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Critical Review

The Relationship Between Travel Distance for Treatment and Outcomes in Patients Undergoing Radiation Therapy: A Systematic Review

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Purpose: Although recent technological advances in radiation therapy have significantly improved treatment outcomes, the global distribution of radiation therapy is unbalanced, making access especially challenging for patients in rural or low-resource settings because of travel burden. This systematic review aimed to explore the impact of geographic distance to treatment facilities on survival, as well as other treatment outcomes, among patients undergoing radiation therapy.

Methods and Materials: A search of four databases (PubMed, Embase, CINAHL, and Web of Science) was performed. Studies were included if they were primary literature, published between May 2000 and May 2023, and reported the travel distances for patients undergoing radiation therapy for malignant conditions and its influence on survival outcomes. Studies were excluded if they did not report primary outcomes, were published before 2000, or were non-English.

Results: After review, 23 studies were included. Most studies were conducted in the United States, with cervical cancer being the most frequently studied disease site. Data suggested that travel distances vary significantly, with patients often traveling a median distance of 20 miles to radiation therapy. Among the studies, 5 reported a negative impact on overall survival, often associating greater travel with nonadherence to recommended care. Other survival metrics, including progression-free survival and all-cause mortality, were also assessed, demonstrating similar variability in relation to travel distance. Conversely, seven studies found no significant impact on overall survival, and four suggested a positive impact on overall survival, with improved outcomes at centers with higher case volumes. Some data also revealed an inverse correlation between travel distance and the likelihood of receiving guideline-concordant radiation therapy.

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Conclusions: The impact of travel distance on radiation therapy outcomes is varied. Our findings underscore the challenges posed by travel in accessing radiation therapy and the disparities affecting particular patient demographic groups. Additional studies are needed to thoroughly assess the impacts of geographic disparities and to identify effective measures to address these challenges.
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Introduction

Over the past two decades, the field of radiation oncology has witnessed remarkable technological advancements.[1,2] As a result, the precision and efficacy of radiation treatments have improved substantially, contributing to higher survival rates and reduced toxicities.[1,2] Evidence of this progress is seen in the increase in locoregional tumor control rates after primary radiation therapy, which has risen from 30% in the 1980s to ~80% today.[1] Despite these advancements, the availability and application of such technologies are not uniform globally, with >90% of the population in low-income countries lacking access to radiation therapy services.[3] This discrepancy highlights the considerable obstacle that geographic location presents in accessing and benefiting from these advanced radiotherapeutic techniques.[4]

In the United States and globally, the accessibility of radiation therapy services varies considerably.[5] Patients in rural or low-resource areas frequently face a greater travel burden to reach treatment centers.[6,7] The challenges associated with long-distance travel, including the associated time, cost, and inconvenience, not only affect patients' decisions regarding the pursuit of radiation therapy but can negatively impact their overall treatment experience and outcomes.[8-12] Additionally, the stress of traveling for treatment can have significant psychological impacts, affecting patients' overall quality of life and well-being.[13,14] Despite the clear burden that travel places on patients, a thorough examination of how the global differences in the distances patients travel for radiation therapy services impact treatment outcomes has yet to be conducted.

This systematic review investigates the relationship between geographic distance and survival, including overall survival, mortality-to-incidence ratio, and progression-free survival, for patients undergoing radiation therapy globally. We also explored the impact of travel distance on other aspects of treatment, such as treatment adherence and receipt of guideline-concordant care. By examining the literature, we aimed to contribute to a deeper understanding of the challenges and disparities associated with accessing radiation therapy services.

Methods and Materials

This systematic review followed the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines.[15] The complete checklist is included in the Supplementary Material – Appendix.

Search strategy

Eligible studies were identified by searching PubMed, Embase, CINAHL, and Web of Science. The complete search strategy can be found in Supplementary Material – Appendix B. These searches were completed between May 2023 and June 2023 and pertained to material published within the last 23 years, from May 2000 to May 2023.

Selection criteria

All observational, retrospective, and either randomized or nonrandomized studies that reported on distance traveled (in miles or kilometers) and overall survival, along with other survival metrics, such as mortality-to-incidence ratios and progression-free survival (as outlined below in Data items), among patients undergoing radiation therapy were included. Studies were excluded if they were not written in English, were not primary literature, or were published before May 2000.

Study selection and data collection process

The studies for this review were selected using Covidence software (Fig. 1). Two reviewers independently screened all titles and abstracts, blinded to one another's decisions. A study was included if both reviewers independently determined fulfillment of inclusion criteria. The same process was followed for full-text review, with any disputes discussed among the authors and, if necessary, resolved by a third reviewer.

