	.117
≥\$63,000	1.29 (1.08–1.54)	.005	1.45 (1.19–1.78)	<.001
Unknown	1.11 (0.51–2.41)	.786	0.48 (0.04–6.25)	.575
CCI score				
0	Ref		—	—
1	0.96 (0.81–1.13)	.592	—	—
2	0.88 (0.63–1.23)	.446	—	—
≥3	0.99 (0.55–1.76)	.970	—	—
Primary tumor site				
Extremity	Ref		Ref	
Head and neck	6.16 (4.32–8.79)	<.001	7.91 (5.46–11.47)	<.001
Thorax	1.36 (1.10–1.68)	.005	1.45 (1.16–1.82)	.001
Abdomen/Pelvis	1.90 (1.63–2.20)	<.001	2.05 (1.75–2.41)	<.001
Other/NOS	1.13 (0.74–1.71)	.580	1.20 (0.78–1.85)	.414
Histology				
Unclassified	Ref		Ref	
Undifferentiated pleomorphic sarcoma	0.76 (0.62–0.93)	.007	0.97 (0.78–1.21)	.818
Fibrosarcoma/Myxofibrosarcoma	0.85 (0.71–1.01)	.071	0.90 (0.75–1.09)	.294
Liposarcoma	1.06 (0.89–1.26)	.542	1.00 (0.83–1.21)	.965
Leiomyosarcoma	1.08 (0.89–1.30)	.454	1.14 (0.93–1.40)	.204
Synovial sarcoma	1.11 (0.85–1.46)	.440	0.99 (0.73–1.34)	.956
Angiosarcoma	2.12 (1.33–3.38)	.002	1.40 (0.84–2.32)	.195
MPNST	1.66 (1.21–2.28)	.002	1.48 (1.05–2.07)	.025
Tumor size				
≤5 cm	Ref		Ref	
5.1–10 cm	1.26 (1.09–1.45)	.002	1.32 (1.13–1.54)	<.001
10.1–15 cm	1.56 (1.31–1.85)	<.001	1.78 (1.47–2.15)	<.001
>15 cm	1.45 (1.20–1.75)	<.001	1.72 (1.40–2.12)	<.001
Tumor grade				
2	Ref		—	—
3	1.01 (0.88–1.17)	.875	—	—
Receipt of chemotherapy				
No	Ref		Ref	
Yes	1.27 (1.10–1.47)	.001	1.14 (0.96–1.34)	.127
Unknown	1.08 (0.71–1.64)	.716	0.87 (0.56–1.35)	.526
Year of diagnosis				
2004–2007	Ref		Ref	
2008–2011	1.58 (1.34–1.87)	<.001	1.74 (1.46–2.09)	<.001
2012–2015	1.95 (1.66–2.28)	<.001	2.25 (1.89–2.68)	<.001

Abbreviations: CCI, Charlson-Deyo comorbidity index; MPNST, malignant peripheral nerve sheath tumor; NOS, not otherwise specified; OR, odds ratio.

with improved outcomes in patients with both STS and other malignancies,^{40–44} we were interested in assessing whether RT use was increased at academic centers. Although we noted no difference in overall RT use, academic centers were more likely to use both neoadjuvant RT and IMRT. In light of these data, future strategies aimed at making RT more accessible, convenient, and cost-conscious are certainly warranted. Recent studies have suggested that shorter RT regimens may have an acceptable toxicity profile and increase the likelihood of neoadjuvant use,⁴⁵ which is encouraging for both patients and providers. Further work evaluating access to and quality of treatment

is warranted to improve outcomes in this patient population.

