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Association between geographic access to cancer care and receipt of radiation therapy for rectal cancer

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Abstract

Purpose—Trimodality therapy (chemoradiation and surgery) is standard of care for Stage II/III rectal cancer but nearly one third of patients do not receive radiation therapy (RT). We examined the relationship between density of radiation oncologist and travel distance to receipt of RT.

Materials/Methods—A retrospective study based on the National Cancer Data Base identified 26,845 patients aged 18–80 with Stage II/III rectal cancer diagnosed between 2007–2010. Radiation oncologists were identified through Physician Compare Dataset. Generalized Estimating Equations clustering by Hospital Service Area was utilized to examine the association between geographic access and receipt of RT, controlling for patient sociodemographic and clinical characteristics.

Results—70% of patients received RT within 180 days of diagnosis or within 90 days of surgery. Compared to travel distance <12.5 miles, patients diagnosed at reporting facility who traveled ≥50 miles had a decreased likelihood of receipt of RT (50–249 miles: adjusted Odds Ratio [aOR] 0.75, p<.001; ≥250 miles: aOR 0.46, p=.002), all else being equal. Density level of radiation oncologists was not significantly associated with receipt of RT. Patients who were female, nonwhites, ≥50 years, and with comorbidities were less likely to receive RT (p<.05). Patients who were uninsured but self-paid for their medical services, initially diagnosed elsewhere but treated at reporting facility, and resided in Midwest had increased likelihood of receipt of RT (p<.05).

Conclusions—Increased travel burden was associated with a decreased likelihood of receiving RT for stage II/III rectal cancer patients when all else being equal, but radiation oncologist density was not. Further research in geographic access and establishing transportation assistance programs, or lodging services for patients with unmet need may help decrease geographic barriers and improve the quality of rectal cancer care.

Introduction

The efficacy of adjuvant chemoradiation therapy for surgically resectable Stage II/III rectal cancer is well-established from randomized trials. These studies demonstrated an increase in local control, disease-free and overall survival when combined with a 5-fluorouracil based chemotherapy after surgical resection. Preoperative chemoradiation followed by surgery is often employed to allow sphincter-preservation and to decrease bowel morbidity. NCCN treatment guidelines also recommend radiation therapy (RT), either pre-operatively or post-operatively for stage II/III rectal cancer.[1] However, a large proportion of patients do not receive recommended RT.[2–4]

Because RT requires access to radiation oncologists and linear accelerators for treatment, the receipt of RT may be partly influenced by geographic access. Geographic availability of RT resources may be evaluated by assessing geographic distribution of radiation oncologists and/or travel burden experienced by the patient. Higher population density of radiation oncologists is associated with increased likelihood of receiving RT[5] and improved treatment outcome.[6] Studies have demonstrated, however, that radiation oncologists are geographically maldistributed across the nation,[7, 8] clustered at academic centers[7] and of limited accessibility relative to other oncology specialists.[9] Traveling long distances to cancer care is a barrier to cancer treatment,[10–12] associated with decreased utilization of RT,[13–15] or worse treatment outcome.[16] Even with data on association between geographic access and receipt of RT, there is limited information specific to rectal cancer. Therefore, we sought to examine the relationship nationally between geographic access to cancer care and receipt of RT for stage II/III rectal cancer.

Methods and Materials

Data source

The National Cancer Data Base (NCDB), a hospital-based cancer registry that is jointly sponsored by the American College of Surgeons and the American Cancer Society, contains standardized data collected from over 1,500 Commission on Cancer (CoC)-accredited facilities and captures around 70% of newly diagnosed cancer cases in the United States.[17] The Morehouse School of Medicine Institutional Review Board reviewed this study and granted IRB review exemption.

The Centers for Medicare and Medicaid Services Physician Compare dataset was used to identify number and location of radiation oncologists. It includes physicians and other providers, identified by National Provider Identifier, who have submitted Medicare claims in the previous 12 months. The data contains demographic information, practice location and specialty designation and is updated monthly.

Study population

Patients with first primary American Joint Committee On Cancer collaborative stage II/III rectal cancer (*International Classification of Disease for Oncology*, 3rd *Edition* site codes: C19.9–C20.9) with no distant metastasis, diagnosed between 2007 and 2010, aged 18 to 80, who were surgical candidates, and treated at CoC-accredited facilities were selected. Patients were considered surgical candidates if they received cancer-directed surgery (including partial or total proctectomy) within six months of diagnosis. Patients were excluded if receipt of RT, RT administration dates, surgical treatment or area of residence was unknown (Figure 1). Due to small numbers, patients who had government sponsored insurance other than Medicaid and Medicare (e.g. Indian Bureau of Affairs, Public Health Service) (n=149) were excluded from the study.