Data items

The primary outcomes of interest were distance traveled for treatment and survival in patients undergoing radiation therapy. To comprehensively evaluate survival, a range of metrics were included, such as overall survival, mortality-to-incidence ratio, cancer-specific survival, progression-free survival, treatment-related mortality, and recurrence-free survival. Data were also

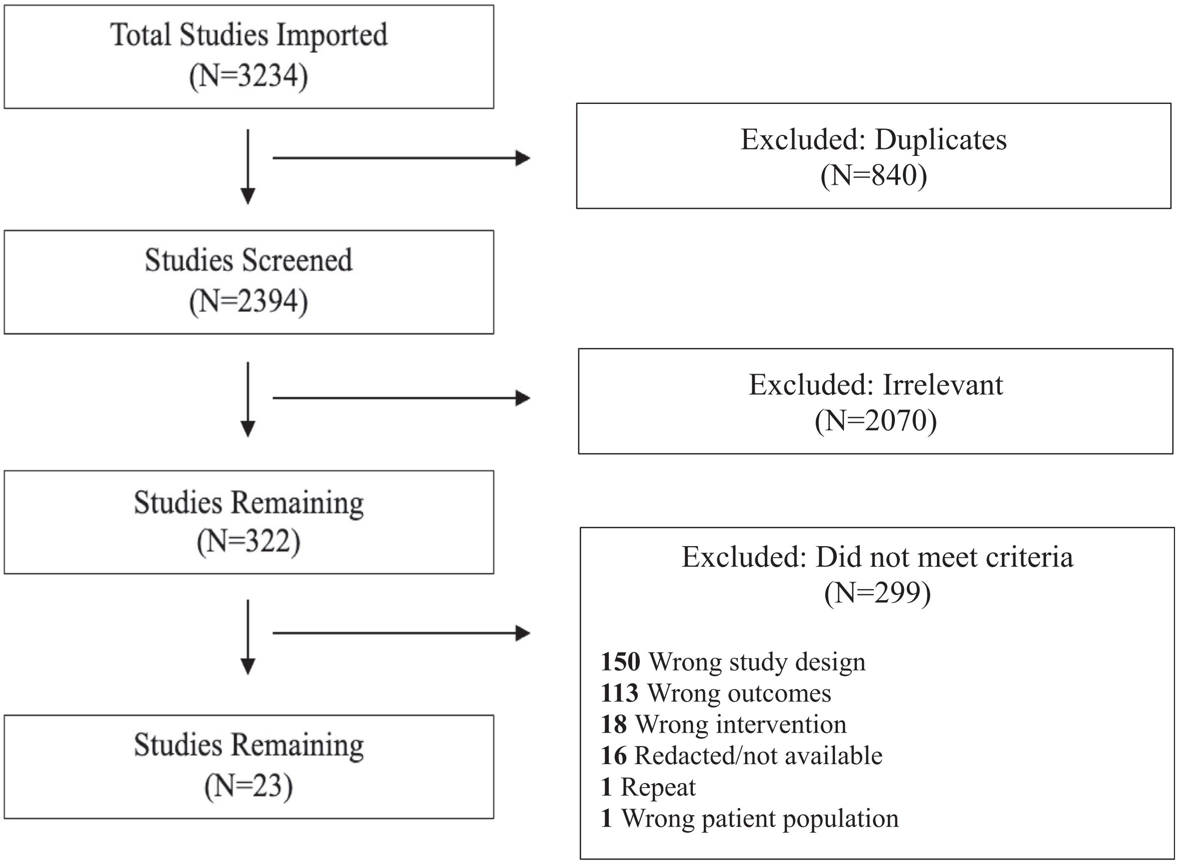

Figure 1 Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) flow diagram.

gathered on additional treatment-related outcomes such as treatment adherence, adherence to care guidelines, and follow-up adherence. Additionally, information was collected on costs related to travel and transportation, differences in survival outcomes between urban and rural communities, and the relationship between insurance status and the distance traveled for treatment. To facilitate consistent comparisons across studies, travel distances initially reported in kilometers were converted and standardized to miles. Two authors performed data extraction independently, with discrepancies discussed and resolved by both or, if necessary, by a third author.