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Radiotherapy Remains Underused in the Treatment of Soft-Tissue Sarcomas: Disparities in Practice Patterns in the United States

Vishruth K. Reddy, MD, PhD; Varsha Jain, MD, PhD; Sriram Venigalla, MD; William P. Levin, MD; Robert J. Wilson II, MD; Kristy L. Weber, MD; Anusha Kalbasi, MD; Ronnie A. Sebro, MD, PhD; and Jacob E. Shabason, MD, MTR

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eFigure 1: CONSORT Diagram of the Patient Cohort

eTable 1: Baseline Patient Characteristics

eTable 2: Factors Associated With Receipt of Radiotherapy in Patients With Tumors >5 cm

eTable 3: Factors Associated With Receipt of Radiotherapy in Patients With Abdominal/Pelvic Tumors

eFigure 1. CONSORT diagram of the patient cohort.

Abbreviation: 3DCRT, 3D conformal radiotherapy; IMRT, intensity-modulated radiotherapy; LSS, limb-sparing surgery; NCDB, National Cancer Database; RT, radiotherapy.

eTable 1. Baseline Patient Characteristics

Characteristic	No (%)	Yes (%)	Total (%)	Chi-Square P Value
Total, n	11,654 (42)	15,772 (58)	27,426 (100)	
Age				<.001
<70 y	7,308 (63)	10,462 (66)	17,770 (65)	
≥70 y	4,346 (37)	5,310 (34)	9,656 (35)	
Sex				<.001
Male	5,952 (51)	8,857 (56)	14,809 (54)	
Female	5,702 (49)	6,915 (44)	12,617 (46)	
Race/Ethnicity				<.001
Non-Hispanic White	9,205 (79)	12,686 (80)	21,891 (80)	
Non-Hispanic Black	1,145 (10)	1,427 (9)	2,572 (9)	
Hispanic	732 (6)	910 (6)	1,642 (6)	
Other	572 (5)	749 (5)	1,321 (5)	
Facility area				.007
Metropolitan	9,549 (82)	12,851 (81)	22,400 (82)	
Urban	1,549 (13)	2,151 (14)	3,700 (13)	
Rural	174 (1)	253 (2)	427 (2)	
Unknown	382 (3)	517 (3)	899 (3)	
Facility location				<.001
East	2,281 (20)	2,849 (18)	5,130 (19)	
South	3,621 (31)	4,680 (30)	8,301 (30)	
Central	2,392 (21)	3,774 (24)	6,166 (22)	
West	1,880 (16)	2,582 (16)	4,462 (16)	
Unknown	1,480 (13)	1,887 (12)	3,367 (12)	
Facility type				<.001
Nonacademic	4,880 (42)	6,548 (42)	11,428 (42)	
Academic	5,294 (45)	7,337 (47)	12,631 (46)	
Unknown	1,480 (13)	1,887 (12)	3,367 (12)	
Insurance				<.001
Commercial	5,089 (44)	7,608 (48)	12,697 (46)	
Medicare	5,153 (44)	6,348 (40)	11,501 (42)	
Medicaid	649 (6)	846 (5)	1,495 (5)	
Uninsured	420 (4)	475 (3)	895 (3)	
Other	343 (3)	495 (3)	838 (3)	
Distance to treatment facility				<.001
≤40 miles	8,279 (71)	11,734 (74)	20,013 (73)	
>40 miles	3,234 (28)	3,887 (25)	7,121 (26)	
Unknown/Missing	141 (1)	151 (1)	292 (1)	

(continued)

eTable 1. Baseline Patient Characteristics (cont.)