Outcome and Covariates

The primary outcome was receipt of RT. The consensus for optimal management of rectal cancer has changed over the past decade. Several randomized clinical trials support either preoperative or postoperative irradiation.[18, 1920] In order to include both treatment sequencing patterns, receipt of RT was allowed within 180 days of diagnosis or 90 days of surgery in the NCDB. Time from diagnosis to RT was calculated from the date of cancer diagnosis to the RT start date while time from surgery to RT was calculated from the surgical date to the RT start date.

The major variables of interest were density level of radiation oncologists in a patient's area of residence and travel distance to cancer treatment facility. Radiation Oncologists were identified through a November 2013 Physician Compare dataset if their primary specialty was listed as radiation oncology. The number of unique radiation oncologists was counted per Hospital Service area (HSA). HSAs, developed by the Dartmouth Atlas of Health Care[21], are geographic areas covering one or more ZIP codes where medical resources are used based on the analysis of travel patterns for routine hospital care. The density was then calculated as the number of unique radiation oncologists per 100,000 residents in each HSA. Because many HSAs did not have radiation oncologists, a separate density level was created as "no radiation oncologist." Among HSAs with ≥1 radiation oncologist, quartiles of density level were created from Q1 to Q4, with Q1 as the lowest quartile and Q4 as the highest quartile. Each patient was, then, assigned with a density level of radiation oncologists based on the HSA of residence at diagnosis.

Travel distance to cancer treatment was defined as driving distance between the centroids of ZIP codes of patient residence at diagnosis and reporting facility, as calculated by using Google Maps in the NCDB dataset. It was categorized as 0–12.49, 12.5–49.9, 50–249 and ≥250 miles, based on previous literature.[22–24] For patients who lived outside the continental U.S. but traveled back to seek cancer treatment, their travel distance was calculated by the "crow-fly" method.

Other variables of interest extracted from the NCDB included: patient demographics (age at diagnosis, gender, race/ethnicity), comorbidity, socioeconomic status (median income of their neighborhood), insurance, census region, location of diagnosis, facility type, and cancer stage. Patient insurance status was defined as private, uninsured-charity, uninsured-self-pay, Medicaid, younger Medicare (age 18–64) and older Medicare (age ≥65). Race/ethnicity was categorized as non-Hispanic white, black, Hispanic, other and missing. Comorbidity was designated by the Charlson-Deyo comorbidity score based on medical conditions captured in comorbidity and complication fields. Median income in the neighborhood of a patient's residence was derived from 2000 US Census data and categorized based on national quartiles by ZIP code. Location of diagnosis was defined using the class of case codes. Initial diagnosis at reporting facility was defined by codes 10–14, while initial diagnosis elsewhere was defined by codes 20–22. Facility type was assigned by the CoC accreditation program.

Statistical Analysis

Geographic distribution of radiation oncologists was mapped by ArcGIS software (version 10.2.2). Patient characteristics were summarized overall, by density level of radiation oncologists, by travel distance, and by location of diagnosis. Chi-squared tests were used to determine if statistically significant differences existed at 0.05 levels. Generalized

Estimating Equations (GEE) clustering by HSA were utilized to examine the association between geographic access and receipt of RT, controlling for patient sociodemographic and clinical characteristics. GEE is a multivariate model that allows for potential correlation among patients within the same HSA. Pairwise comparison of interaction terms between main effects (radiation oncologist density, travel distance) and all other covariates were evaluated and included in the model if significant interaction was found. Two-sided p values with significance level at 0.05 were reported. All statistical analyses were performed using SAS 9.4 (Cary, NC).

Results

Geographic distribution of Radiation Oncologists Nationwide

A total of 4,253 radiation oncologists were identified. Figure 2 shows geographic distribution of radiation oncologists in quartiles at HSA level. Of 3436 HSAs in the U.S., 1053 (30.7%) HSAs have at least one radiation oncologist. The density levels from Q1 to Q4 are 0–1.46, 1.47–2.32, 2.33–4.22, and ≥4.23, respectively, and overall average density is 1.28 radiation oncologists (Interquartile range [IQR]: 1.25) per 100,000 residents. While over half of HSAs have no radiation oncologists, only 26.1% of population resided in those HSAs. The HSAs with no radiation oncologists were more likely to have smaller population (average 27000s–32000s residents) and in Midwest or South regions.

Sensitivity analyses were conducted using de-identified American Society for Radiation Oncology (ASTRO) membership data aggregated by ZIP code of practice location to define the number and location of radiation oncologists. Overall, geographic distribution of ASTRO-member radiation oncologists was similar to those based on Physician Compare but did not capture a greater number of radiation oncologists in majority of the HSAs.

Patient Characteristics

Among 26,845 rectal cancer patients identified as study cohort, nearly 70% of them received RT within 180 days of diagnosis or within 90 days of surgery (Table 1). Median age was 60 years (IQR: 17). Most RT, if performed, was received pre-operationally (75%) and in reporting facilities (68%). The majority (99%) of RT was external beam RT with median total dose of 50.4Gy. Median time from diagnosis to initiation of RT was 38 days while median time between initiation of RT and surgery was 84 days (prior to surgery).