Data analysis

The Newcastle−Ottawa Quality Assessment form was used to evaluate the risk of bias for the cohort studies and the cross-sectional study (Supplementary Material − Appendix C). Descriptive statistics were conducted using Microsoft Excel.[16]

Results

Study characteristics

From the initial identification of 3234 articles, 23 studies were included in the final analysis. Studies were excluded for several reasons, including duplication of existing studies, incorrect study design, non−English language publications, patients not receiving radiation therapy, and lack of reported distance and/or survival data (Fig. 1). Most studies (17 studies, 74%) were conducted in the United States, whereas two studies originated from Australia and two from Canada (Table 1). In 56% of studies, the radiation therapy treatment modality (ie, external beam radiation therapy, stereotactic body radiation therapy, among others) was not specified. Cervical cancer was

Table 1 Study characteristics (n = 23)

Category	Study characteristics	N (%)
Countries of study	United States	17 (74)
	Australia	2 (9)
	Canada	2 (9)
	Greece	1 (4)
	South Wales	1 (4)
Study design	Cohort	22 (95)
	Cross-sectional	1 (4)
Disease site	Cervical cancer	5 (22)
	Sarcoma	3 (13)
	Non-small cell lung cancer	3 (13)
	Head and neck cancer	2 (9)
	Breast cancer	2 (9)
	Rectal cancer	2 (9)
	Medulloblastoma	1 (4)
	Mesothelioma	1 (4)
	Not specified	1 (4)
	Sinonasal malignancies	1 (4)
	Prostate cancer	1 (4)
	Anal squamous cell carcinoma	1 (4)

the most common disease site reported (5 studies, 22%), followed by sarcomas and (13) non−small cell lung cancer (3 studies each, 13%), as shown in Table 1.

Distance traveled

The median distance traveled by patients to their treating facility was <20 miles, despite a significant range observed across different studies from 0 to 5040 miles (Table 2).[17-35] Specifically, six studies found that patients traveled further for treatment at high-volume academic centers.[17-21] For example, Liu et al.[21] found that patients traveled a median distance of 1008 miles, ranging from 0.6 to 5817 miles, to receive radiation therapy at MD Anderson Cancer Center.

Most studies (15 studies, 62%) demonstrated demographic and socioeconomic factors influencing travel distances. These included race, socioeconomic status, and insurance coverage. For example, one study found that compared with those traveling <15 miles, patients traveling 15 miles or more were more likely to be Caucasian, younger, and covered by private insurance or Medicare.[22] Another study revealed that living at a greater distance from cancer treatment centers not only correlated with a non-Hispanic ethnic background but was also linked to residing in economically underprivileged and rural regions.[36] Socioeconomic status, insurance coverage, and demographic characteristics also influenced patients' access to cancer treatment and outcomes. Hung et al[36] found that Black patients and those living farther than 30 minutes from the nearest provider experienced longer delays in treatment initiation. These findings align with those of Showalter et al,[23] who identified predictors of increased mortality risk, including being unmarried, older age, Black race, and having more comorbidities. Furthermore, Nasioudis et al[24] highlighted racial disparities in treatment modalities, with Black women being less likely to receive external beam radiation therapy compared with White women (P = .037), which was associated with inferior overall survival.

Impact of travel distance on overall survival

Across the studies, most (18 studies, 78%) examined the impact of distance on overall survival with mixed results (Table 3).[18-20,22,24-33] For example, Moten et al[22] found no significant difference in the 5-year overall survival rate of patients who traveled ≥15 miles to treatment and those who traveled <15 miles (66.7% vs 66.4%, respectively; P = .36). Similarly, six other studies reported no significant impact of travel distance on overall survival.[20,25-28,37] Conversely, Sura et al and Panagopoulou et al found a negative association between travel distance and overall survival, suggesting that longer distances may be linked to poorer survival outcomes.[29,30] Specifically, Sura et al[29] focused on patients with lung cancer across the United States and found distances ≥50 miles versus <50 miles after multivariate analysis were associated with inferior overall survival. Additionally, a US-based study by Longacre et al,[31] focusing on patients with breast cancer, found that individuals residing >50 miles from a radiation facility in the United States initially experienced poorer survival outcomes compared with those within 10 miles (P < .001). However, the negative correlation between survival and distance ceased to be significant in the multivariable Cox model when patients received guideline-concordant care.[31] Meanwhile, four studies[18,19,32,33] reported improved overall survival for patients traveling further distances. Three studies[18,20,32], specifically, indicated that patients treated at high-volume centers, often determined by case volume, tended to experience improved survival rates despite longer travel.