Characteristic	No (%)	Yes (%)	Total (%)	Chi-Square P Value
Zip code education level				.134
≥21%	1,750 (15)	2,282 (14)	4,032 (15)	
13%–20.9%	2,780 (24)	3,739 (24)	6,519 (24)	
7%–12.9%	3,877 (33)	5,291 (34)	9,168 (33)	
<7%	3,103 (27)	4,312 (27)	7,415 (27)	
Unknown	144 (1)	148 (1)	292 (1)	
Zip code income level, USD				.012
<\$38,000	1,843 (16)	2,363 (15)	4,206 (15)	
\$38,000–\$47,999	2,610 (22)	3,482 (22)	6,092 (22)	
\$48,000–\$62,999	3,034 (26)	4,253 (27)	7,287 (27)	
≥\$63,000	4,014 (34)	5,512 (35)	9,526 (35)	
Unknown	153 (1)	162 (1)	315 (1)	
CCI score				<.001
0	9,248 (79)	12,931 (82)	22,179 (81)	
1	1,881 (16)	2,282 (14)	4,163 (15)	
2	394 (3)	426 (3)	820 (3)	
≥3	131 (1)	133 (1)	264 (1)	
Primary tumor site				<.001
Head and neck	819 (7)	839 (5)	1,658 (6)	
Upper extremity	1,549 (13)	2,669 (17)	4,218 (15)	
Lower extremity	4,070 (35)	7,751 (49)	11,821 (43)	
Thorax	1,327 (11)	1,304 (8)	2,631 (10)	
Abdomen/Pelvis	3,535 (30)	2,880 (18)	6,415 (23)	
Other/NOS	354 (3)	329 (2)	683 (2)	
Histology				<.001
Unclassified	3,326 (29)	5,076 (32)	8,402 (31)	
Undifferentiated pleomorphic sarcoma	1,240 (11)	2,186 (14)	3,426 (12)	
Fibrosarcoma/Myxofibrosarcoma	1,559 (13)	2,123 (13)	3,682 (13)	
Liposarcoma	1,691 (15)	2,501 (16)	4,192 (15)	
Leiomyosarcoma	2,401 (21)	1,987 (13)	4,388 (16)	
Synovial sarcoma	393 (3)	852 (5)	1,245 (5)	
Angiosarcoma	569 (5)	369 (2)	938 (3)	
MPNST	475 (4)	678 (4)	1,153 (4)	
Tumor size				<.001
≤5 cm	5,084 (44)	4,843 (31)	9,927 (36)	
5.1–10 cm	3,509 (30)	6,050 (38)	9,559 (35)	
10.1–15 cm	1,558 (13)	2,815 (18)	4,373 (16)	
>15 cm	1,503 (13)	2,064 (13)	3,567 (13)	

(continued on next page)

eTable 1. Baseline Patient Characteristics (cont.)

Characteristic	No (%)	Yes (%)	Total (%)	Chi-Square P Value
Tumor grade				<.001
2	3,335 (29)	3,105 (20)	6,440 (23)	
3	8,319 (71)	12,667 (80)	20,986 (77)	
Clinical stage				<.001
II	5,084 (44)	4,843 (31)	9,927 (36)	
III	6,570 (56)	10,929 (69)	17,499 (64)	
Receipt of chemotherapy				<.001
No	9,718 (83)	12,152 (77)	21,870 (80)	
Yes	1,542 (13)	3,250 (21)	4,792 (17)	
Unknown	394 (3)	370 (2)	764 (3)	
Year of diagnosis				<.001
2004	869 (7)	1,078 (7)	1,947 (7)	
2005	902 (8)	1,216 (8)	2,118 (8)	
2006	911 (8)	1,221 (8)	2,132 (8)	
2007	944 (8)	1,294 (8)	2,238 (8)	
2008	950 (8)	1,339 (8)	2,289 (8)	
2009	1,053 (9)	1,390 (9)	2,443 (9)	
2010	972 (8)	1,248 (8)	2,220 (8)	
2011	877 (8)	1,301 (8)	2,178 (8)	
2012	925 (8)	1,274 (8)	2,199 (8)	
2013	990 (8)	1,374 (9)	2,364 (9)	
2014	1,150 (10)	1,527 (10)	2,677 (10)	
2015	1,111 (10)	1,510 (10)	2,621 (10)	

Abbreviations: CCI, Charlson-Deyo comorbidity index; MPNST, malignant peripheral nerve sheath tumor; NOS, not otherwise specified.

eTable 2. Factors Associated With Receipt of Radiotherapy in Patients With Tumors >5 cm