Among those patients who did not receive RT, 6.5% of them received RT but in a later time period, with median time from diagnosis as 226 days and median time from surgery as 203 days (after surgery). Of others who did not receive RT, 86% of the reason for not receiving RT was “not part of first course of treatment”; 6% involved patient refusal; 3% was not recommended by doctors because of other risk factors; 1% was recommended by physicians but reason unknown why not administered; and 3% was recommended by doctors but unknown whether administered.

Around a quarter (27.8%) of patients resided in areas with no radiation oncologist (Supplementary Table 1). The majority (75%) of those residing in areas with no radiation oncologists sought treatment at facilities in areas with ≥1 radiation oncologists. Patients resided in areas with no radiation oncologists who traveled to seek RT were more likely to go to an academic comprehensive cancer program or NCI-designated facilities compared with patients resided in areas with radiation oncologists. As expected, most patients (75%) who resided in areas with ≥1 radiation oncologists did not seek treatment in areas with higher density of radiation oncologists.

Nearly half (45.8%) of patients had traveled <12.5 miles to the reporting facility (Supplementary Table 2A). Patients who resided in “no radiation oncologist” HSAs traveled almost three times as far to a reporting facility for treatment compared with those who resided in areas with ≥1 radiation oncologists (median distance: 30 vs. 11 miles, p<.001). Since there was a significant interaction between travel distance and diagnosis location (p<.001), stratified descriptive analyses showed that among patients diagnosed at reporting facility, those traveled ≥50 miles were less likely to receive RT than those traveled shorter distance (Supplementary Table 2B). This trend, however, was opposite among patients diagnosed elsewhere (Supplementary Table 2C).

Almost half (45.6%) of our study cohort were diagnosed elsewhere but treated at reporting facility (Table 2). Compared with patients diagnosed and treated at reporting facility, those diagnosed elsewhere were more likely to receive RT (65% vs. 75%, p<.001), reside in areas without any radiation oncologists (23% vs. 33%, p<.001), and travel ≥50 miles to reporting facility (7% vs. 23%, p<.001). Patients were less likely to seek treatment in different facilities if aged ≥76, black race, female, uninsured or Medicaid insured, with comorbidities, resided in areas with lower median income.

Factors associated with receipt of radiation therapy

The adjusted associations between geographic access to and receipt of RT are shown in Table 3 and stratified analyses by diagnosis location are presented in Supplementary Table 3. In univariate analysis (Supplementary Table 2A), receipt of RT was lower among whom traveled <12.5 miles. These untreated patients were more likely to be female, of non-white races, ≥50 years, had ≥1 comorbidities, lower income, non-private insurance, or resided in the South. However, after taking into account all the variables in multivariate analyses, patients diagnosed at reporting facility who traveled ≥50 miles had a decreased likelihood of receipt of RT (50–249 miles: adjusted Odds Ratio [aOR] 0.75, p=<.001; ≥250 miles: aOR 0.46, p=.002) than those traveled <12.5 miles. This likely indicates that the patient population varied significantly as distance from the reporting facility changed. Hence, taking into account these other variables is important in estimating the effect of distance.

Overall, density level of radiation oncologists was not significantly associated with receipt of RT. For patients diagnosed at reporting facility, lower density level of radiation oncologists had a trend in decreasing likelihood of receiving RT but without statistical significance in every level (Supplementary Table 3). On the other hand, for patients diagnosed elsewhere, those resided in areas with no radiation oncologist had greater likelihood in receipt of RT (aOR 1.21, p=0.04). In addition, for patients diagnosed at reporting facility, those treated at comprehensive cancer program, academic cancer program and NCI program had greater likelihood in receiving RT while there was no difference in receipt of RT across facility types for patients diagnosed elsewhere. Patients who were uninsured but self-paid for their medical services, diagnosed elsewhere, or resided in the Midwest region had increased likelihood of receiving RT.

Discussion

In this study, we observed two distinguished treatment patterns in receipt of RT. Among patients diagnosed and treated at reporting facility, those traveled ≥50 miles were less likely to receive RT compared with those traveled <12.5 miles, all else being equal, and there was a trend observed between radiation oncologist density and receipt of RT. On the other hand, among patients diagnosed elsewhere but treated at reporting facility, traveling longer distance was not associated with decreasing likelihood of receiving RT.

Despite the fact that combined RT, with or without chemotherapy, plus surgery has been a consensus guideline treatment for stage II/III rectal cancer patients, only 70% of our study cohort received RT. For the majority of those not receiving RT, the reason given was redundantly that RT was not included as part of first course of treatment. Similar RT underuse among patients in the SEER registry with 32.35% of stage II/III rectal cancer patients not receiving RT was reported.[2] Based on guidelines and expert opinion, the optimal utilization rate was estimated around 73.6% (±0.7%)[25]; however, the actual utilization rate was found lower.[26, 27] Similar to previous studies,[2, 27, 28] our study found that patients with older age, female sex and a diagnosis in earlier study years were associated with a decreased likelihood of receiving RT.