Impact on other survival metrics

The relationship between travel distance and other survival metrics also demonstrated varied impacts (Table 4).[18-22,24-33] Chan et al[34] and Loree et al[25] reported adverse outcomes associated with longer travel distances in Canada, indicating that increased distance can exacerbate all-cancer mortality-incidence

Table 2 Average distance traveled across studies (n = 23) by patient volume and study characteristics (n = 23)

Reference	Number of patients	High- vs low-volume centers	Average distance reported
Moten 2020 [22]	11,085	No information on hospital volume	Median distance traveled was 15.6 miles, with a range of 0 to 5040 miles. 49.0% traveled < 15 miles, and 51.0% traveled ≥ 15 miles.
Chan 2019 [34]	162,515	No information on hospital volume	Median distance to nearest radiation therapy center was 63.21 miles (range, 0.71-1301.85).
Loree 2017 [25]	2723	No information on hospital volume	Median distance was 11.68 miles (IQR, 5.22-61.52).
Showalter 2016 [36]	External beam RT − 802 Brachytherapy − 565	Treatment at high-volume center Yes: 876 (87.2) No: 129 (12.8) Missing: 43 (−)	Mean driving distance to the largest volume treatment facility was 26 miles (median, 14 miles). Mean straight-line distance to nearest high-volume facility was 16 miles (median, 7 miles).
Sura 2018 [29]	1629	No information on hospital volume	Not listed
Vetterlein 2017 [17]	168,183	Facility caseload quartiles, no. of cases per y <.001 >254: 192,033 (24.8) 141-254: 194,924 (25.1) 74-140: 177,702 (22.9) <74: 211,340 (27.2)	Distances categorized as short if <12.5 miles (4.5% of patients), intermediate if 12.5-49.9 miles (33.4% of patients), and long if 50-249.9 miles (12.1% of patients) to their treating facility.
Gunderson 2013 [26]	159	No information on hospital volume	<15 Miles (29%), 15-30 miles (21%), 30-50 miles (17%), >50 miles (33%).
Nasioudis 2020 [24]	3436	No information on hospital volume	Travel distance (miles) $P < .001$ No EBRT <12.5 miles 432 (42.1) 1251 (52.9) 12.5-49.9 miles 364 (35.5) 808 (34.2) ≥50 miles 230 (22.4) 304 (12.9)
Lazarides 2019 [18]	12,435	9 High-volume centers (≥20 STS-E patients annually): 3310 patients 1263 low-volume centers (<20 patients annually): 22,096 patients	6299 Patients traveled < 6 miles to low-volume centers, and 1806 patients traveled > 42 miles to high-volume centers.
Graboyes 2018 [19]	33,354	Facility annual volume, quartiles 1-9: 27,447 patients 9 to 17: 30,574 patients 17 to 43: 29,050 patients 43: 30,929 patient	Mean travel distance was: 5, 15, and 94 miles for short, intermediate, and long distances, respectively.
Rauh 2018 [27]	180	High volume: 180 (all)	The median distance to University of Virginia was 72.0 miles.
Mell 2010 [35]	479	No information on hospital volume	Distance traveled was >15 miles for 267 patients (55.7%).

(*continued on next page*)

Table 2 (*Continued*)

Reference	Number of patients	High- vs low-volume centers	Average distance reported
Ngoo 2020[53]	207	No information on hospital volume	Mean distance ± SD (range) was 160.87 ± 166.59 miles; 81.6% of patients were from remote communities and 55.1% traveled >200 km for treatment.
Liu 2021 [21]	96	No information on hospital volume	Median distance from MD Anderson was 1008 miles, with a range of 1-5817.28 miles.
Ramey 2018 [28]	Non-IMRT, nonproton: 4079 IMRT, proton: 3153	Reporting facility anal cancer patient volume Lower third of facilities 996 (7.9) Middle third of facilities 2635 (21.0) Upper third of facilities 8915 (71.1)	Distances to the reporting center were categorized by miles: ≤10 (55.9%), 11-20 (20.5%), 21-50 (16.1%), >50 (6.8%). Average distances were not clearly defined but varied by category.
Longacre 2021 [31]	26,606	No information on hospital volume	75% of Patients lived within 10 miles of a radiation facility, and 10% lived at least 25 miles away.
Burmeister 2010[54]	1535	No information on hospital volume	62% Lived within 31.07 miles of a center, 13% lived 31.07-124.27 miles away, and 25% lived >124.27 miles away.
McGunigal 2021[55]	7270	No information on hospital volume	Half of PORT patients resided within 10 miles of treatment facility.
Wang 2021 [20]	12,576	High volume centers: 988 patients Low volume centers: 886 patients	Median travel distance was 9.6 miles, with patients in the highest quartile traveling ≥ 23.0 miles.
Schmitz 2019 [32]	689	Long distance to high-volume centers: 1250 Local, low-volume centers: 1309	Median travel distance was 14 miles. The short patient travel to low-volume hospitals (ST/LV) group traveled a median of 4 miles to local centers, whereas the long patient travel to high-volume hospitals (LT/HV) group traveled a median distance of 56 miles.
Dioso 2023 [33]	88 Urban 22 Rural	No information on hospital volume	Rural patients traveled an average of 44.4 miles (SD 52.1), and urban patients traveled an average of 10.4 miles (SD 11.0).
Linton 2017 [37]	36	No information on hospital volume	Geographic remoteness categorized as major city (67%) and regional/remote (33%); distance to oncological multidisciplinary teams was <10 km for 65%, <50 km for 92%.
Panagopoulou 2012 [30]	2823	No information on hospital volume	Not reported