Factor	Univariate Analysis		Multivariate Analysis	
	OR (95% CI)	P Value	OR (95% CI)	P Value
Age				
<70 y	Ref		Ref	
≥70 y	0.81 (0.76–0.86)	<.001	0.85 (0.77–0.93)	<.001
Sex				
Male	Ref		Ref	
Female	0.80 (0.76–0.86)	<.001	0.82 (0.77–0.88)	<.001
Race/Ethnicity				
Non-Hispanic White	Ref		Ref	
Non-Hispanic Black	0.86 (0.78–0.95)	.004	0.87 (0.78–0.98)	.017
Hispanic	0.83 (0.73–0.94)	.003	0.85 (0.74–0.98)	.022
Other	0.88 (0.76–1.01)	.076	0.86 (0.74–1.00)	.048
Facility area				
Metropolitan	Ref		—	—
Urban	1.02 (0.94–1.12)	.617	—	—
Rural	1.05 (0.82–1.35)	.677	—	—
Unknown	1.01 (0.85–1.20)	.885	—	—
Facility location				
East	Ref		Ref	
South	1.02 (0.93–1.11)	.694	1.05 (0.95–1.16)	.315
Central	1.24 (1.13–1.37)	<.001	1.32 (1.19–1.46)	<.001
West	0.99 (0.90–1.10)	.893	1.03 (0.92–1.15)	.634
Unknown	1.09 (0.97–1.22)	.149	0.99 (0.86–1.14)	.865
Facility type				
Nonacademic	Ref		Ref	
Academic	1.08 (1.02–1.16)	.015	1.05 (0.98–1.13)	.172
Insurance				
Commercial	Ref		Ref	
Medicare	0.76 (0.72–0.82)	<.001	0.86 (0.79–0.95)	.002
Medicaid	0.81 (0.71–0.92)	.001	0.91 (0.79–1.04)	.166
Uninsured	0.68 (0.58–0.81)	<.001	0.69 (0.58–0.83)	<.001
Other	0.92 (0.77–1.11)	.398	0.95 (0.78–1.15)	.593
Distance to treatment facility				
≤40 miles	Ref		Ref	
>40 miles	0.86 (0.80–0.92)	<.001	0.75 (0.69–0.81)	<.001
Unknown/Missing	0.76 (0.58–1.00)	.052	1.20 (0.45–3.26)	.714
Zip code education level				
≥21%	Ref		Ref	
13%–20.9%	1.10 (1.00–1.22)	.053	1.07 (0.96–1.19)	.248
7%–12.9%	1.14 (1.04–1.25)	.007	1.06 (0.94–1.19)	.373
<7%	1.17 (1.06–1.28)	.002	1.06 (0.92–1.22)	.402
Unknown	0.85 (0.64–1.12)	.252	0.72 (0.17–3.15)	.664

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eTable 2. Factors Associated With Receipt of Radiotherapy in Patients With Tumors >5 cm (cont.)