Possible explanations for underuse of RT include: referral to a radiation oncologist was not made, some radiation oncologists failed to follow treatment guidelines to deliver RT, and that these data under-report the use of RT given that NCDB is a hospital-based registry and outpatient RT might not be captured well. In a study evaluating completeness of NCDB treatment data by comparing with private payer claims in Ohio, NCDB captured 84% of RT in colorectal cases.[29] Similar under-ascertainment of RT was also reported by studies using population-based cancer registry data.[3031] Walker et al. reported that delay in the start of RT, residence in a newer cancer registry, advanced age or rural county were associated with under-ascertainment of RT. Therefore, even though CoC-accredited programs required facilities to capture all first course treatment, our study cannot rule out possible under-ascertainment of RT use in the NCDB.

A substantial variation in the density of radiation oncologists across the country was observed in this study, which is consistent with previous findings.[6, 7, 9, 32] Aneja et al. used the Area Resource File to examine geographic access to radiation oncologists.[6, 7] They reported that radiation oncologist density varies regionally and were inequitably distributed, being primarily located in metropolitan areas and being absent in 66% of 2472 counties or 44% of 949 Health Service Areas in the U.S. By using linked SEER-Medicare claims and the American Medical Association Masterfile, Baldwin et al. reported that one fourth of colorectal cancer patients did not have radiation oncology services available within 30 miles of their residence.[9] Since radiation oncologists cannot deliver external beam RT without a linear accelerator, geographic distribution of facilities equipped with radiation delivery units can also provide insights into RT accessibility. By merging data from the Radiologic Physics

Center, the Radiation Dosimetry Services, and the American Hospital Association and state health department, Ballas et al. identified 2246 unique radiation facilities in the U.S. and found that people in many rural areas would need to travel great distances to access RT.[32]

Despite geographical mal-distribution of radiation oncologists, radiation oncologist density was not statistically significantly associated with receipt of RT. It is likely that travel distance trumps density and that the clustering unit HSA does not accurately reflect referral/travel patterns for RT. On the other hand, it is quite encouraging that a great proportion of patients who resided in areas with no radiation oncologist still received RT by traveling to areas with ≥1 radiation oncologists. Interestingly, they were more likely to travel to academic or NCI-designated cancer programs, which might not be the nearest RT facility. It is possible these patients were seeking care from providers perceived to have more experience or better quality of care.[33, 34] However, some patients are unable to travel or obtain a referral. Our study showed that patients who were older, black, with comorbidities, uninsured or insured by Medicaid were less likely to change facility after diagnosis. Travel distance could be a barrier.

We found that travel distance to cancer treatment facility was a significant factor associated with decreased use of RT among rectal cancer patients diagnosed and treated at the same facility. Like the findings reported for other cancer diagnoses, traveling a long distance to cancer care decreased the likelihood of receiving standard treatment.[10, 13, 15, 27, 35, 36] Onega et al. and Punglia et al. found that travel distance to a RT facility was associated with the selection of treatment. They found that early-stage breast cancer women were more likely to select mastectomy instead of breast-conserving surgery plus post-operative RT when travel distance to nearest RT facility was longer.[13, 15] Mackillop et al.[27] found that cancer patients who resided >50 km from the nearest RT center had significantly lower rate of receiving RT. In addition, travel burden varied between different race/ethnicities. Guidry et al. reported that non-white patients were more likely to consider transportation (e.g. distance and lack of transportation) as a barrier to cancer treatment and possibly forgo needed treatment.[10] Onega et al. also found that black patients who resided in rural areas that required longer travel distance were less likely to access care, compared to rural whites.[35] Based on simulation results in finding optimal locations for radiation, studies suggested adding new centers in underserved areas or non-centralized small-city to improve geographic access.[37, 38]

Our study has several limitations. First, the NCDB captures only patients who are diagnosed or treated in CoC-accredited facilities and may not be representative of all cancer patients in the United States. However, when comparing stage II/III rectal cancer patients reported by the NCDB and the SEER18 (Supplementary Table 4), most of patient demographic and clinical characteristics were similar, except race/ethnicity. The NCDB identified fewer patients with Hispanic Ethnicity than the SEER.[39] Second, NCDB did not capture all RT locations to calculate travel distance. Since our entire study cohort made treatment decisions at reporting facilities and two-thirds received RT at reporting facility, travel distance to the reporting facility should be a sound proxy measure to estimate travel burden. Third, travel distance was measured between the centroids of ZIP codes of patient residence and reporting facility and might be underestimated if patient resided in the same ZIP code as the reporting facility. However, ZIP codes are the smallest geographic detail we can obtain for the study in order to protect patient privacy.