Table 3 Overall survival outcome (n = 18)

Reference	Reported overall survival outcomes.	Impact of longer travel distance on OS
Moten 2020 [22]	For all stages combined, there was no significant difference in the 5-y OS of patients who traveled ≥15 miles and those who traveled <15 miles to treatment (66.7% vs 66.4%, *P* = .36).	No impact
Loree 2017 [25]	Living >62 miles away from a treatment center was not associated with worse OS (HR, 1.21 [95% CI, 0.93-1.57], *P* = .16).	No impact
Sura 2018 [29]	After multivariate Cox regression analysis distance < 50 miles vs ≥ 50 miles (*P* value = .079; OR, 0.749 [95% CI, 0.542-1.035]).	Negative
Gunderson 2013 [26]	4-y Overall survival (57% vs 62%; *P* = .73) were similar between those traveling <30 miles and >30 miles.	No impact
Nasioudis 2020 [24]	Rates of EBRT administration for patients who traveled short vs intermediate vs long distances were 74.3%, 68.9%, and 56.9%, respectively (*P* < .0001). Patients who received adjuvant EBRT (n = 2225) had better OS than those who did not (n = 988) (*P* < .001); 5-y OS rate was better with adjuvant EBRT vs without adjuvant EBRT (79.9% vs 70.9%, *P* < .0001).	Negative
Lazarides 2019 [18]	Despite traveling longer distances, patients who traveled to a high-volume center (>41.7 miles, highest quartile) also had improved 5-y OS and a lower risk of mortality (HR, 0.79 [95% CI, 0.73-0.85], *P* < .001).	Positive
Graboyes 2018 [19]	Long distance travel was associated with treatment at academic centers. Traveling a long distance for treatment (50-249.9 miles) was associated with improved OS (HR, 0.93 [95% CI, 0.89-0.96]).	Positive
Rauh 2018 [27]	No significant difference was found in OS (*P* = .43) when comparing patients who lived <72 miles vs >72 miles from the academic center.	No impact
Ramey 2018 [28]	There were significant distance-related disparities in survival rates. Multivariable analysis assessing impact of distance on OS Distance — HR (95% CI — *P* value ≤10 miles — Reference 11-20 miles — 0.95 (0.83-1.08) — .443 11-20 miles — 0.95 (0.81-1.12) — .565 50 miles — 0.93 (0.74-1.17) — .559	No impact
Longacre 2021 [31]	Patients with NSCLC who lived >124 miles from a treatment center had slightly worse survival than those who lived <31 miles away (HR, 1.14 [95% CI, 1.00-1.31], *P* = .057).	Negative
Burmeister 2010[54]	Patients with NSCLC who lived >124 miles from a treatment center had slightly worse survival than those who lived <31 miles away (HR, 1.14 [1.00-1.31] *P* = .057).	Negative
Wang 2021 [20]	There was no association between travel distance and OS. Compared with women receiving treatment at a low volume, local hospital, women who traveled to a high-volume center had decreased mortality (HR, 0.80 [95% CI, 0.68-0.95]).	No impact
Schmitz 2019 [32]	OS was significantly improved for patients who traveled long distances to high-volume centers vs patients who traveled shorter distances to low-volume centers (HR, 0.73 [95% CI, 0.60-0.88], *P* = .0009).	Positive
Dioso 2023 [33]	Patients from Frontier counties traveled an average of 98.4 miles (SD, 60.0), rural patients traveled an average of 44.4 miles (SD, 52.1), and urban patients traveled an average of 10.4 miles (SD, 11.0) to receive definitive RT. Frontier patients demonstrated longer survival when compared with urban patients with squamous cell carcinomas (100.6 [86.9] vs 72.5 [93.3]) and neuroendocrine tumors (110.0 [SD 91.0] vs 73.7 [SD 96.3]).	Positive
Linton 2017 [37]	There was no significant difference in OS between patients residing in major cities and patients living within 31 miles of oncological multidisciplinary teams (*P* = .539).	No impact
Panagopoulou 2012 [30]	Travel distances > 217 miles and traveling times > 4 h were independently associated with worse outcomes (HR = 1.43 [95% CI, 1.06-1.94], *P* = .03 and HR, 1.34, *P* = .01, respectively).	Negative