Factor	Univariate Analysis		Multivariate Analysis	
	OR (95% CI)	P Value	OR (95% CI)	P Value
Zip code income level, USD				
<\$38,000	Ref		Ref	
\$38,000–\$47,999	1.05 (0.95–1.16)	.374	0.97 (0.87–1.08)	.588
\$48,000–\$62,999	1.09 (0.99–1.20)	.076	0.97 (0.86–1.09)	.614
≥\$63,000	1.10 (1.00–1.21)	.046	0.94 (0.83–1.08)	.401
Unknown	0.84 (0.64–1.11)	.228	0.81 (0.27–2.39)	.697
CCI score				
0	Ref		Ref	
1	0.80 (0.74–0.87)	<.001	0.86 (0.79–0.94)	.001
2	0.75 (0.63–0.90)	.001	0.81 (0.68–0.98)	.027
≥3	0.60 (0.45–0.80)	.001	0.68 (0.50–0.92)	.013
Primary tumor site				
Extremity	Ref		Ref	
Head and neck	0.58 (0.48–0.69)	<.001	0.65 (0.54–0.78)	<.001
Thorax	0.47 (0.43–0.53)	<.001	0.47 (0.42–0.53)	<.001
Abdomen/Pelvis	0.34 (0.32–0.37)	<.001	0.36 (0.33–0.39)	<.001
Other/NOS	0.37 (0.31–0.45)	<.001	0.41 (0.34–0.50)	<.001
Histology				
Unclassified	Ref		Ref	
Undifferentiated pleomorphic sarcoma	1.11 (0.99–1.23)	.065	1.09 (0.97–1.22)	.146
Fibrosarcoma/Myxofibrosarcoma	0.86 (0.77–0.95)	.004	0.90 (0.80–1.00)	.056
Liposarcoma	0.78 (0.71–0.85)	<.001	0.90 (0.82–1.00)	.039
Leiomyosarcoma	0.52 (0.47–0.57)	<.001	0.70 (0.63–0.78)	<.001
Synovial sarcoma	1.23 (1.04–1.46)	.016	1.12 (0.94–1.35)	.214
Angiosarcoma	0.32 (0.26–0.39)	<.001	0.40 (0.32–0.49)	<.001
MPNST	0.80 (0.68–0.93)	.004	0.91 (0.78–1.08)	.286
Tumor size				
5.1–10 cm	Ref		Ref	
10.1–15 cm	1.05 (0.97–1.13)	.218	1.03 (0.95–1.12)	.421
>15 cm	0.80 (0.74–0.86)	<.001	0.82 (0.75–0.89)	<.001
Tumor grade				
2	Ref		Ref	
3	1.45 (1.35–1.57)	<.001	1.39 (1.28–1.51)	<.001
Receipt of chemotherapy				
No	Ref		Ref	
Yes	1.49 (1.38–1.60)	<.001	1.33 (1.22–1.45)	<.001
Unknown	0.67 (0.56–0.80)	<.001	0.63 (0.52–0.76)	<.001
Year of diagnosis				
2004–2007	Ref		Ref	
2008–2011	1.04 (0.96–1.12)	.355	1.08 (1.00–1.17)	.060
2012–2015	1.10 (1.02–1.18)	.014	1.17 (1.08–1.27)	<.001

Abbreviations: CCI, Charlson-Deyo comorbidity index; MPNST, malignant peripheral nerve sheath tumor; NOS, not otherwise specified; OR, odds ratio.

eTable 3. Factors Associated With Receipt of Radiotherapy in Patients With Abdominal/Pelvic Tumors

Factor	Univariate Analysis		Multivariate Analysis	
	OR (95% CI)	P Value	OR (95% CI)	P Value
Age				
<70 y	Ref		Ref	
≥70 y	0.87 (0.78–0.97)	.009	0.86 (0.75–0.99)	.045
Sex				
Male	Ref		Ref	
Female	0.76 (0.69–0.84)	<.001	0.81 (0.72–0.89)	<.001
Race/Ethnicity				
Non-Hispanic White	Ref		Ref	
Non-Hispanic Black	0.78 (0.66–0.92)	.004	0.79 (0.66–0.95)	.010
Hispanic	1.00 (0.82–1.22)	.994	1.01 (0.82–1.25)	.915
Other	0.80 (0.63–1.01)	.065	0.81 (0.63–1.04)	.099
Facility area				
Metropolitan	Ref		—	—
Urban	1.03 (0.88–1.19)	.743	—	—
Rural	1.44 (1.00–2.08)	.048	—	—
Unknown	1.02 (0.76–1.38)	.882	—	—
Facility location				
East	Ref		Ref	
South	0.89 (0.77–1.03)	.127	0.92 (0.79–1.07)	.285
Central	1.21 (1.04–1.40)	.015	1.27 (1.08–1.48)	.003
West	1.06 (0.90–1.25)	.507	1.13 (0.95–1.34)	.175
Unknown	1.12 (0.93–1.34)	.234	0.98 (0.80–1.20)	.858
Facility type				
Nonacademic	Ref		—	—
Academic	1.04 (0.94–1.16)	.437	—	—
Insurance				
Commercial	Ref		Ref	
Medicare	0.86 (0.77–0.96)	.006	0.93 (0.80–1.07)	.281
Medicaid	1.01 (0.82–1.25)	.894	1.04 (0.83–1.30)	.727
Uninsured	0.96 (0.73–1.26)	.777	1.04 (0.78–1.39)	.775
Other	0.81 (0.60–1.10)	.184	0.84 (0.61–1.15)	.273
Distance to treatment facility				
≤40 miles	Ref		Ref	
>40 miles	0.88 (0.78–0.98)	.024	0.83 (0.74–0.94)	.003
Unknown/Missing	0.87 (0.53–1.43)	.574	0.81 (0.49–1.36)	.433
Zip code education level				
≥21%	Ref		—	—
13%–20.9%	1.07 (0.91–1.25)	.437	—	—
7%–12.9%	1.07 (0.92–1.25)	.359	—	—
<7%	1.13 (0.97–1.33)	.122	—	—
Unknown	0.82 (0.49–1.38)	.461	—	—