While many factors influence treatment decisions, geographic location is an important and potentially alterable factor that might affect treatment patterns. Further research in geographic access and establishing transportation assistance programs, or lodging services for patients with unmet need may help decrease geographic barriers and improve the quality of rectal cancer care.

Supplementary Material

Refer to Web version on PubMed Central for supplementary material.

Acknowledgments

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Summary

In a cohort of 26,845 stage II/III rectal cancer patients extracted from the National Cancer Data Base, we sought to examine the relationship between density of radiation oncologist and travel distance to receipt of radiation. Our findings showed that increased travel burden was associated with a decreased likelihood of receiving radiation therapy when all else being equal, but radiation oncologist density was not.

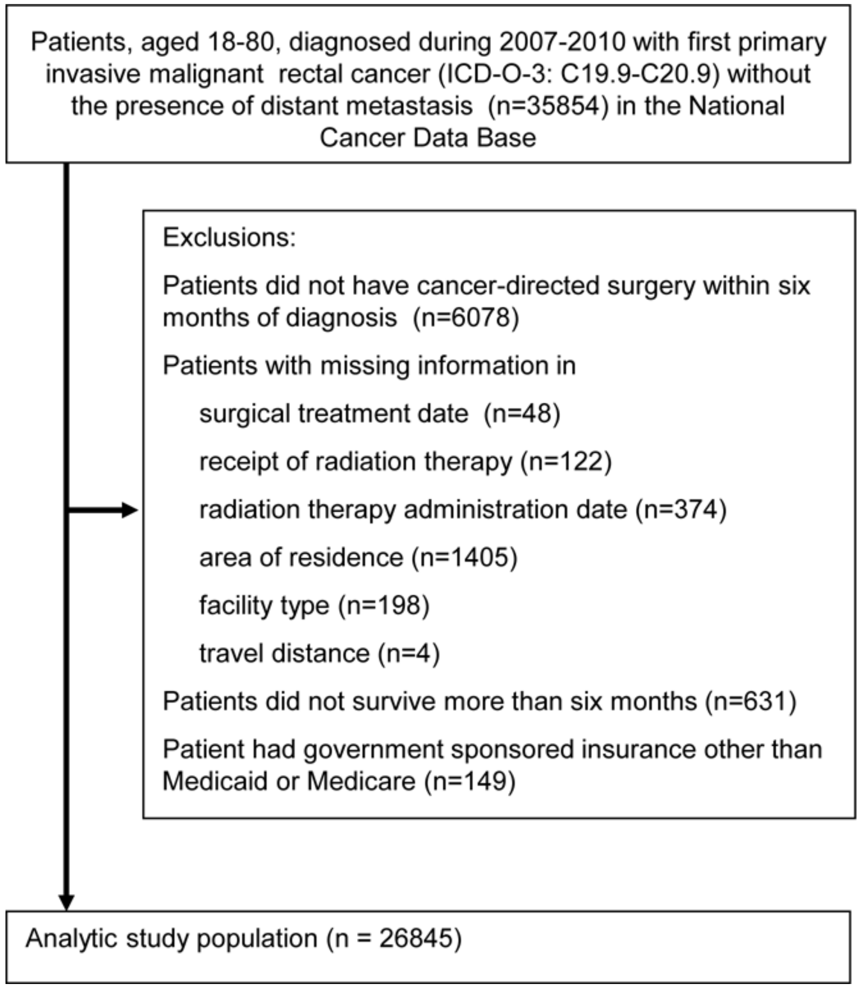
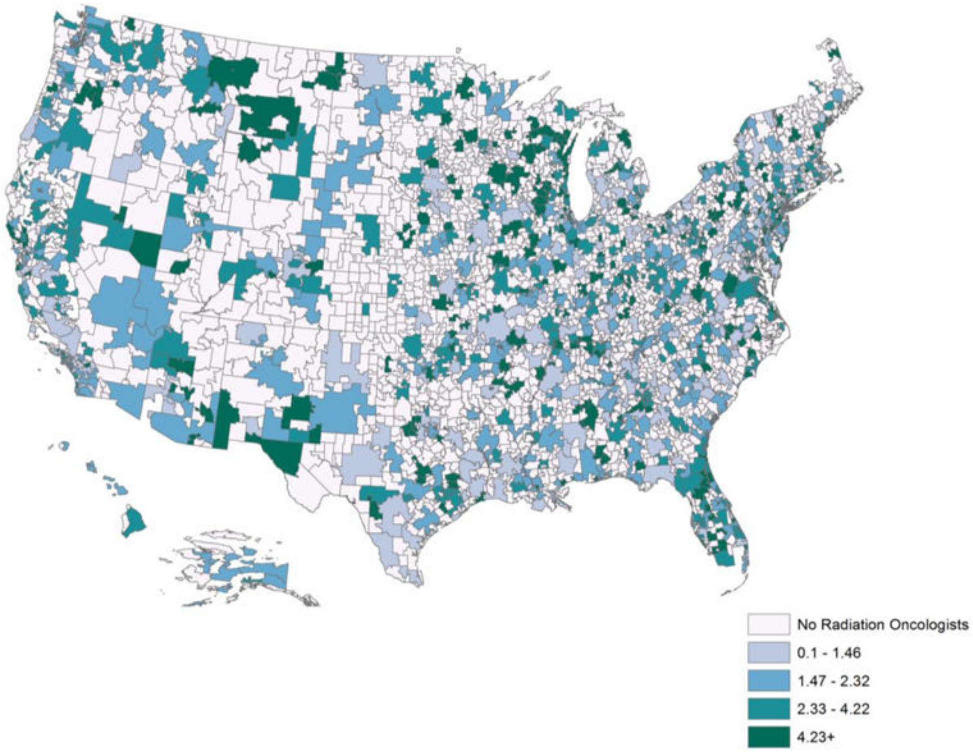