Abbreviations: EBRT, external beam radiation therapy; HR, hazard ratio; OS, overall survival; RT, radiation therapy; NSCLC, non-small cell lung cancer.

ratios and cancer-specific survival. A US-based study focused on patients with head and neck cancer in California similarly noted a negative association with treatment-related mortality for patients traveling >15 miles.[35] In contrast, Vetterlein et al.[17] found a positive relationship between long travel distances and overall mortality rates in patients with prostate cancer. Additionally, Schmitz et al[32] showed that 30-day mortality significantly improved in patients who traveled long distances to high-volume centers versus those who

Table 4 Other metrics of survival (n = 12)

Reference	Reported survival outcomes.	Metric	Impact of travel distance on survival
Chan 2019 [34]	Distance to RT was found to be statistically significant predictor of increased all-cancer MIR (worse outcomes) ($P < .01$).	MIR	Negative
Loree 2017 [25]	Living > 62 miles away from a treatment center was associated with worse CSS (HR, 1.39 [95% CI, 1.03-1.88], $P = 0.031$).	CSS	Negative
Showalter 2016 [36]	Distance to a high-volume facility related to all-cause mortality with increasing distance up to ≥41 miles showed incremental risk. Distance to high-volume facility (vs ≥ 29 miles) Distance HR (95% CI) <3.5 miles 0.80 (0.52, 1.24) 3.5-8.1 miles 0.84 (0.54, 1.30) 8.1-29.0 miles 0.91 (0.62, 1.34) 29+ miles 1.00 referent Distance to treatment facility (vs ≥41 miles) Distance HR (95% CI) <6.7 miles 0.93 (0.63, 1.36) 6.7-16.7 miles 1.09 (0.76, 1.55) 8.1-29.0 miles 1.15 (0.84, 1.56) 29+ miles 1.00 referent	All-cause mortality	Negative
Vetterlein 2017 [17]	Long travel distance [49.9-249.9 miles] was associated with favorable overall mortality rates in patients who underwent radiation therapy (HR, 0.85 [95% CI, 0.79-0.91], $P < .001$).	Overall mortality	Positive
Gunderson 2013 [26]	4-y PFS (53% vs 52%; $P = .992$) were similar between those traveling <30 miles and >30 miles.	PFS	No impact
Lazarides 2019 [18]	Despite traveling longer distances, patients who traveled to a high-volume center (>41.7 miles, highest quartile) also had improved 5-y OS and a lower risk of mortality (HR, 0.79 [95% CI, 0.73-0.85], $P < 0.001$).	Mortality	Positive
Mell 2010 [35]	Distance traveled (>15 miles: HR, 0.36 [95% CI, 0.18-0.74], $P = .006$) was a strong predictor of treatment-related mortality.	Treatment-related mortality	Negative
Liu 2021 [21]	There was no statistically significant association for 3-y failure-free survival between residing >1066 miles than for patients residing ≤ 1066 miles from MD Anderson (HR, 1.34 [95% CI, 0.65-2.74], $P = .43$).	Freedom from survival	No impact
Rauh 2018 [27]	No significant difference was found in PFS ($P = .49$) when comparing patients who lived <72 miles and >72 miles from the academic center.	PFS	No impact
Ngoo 2020[53]	Neoadjuvant type, remoteness, socioeconomic indices, and distance from treatment were not prognostic on univariate or multivariate analysis for cancer-specific survival or recurrence-free survival.	CSS, recurrence-free survival	No impact
McGunigal 2021[55]	Distance traveled showed varied predictors of mortality, with some distances associated with higher hazard ratios. Predictors of mortality Distance HR (95% CI) *P* value 20-50 miles 1.25 (1.05, 1.48) 0.01 >50 miles 0.86 (0.69, 1.07) 0.18 Unknown 1.23 (0.64, 2.34) 0.53	Mortality	No impact
Schmitz 2019 [32]	Improved 30-d mortality and long-term survival for patients traveling longer distances to high-volume centers, with a 27% survival benefit after adjustment.	30-d Mortality	Positive

Abbreviations: CSS, cancer-specific survival; MIR, mortality-to-incidence ratio; PFS, progression-free survival.

stayed closer to home and received care at lower-volume centers. However, studies such as Gunderson et al[26] and Rauh et al[27] showed no significant impact of travel distance on progression-free survival.