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eTable 3. Factors Associated With Receipt of Radiotherapy in Patients With Abdominal/Pelvic Tumors (cont.)

Factor	Univariate Analysis		Multivariate Analysis	
	OR (95% CI)	P Value	OR (95% CI)	P Value
Zip code income level, USD				
<\$38,000	Ref		—	—
\$38,000–\$47,999	0.97 (0.82–1.14)	.703	—	—
\$48,000–\$62,999	1.08 (0.92–1.27)	.328	—	—
≥\$63,000	1.06 (0.91–1.23)	.438	—	—
Unknown	0.75 (0.45–1.26)	.279	—	—
CCI score				
0	Ref		—	—
1	0.85 (0.74–0.97)	.017	—	—
2	0.91 (0.68–1.21)	.521	—	—
≥3	0.95 (0.61–1.48)	.831	—	—
Histology				
Unclassified	Ref		Ref	
Undifferentiated pleomorphic sarcoma	1.21 (0.99–1.47)	.063	1.19 (0.97–1.46)	.096
Fibrosarcoma/Myxofibrosarcoma	0.84 (0.70–1.01)	.061	0.95 (0.78–1.15)	.581
Liposarcoma	0.74 (0.64–0.86)	<.001	0.79 (0.68–0.93)	.003
Leiomyosarcoma	0.56 (0.49–0.64)	<.001	0.59 (0.51–0.68)	<.001
Synovial sarcoma	1.48 (1.09–1.99)	.011	1.36 (0.99–1.87)	.055
Angiosarcoma	0.39 (0.27–0.56)	<.001	0.41 (0.28–0.59)	<.001
MPNST	0.93 (0.72–1.19)	.557	0.93 (0.71–1.20)	.563
Tumor size				
≤5 cm	Ref		Ref	
5.1–10 cm	1.60 (1.41–1.82)	<.001	1.58 (1.38–1.80)	<.001
10.1–15 cm	1.51 (1.30–1.76)	<.001	1.48 (1.26–1.73)	<.001
>15 cm	0.83 (0.72–0.97)	.020	0.80 (0.68–0.95)	.008
Tumor grade				
2	Ref		Ref	
3	1.50 (1.34–1.69)	<.001	1.40 (1.24–1.59)	<.001
Receipt of chemotherapy				
No	Ref		Ref	
Yes	1.32 (1.16–1.50)	<.001	1.17 (1.02–1.35)	.023
Unknown	0.68 (0.50–0.94)	.019	0.65 (0.47–0.91)	.011
Year of diagnosis				
2004–2007	Ref		Ref	
2008–2011	0.99 (0.88–1.12)	.911	1.01 (0.89–1.14)	.931
2012–2015	0.80 (0.71–0.91)	<.001	0.84 (0.74–0.96)	.010

Abbreviations: CCI, Charlson-Deyo comorbidity index; MPNST, malignant peripheral nerve sheath tumor; OR, odds ratio.