Figure 1.
Patient selection schema



	No RO	Q1 RO (low)	Q2 RO	Q3 RO	Q4 RO (high)
% of HSAs	69.4	7.65	7.65	7.65	7.65
% of population	26.1	23.1	21.8	19.9	9.0
% of study cohort	27.8	20.9	22.3	19.6	9.4
% of study cohort had no radiation therapy	25.2	22.4	23.1	20.4	8.9

Figure 2.
Radiation Oncologists per 100,000 residents by Hospital Service Area (HSA)

Table 1

Characteristics of Stage II–III rectal cancer patients

Categories	Total
	N=26845
	N (%)
Radiation Therapy	
No RT within 180 days of diagnosis	8169 (30.43)
have RT within 180 days of diagnosis	18676 (69.57)
Density of RO	
no RO	7467 (27.82)
RO_Q1 (low)	5609 (20.89)
RO_Q2	5993 (22.32)
RO_Q3	5254 (19.57)
RO_Q4(high)	2522 (9.39)
Travel Distance	
0–12.49 miles	12302 (45.83)
12.5–49.9 miles	10632 (39.61)
50–249 miles	3552 (13.23)
≥250 miles	359 (1.34)
Age Group	
18–50	6317 (23.53)
51–64	10779 (40.15)
65–70	4460 (16.61)
71–75	2941 (10.96)
76–80	2348 (8.75)
Gender	
Male	16171 (60.24)
Female	10674 (39.76)
Race/Ethnicity	
Non-Hispanic white	19939 (74.27)
Hispanic	1487 (5.54)
Black	2260 (8.42)
Others	1286 (4.79)
Missing	1873 (6.98)
Insurance	
Uninsured, self-pay	836 (3.11)
Uninsured, charity	459 (1.71)
Medicaid	1638 (6.1)
Younger Medicare	1194 (4.45)
Older Medicare	7939 (29.57)
Private	14413 (53.69)
Missing	366 (1.36)

Categories	Total
Diagnosis Year	
2007	7113 (26.5)
2008	6745 (25.13)
2009	6519 (24.28)
2010	6468 (24.09)
Stage	
Stage II	11202 (41.73)
Stage III	15643 (58.27)
Rural/Urban†	
Rural	5387 (20.07)
Urban	20988 (78.18)
Unknown	470 (1.75)
Region	
Northeast	5051 (18.82)
Midwest	7365 (27.44)
South	10126 (37.72)
West	4303 (16.03)
Median Income-Quartile 2000‡	
<$30,000	3761 (14.01)
$30,000–$34,999	5081 (18.93)
$35,000–$45,999	7428 (27.67)
$46,000+	10240 (38.14)
Missing	335 (1.25)
Facility Type	
Community Cancer Program	2939 (10.95)
Comprehensive Community Cancer Program	12808 (47.71)
Academic Comprehensive Cancer Program	5852 (21.8)
NCI Program/Network	2517 (9.38)
Other	2729 (10.17)
Charlson Comorbidity Score	
0	20576 (76.65)
1	4651 (17.33)
2+	1618 (6.03)
Diagnosis location	
Diagnosed at reporting facility	14607 (54.41)
Diagnosed elsewhere	12238 (45.59)

*Uninsured-charity was included for patients without insurance and for whom the facility declared their care as charity write-off. The uninsured-self-pay was defined as when patients have no insurance but are responsible for their own charges.

†Rural/Urban is based on 2003 Rural-Urban Continuum Codes developed by the United States Department of Agriculture, Economic Research Service. Counties whose continuum codes between 1 and 3 were considered urban while counties with continuum codes between 4 and 9 were grouped as rural.