Impact on care delivery

Several studies investigated the secondary effects of travel distance on treatment outcomes. Research by Liu et al.[21] demonstrated that pediatric patients with medulloblastoma living >1066 miles from treatment centers experienced a delay in treatment initiation of 1 to 2 weeks compared with those living closer. This is corroborated by Ramey et al,[28] who noted longer times for treatment initiation for patients traveling >50 miles. Results from studies conducted by Hung et al. and Moten et al. also echo these findings.[22,36] Furthermore, the data revealed a correlation between travel distance and the likelihood of receiving guideline-concordant radiation therapy.[22-24,31,34] For instance, the integration of brachytherapy and external beam radiation therapy for cervical cancer, a standard recommended by cancer care guidelines, was markedly lower among patients facing substantial travel distances.[34] Meanwhile, another study focused on patients with cervical cancer found that the rate of external beam radiation therapy administration was significantly lower among patients who traveled intermediate (12.5-49.9 miles) and long (≥50 miles) distances.[24]

Three studies specifically focused on treatment patterns among rural patients.[17,25,33] One study on rural patients with rectal cancer indicated a trend toward a lower probability of receiving radiation therapy ($P = .08$) and a higher likelihood of undergoing surgery ($P = .051$). Moreover, rates of radiation therapy were found to be lowest in rural areas (83.5%) compared with urban centers (88.0% for large [100,000+], 87.8% for medium [30,000−99,999], and 88.1% for small [1,000-29,999] communities, $P = .0057$).[25] The time between diagnosis and oncology consultation was also significantly longer for rural patients. Specifically, patients living >62 miles from a treatment center experienced longer delays from diagnosis to consultation than those within close proximity ($P < .0001$).[25]

Discussion

Our study showed a wide range of travel distances to treatment facilities, highlighting that patients frequently undertake long journeys to access care, especially when seeking treatment at high-volume academic institutions. Demographic and socioeconomic variables, including race, socioeconomic status, and insurance coverage, play a significant role in these travel patterns and treatment outcomes. Notably, patients traveling longer distances for treatment and those more significantly affected by travel often belonged to specific demographic groups, particularly rural[33] and Black patients,[36] underscoring underlying inequities in health care access. Overall, the data from this review emphasize how distance acts as a significant obstacle to accessing guideline-concordant radiation therapy care in a timely manner, consequently influencing survival rates and other aspects related to the treatment of patients undergoing radiation therapy. Furthermore, it underscores a scarcity of research in this area, revealing a significant lack of studies from many geographic regions worldwide, particularly those experiencing rapid increases in cancer cases.

Impact of travel distance on treatment and outcomes

The relationship between travel distance and survival outcomes is complex. Although some studies found a negative impact of longer travel distances on survival, others reported positive effects, often associated with treatment at high-volume centers. This variation suggests that the quality of the treatment facility and the adherence to guideline-concordant care may mitigate some of the disadvantages associated with longer travel distances.[7] However, the fact remains that patients who face significant travel burdens are at risk of treatment delays, increased costs, and added psychological stress, all of which can adversely affect their overall treatment experience and outcomes.[10,38] The results further emphasize the role of sociodemographic elements such as race, socioeconomic status, and insurance coverage in shaping patients' access to health care services.[39]

Impact of travel distance on psychological distress and quality of life

Patients traveling longer distances for treatment could be at risk for increased psychological distress. Liu et al[21] found that pediatric patients with medulloblastoma living >1066 miles from treatment sites experienced a treatment delay of 1 to 2 weeks compared with their more proximally located counterparts. Such wait times have been shown to contribute to families' psychological distress.[21]

Findings from Ramey et al[28] supported Liu et al's results, noting that patients who traveled >50 miles for treatment experienced significantly longer times to treatment initiation compared with those who traveled shorter distances. Thus, although Ramey et al and Liu et al found no significant association between overall survival and distance traveled, their studies highlighted how the potential emotional distress encountered by patients with longer time to treatment must not be discounted.[21,28] In fact, such emotional distress must be considered in treatment planning and shared decision making. Through this process, patients must be informed of the risks associated with increased psychological distress, including its negative impact on survival outcomes.[40,41]

In addition to the possibility of increased psychological distress, patients traveling greater distances and/or living in rural areas may experience additional consequences with deleterious quality-of-life implications. For patients with rectal cancer, Loree et al[25] found that radiation therapy was used less frequently in rural settings, with increased rates of surgical management and necessary colostomy bags. A systematic review conducted by Vindrola-Padroson et al[42] also demonstrated the financial burden of travel, which was a significant concern in most of the studies included in the review. This economic burden can negatively impact patients' quality of life and care.[43] One study found that nearly half of patients may skip medications because of cost concerns and lack of proper insurance coverage,[44] while a longitudinal study conducted by Chino et al[45] found that patients who were nonadherent to medications were also more likely to cut spending on fundamental needs like food and clothing.