‡Median Income is based on aggregate U.S. 2000 census data for the patient's residential ZIP code

Table 2

Characteristics of Stage II–III rectal cancer patients by location of diagnosis and factors associated with being diagnosed elsewhere

Categories	Diagnosed at reporting facility	Diagnosed elsewhere	χ^2 p-value	Adjusted Odds Ratio (95% CI)	P value
	N=14607 (54.4)	N=12238(45.6)			
	N (%)	N (%)			
Radiation Therapy					
No RT* within 180 days of diagnosis	5119 (35.04)	3050 (24.92)	< 0.0001		
have RT within 180 days of diagnosis	9488 (64.96)	9188 (75.08)			
Travel Distance					
0–12.49 miles	8205 (56.17)	4097 (33.48)	< 0.0001	1	
12.5–49.9 miles	5351 (36.63)	5281 (43.15)		1.7(1.59–1.83)	<.0001
50–249 miles	981 (6.72)	2571 (21.01)		3.92(3.45–4.44)	<.0001
≥250 miles	70 (0.48)	289 (2.36)		4.54(3.47–5.95)	<.0001
Density of Radiation Oncologist (RO)					
no RO	3339 (22.86)	4128 (33.73)	< 0.0001	1.41(1.21–1.64)	<.0001
RO_Q1 (low)	3183 (21.79)	2426 (19.82)		1.05(0.89–1.25)	0.5708
RO_Q2	3587 (24.56)	2406 (19.66)		0.98(0.82–1.17)	0.8407
RO_Q3	3067 (21)	2187 (17.87)		1.05(0.88–1.26)	0.5993
RO_Q4(high)	1431 (9.8)	1091 (8.91)		1	
Age Group					
18–50	3236 (22.15)	3081 (25.18)	< 0.0001	1	
51–64	5801 (39.71)	4978 (40.68)		0.96(0.9–1.03)	0.2835
65–70	2444 (16.73)	2016 (16.47)		0.92(0.82–1.04)	0.1916
71–75	1707 (11.69)	1234 (10.08)		0.89(0.78–1.01)	0.0784
76–80	1419 (9.71)	929 (7.59)		0.85(0.74–0.97)	0.0187
Gender					
Male	8703 (59.58)	7468 (61.02)	0.016	1	
Female	5904 (40.42)	4770 (38.98)		0.95(0.9–1)	0.0411
Race/Ethnicity					
Non-Hispanic white	10741 (73.53)	9198 (75.16)	< 0.0001	1	
Hispanic	822 (5.63)	665 (5.43)		0.97(0.85–1.1)	0.6197

Categories	Diagnosed at reporting facility	Diagnosed elsewhere	χ^2 p-value	Adjusted Odds Ratio (95% CI)	P value
Black	1394 (9.54)	866 (7.08)		0.88(0.8–0.98)	0.0161
Others	661 (4.53)	625 (5.11)		1.13(0.98–1.31)	0.0991
Missing	989 (6.77)	884 (7.22)		1.04(0.93–1.17)	0.4696
Insurance					
Uninsured, self-pay	554 (3.79)	282 (2.3)	< 0.0001	0.54(0.46–0.63)	<.0001
Uninsured, charity	311 (2.13)	148 (1.21)		0.48(0.38–0.6)	<.0001
Medicaid	939 (6.43)	699 (5.71)		0.8(0.71–0.91)	0.0003
Younger Medicare	660 (4.52)	534 (4.36)		0.92(0.81–1.04)	0.2011
Older Medicare	4529 (31.01)	3410 (27.86)		0.97(0.87–1.08)	0.5377
Private	7437 (50.91)	6976 (57)		1	
Missing	177 (1.21)	189 (1.54)		0.93(0.74–1.17)	0.5263
Diagnosis Year					
2007	3969 (27.17)	3144 (25.69)	0.015	1	
2008	3684 (25.22)	3061 (25.01)		1.06(0.98–1.14)	0.1381
2009	3518 (24.08)	3001 (24.52)		1.08(1–1.16)	0.0588
2010	3436 (23.52)	3032 (24.78)		1.1(1.02–1.18)	0.0093
Stage					
Stage II	6228 (42.64)	4974 (40.64)	0.0010	1	
Stage III	8379 (57.36)	7264 (59.36)		1.05(1–1.1)	0.0682
Rural/Urban†					
Rural	2321 (15.89)	3066 (25.05)	< 0.0001		
Urban	12052 (82.51)	8936 (73.02)			
Unknown	234 (1.6)	236 (1.93)			
Region					
Northeast	2772 (18.98)	2279 (18.62)	< 0.0001	1	
Midwest	4171 (28.55)	3194 (26.1)		0.95 (0.83–1.07)	0.3777
South	5395 (36.93)	4731 (38.66)		1.06 (0.94–1.2)	0.3207
West	2269 (15.53)	2034 (16.62)		1.12 (0.97–1.29)	0.1315
Median Income-Quartile 2000					
<$30,000	2008 (13.75)	1753 (14.32)	0.0002	0.89 (0.8–0.98)	0.0159
$30,000–$34,999	2635 (18.04)	2446 (19.99)		0.98 (0.9–1.06)	0.5991