Geographic disparities and access to care

The analysis revealed that travel distances to treatment facilities can be significant, especially for patients traveling to high-volume academic centers. This centralization of care services necessitates long-distance travel, particularly impacting patients from economically disadvantaged and rural areas.[10] These disparities underscore the profound implications for patients, especially those in rural areas, who face a lower likelihood of receiving radiation therapy and endure longer waits from diagnosis to consultation.[38] Such challenges not only delay and deviate from optimal treatment plans but also highlight the broader narrative of health care access difficulties that certain populations face. Our findings align with existing literature on the variability of cancer care access for patients who require radiation therapy, especially in these marginalized communities.[5,7] Treatment maps developed by Stracci et al.[46] have shown that increased availability of radiation therapy centers improved access and cancer care. When the number of radiation therapy centers increased, more patients were treated, and patients traveled shorter distances. Most notably, improvement in access was accompanied by a sharp decline in radiation therapy omission rates after mastectomy for high-risk tumors, falling from 48% in 2001−2002 to 11% in 2008−2011, and for in situ cancers, decreasing from 52% to 28% in 2007−2008, stabilizing at 27% thereafter.[46] This highlights the urgent necessity for focused strategies to overcome these obstacles, aiming to necessitate equal access to efficient cancer treatment for every patient, regardless of their location or socioeconomic background. Merely focusing on the challenge of travel distance is inadequate; a holistic strategy that addresses the root causes of these disparities is essential.

Solutions and policy implications

This review underscores that overall survival should not be the sole marker for treatment success when evaluating patients' treatment experiences versus the distances traveled. Many factors may confound the association between travel distance and survival, such as selection bias where healthier, wealthier patients may be more willing and able to travel to access care, including at tertiary, high-volume centers. Although many studies demonstrated a negative association between distance traveled and overall survival, many found no association or positive association between the two variables. Such discrepancies, as detailed in this review, are compelling reasons to examine additional variables further.

The challenges identified in this review call for innovative solutions and policy interventions to improve access to radiation therapy services. Telehealth, alongside mobile therapy units, presents effective strategies to minimize travel demands, particularly for those in distant locations, by facilitating care for visits that do not require direct treatment activities.[47,48] Furthermore, policies that support the decentralization of radiation therapy services, ensuring that high-quality care is available in a wider range of geographic locations, could significantly alleviate the burden on patients.[49] For example, the establishment of a satellite radiation therapy unit in Spain, managed by the Radiation Oncology Department at Hospital Universitari Sant Joan de Reus, demonstrated that decentralization is not only feasible but also beneficial for patient comfort and results in savings for the health care system.[50] Other strategies that decrease the number of visits required for radiation therapy planning and delivery, such as the implementation of diagnostic computed tomography−enabled planning, may also assist in reducing travel burden.[51] Finally, incorporating advanced radiation therapy technologies like intensity-modulated radiation therapy and image-guided radiation therapy into national plans can boost treatment precision and efficacy and reduce toxicity in breast, lung, and head/neck cancers in low- and middle-income countries. Furthermore, incentivizing collaborations for the manufacturing and maintenance of radiation therapy infrastructure can foster sustainable investment. By adopting innovative technologies and broadening treatment options, radiation therapy centers can elevate cancer care quality and outcomes, thus diminishing cancer morbidity and enhancing long-term survivorship.[52]

Strengths and limitations

Although this review provides valuable insights into the relationship between travel distance and treatment outcomes, particularly survival, in patients receiving radiation therapy, several limitations exist. The concentration of research from the United States restricts the applicability of these findings to global contexts. The overall scarcity of studies, particularly those examining marginalized groups, further limits the generalizability of these results. Additionally, the specific impact of travel distance on various types of cancer was not uniformly reported, highlighting a gap in the literature that future studies should address. Moreover, confounding factors, such as the ability and willingness to travel for treatment, could influence the results of this study. Furthermore, the exclusion of studies from the broader oncology literature, which may have included patients receiving radiation therapy, could have omitted valuable insights regarding travel distance in a wider context. Finally, variations in sample sizes across studies, along with differing definitions of travel distance, hinder the ability to draw consistent conclusions and affect the generalizability of the findings.

Conclusions

The findings of this review underscore the urgent need for concerted efforts to address the disparities in access to radiation therapy services. As the field of radiation oncology advances, ensuring that these technological innovations reach all patients, regardless of their geographic location, must be a priority. Addressing the challenges of travel distance and related barriers is a matter of improving cancer care and a necessary step toward achieving health equity on a global scale.

Disclosures

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Supplementary materials

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