Categories	Diagnosed at reporting facility	Diagnosed elsewhere	χ^2 p-value	Adjusted Odds Ratio (95% CI)	P value
$35,000–$45,999	4133 (28.29)	3295 (26.92)		0.99 (0.91–1.07)	0.7533
$46,000+	5644 (38.64)	4596 (37.56)		1	
Missing	187 (1.28)	148 (1.21)		0.92 (0.73–1.16)	0.4956
Facility Type					
Community Cancer Program	1959 (13.41)	980 (8.01)	< 0.0001	1	
Comprehensive Community Cancer Program	7517 (51.46)	5291 (43.23)		1.29 (1.14–1.46)	<.0001
Academic Comprehensive Cancer Program	3047 (20.86)	2805 (22.92)		1.84 (1.59–2.13)	<.0001
NCI* Program/Network	556 (3.81)	1961 (16.02)		5.65 (4.64–6.87)	<.0001
Other	1528 (10.46)	1201 (9.81)		1.55 (1.31–1.85)	<.0001
Charlson Comorbidity Score					
0	10868 (74.4)	9708 (79.33)	< 0.0001	1	
1	2681 (18.35)	1970 (16.1)		0.83 (0.78–0.89)	<.0001
2+	1058 (7.24)	560 (4.58)		0.62 (0.55–0.7)	<.0001

*RT, Radiation Therapy; NCI, National Cancer Institute

†Since rural/urban status is highly correlated with travel distance, it was not included in the multivariate analyses.

Table 3

The likelihood of receipt of radiation therapy among stage II–III rectal cancer patients

Categories	OR(95% CI)	p value
Travel distance		
(When diagnosed at reporting facility)		
0–12.49 miles	1	
12.5–49.9 miles	0.94(0.87–1.02)	0.1694
50–249 miles	0.75(0.65–0.87)	0.0002
≥250 miles	0.46(0.28–0.74)	0.0015
(When diagnosed elsewhere)		
0–12.49 miles	1	
12.5–49.9 miles	1.11(1.01–1.22)	0.0318
50–249 miles	1.05(0.92–1.19)	0.4331
≥250 miles	0.98(0.74–1.31)	0.9105
Density of Radiation Oncologist (RO)		
No RO	1.04(0.92–1.19)	0.5359
RO Q1 (low)	0.9(0.78–1.04)	0.1435
RO Q2	0.95(0.83–1.09)	0.4848
RO Q3	0.9(0.79–1.04)	0.1469
RO Q4 (high)	1	
Age Group		
18–50	1	
51–64	0.88(0.81–0.94)	0.0006
65–70	0.7(0.62–0.79)	<.0001
71–75	0.54(0.47–0.62)	<.0001
76–80	0.41(0.36–0.48)	<.0001
Race/Ethnicity		
Non-Hispanic white		
Hispanic	0.85(0.75–0.95)	0.0064
Black	0.8(0.72–0.88)	<.0001
Others	0.86(0.75–0.99)	0.0312
Missing	0.96(0.85–1.09)	0.5636
Gender		
Male	1	
Female	0.8(0.76–0.85)	<.0001
Insurance		
Private	1	
Uninsured, self-pay	1.21(1.02–1.44)	0.03
Uninsured, charity-waive	1.17(0.93–1.48)	0.179
Medicaid	1.08(0.96–1.22)	0.1878
Younger Medicare	0.92(0.81–1.06)	0.2555
Older Medicare	1.09(0.97–1.21)	0.1448

Categories	**OR(95% CI)**	**p value**
Missing	1.01(0.81–1.26)	0.9454
Stage		
Stage II	1	
Stage III	0.99(0.94–1.05)	0.8199
Charlson Comorbidity Score		
0	1	
1	0.83(0.77–0.89)	<.0001
2+	0.64(0.57–0.71)	<.0001
Diagnosis Year		
2007	1	
2008	0.98(0.91–1.06)	0.6626
2009	1.04(0.96–1.13)	0.3078
2010	1.05(0.98–1.14)	0.1787
Median Income-Quartile 2000		
<$30,000	1.04(0.95–1.14)	0.4313
$30,000–$34,999	1.14(1.04–1.24)	0.0038
$35,000–$45,999	1.08(1.01–1.16)	0.0177
$46,000+	1	
Missing	1.21(0.93–1.57)	0.1541
Facility Type		
Community Cancer Program	1	
Comprehensive Community Cancer Program	1.16(1.04–1.29)	0.0077
Academic Comprehensive Center Program	1.05(0.93–1.19)	0.3912
NCI Program/Network	1.3(1.11–1.53)	0.0013
Other	1.25(1.08–1.44)	0.003
Region		
Northeast	1	
Midwest	1.29(1.16–1.43)	<.0001
South	0.99(0.89–1.09)	0.779
West	1.02(0.91–1.15)	0.7118
Diagnosis location		
Diagnosed elsewhere	1.41(1.29–1.54)	<.0001
Diagnosed at reporting facility	1	