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Scientific Article

Effects of Wildfire Events on California Radiation Oncology Clinics and Patients

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Purpose: The effect of climate-driven events, such as wildfires, on health care delivery and cancer care is a growing concern. Patients with cancer undergoing radiation therapy are particularly vulnerable to treatment interruptions, which have a direct effect on survival. We report the results of a study characterizing the effect of wildfires on radiation oncology clinics and their patients.

Methods and Materials: A survey of California radiation oncologists was used to evaluate emergency preparedness and the effect of wildfires on the delivery of radiation therapy services between 2017 and 2022. Descriptive statistics and Pearson's χ^2 tests were performed to investigate potential relationships between provider characteristics, practice settings, and perceptions of the effect of wildfire events. California Department of Forestry and Fire Protection data were employed to map the geographic distribution of wildfires to clinic locations.

Results: Response rate was 12.3% (51/415 radiation oncologists), representing 25% of clinics (43/176) in 41% (24/58) of California counties. Sixty-one percent (31/51) of respondents reported being affected by a wildfire, 2 of which are rural clinics (100%, 2/2) and 29 are (59%, 29/49) metropolitan practices. Of these, 18% (9/51) reported a clinic closure, and 29% (15/51) reported staffing shortages. Respondents reported effects on patients, including having to evacuate (55%, 28/51), cancel/reschedule treatments (53%, 27/51), and experiencing physical, mental, or financial hardship due to wildfires (45%, 23/51). Respondents described effects on clinical operations, including being forced to transfer patients (24%, 12/51), transportation interruptions (37%, 19/51), regional/community evacuations (35%, 18/51), and physical/mental health effects (27%, 14/51) on clinic personnel. Less than half of the respondents (47%, 24/51) reported their workplace had a wildfire emergency preparedness plan. Additionally, geographic analysis revealed that 100% (176/176) of clinics were located within 25 miles of a wildfire.

Conclusions: This study highlights the effects of wildfires on radiation oncology clinics and patients and underscores the need for emergency preparedness planning to minimize the consequences of such disasters.

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Research data are stored in an institutional repository and will be shared upon request to the corresponding author.
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Introduction

Climate change is the most pressing public health issue of our time.[1] Severe weather events fueled by climate change cause disruptions in access to life-saving cancer care and increased exposure to environmental hazards.[2-6] Individuals with cancer are particularly vulnerable to the health hazards of climate change because of the respiratory consequences of pollutants, the health consequences of cancer diagnosis and treatment, and their reliance on frequent and timely access to medical facilities during treatment and survivorship care.[3,4,6-10] The delivery of radiation therapy, an essential cancer treatment modality, is especially susceptible to climate disasters as it requires dependable electrical power (ie, for photon- and proton-based therapies), the presence of specialized teams (ie, radiation oncology nurses, radiation therapists, dosimetrists, and medical radiation physicists), and often daily treatments for optimal therapeutic benefit.[6,8,9,11] Delays in treatment of even a few days can have a significant effect on survival outcomes.[12-14]

Emerging evidence highlights the high risk of cancer care interruption during climate-fueled disasters such as wildfires, particularly in marginalized communities where discriminatory policies and practices have resulted in limited resources to prepare for and recover from such events.[4,15-17] Unfortunately, wildfire activity has intensified in recent years, notably in California, which has experienced significant drought.[1,18] Rural areas have been particularly susceptible.[19] Temperature rises and associated disasters threaten not only the health and well-being of individuals but also the stability of the health care system.[20,21]

Understanding the effects of climate-driven disasters on radiation therapy is crucial for health equity and cancer care.[10,22] This study aims to evaluate the effect of California wildfire events on radiation therapy treatment delivery by focusing on physicians' perceptions of the effect on themselves and their clinics, patients, and personnel. Additionally, we examine patterns of California wildfires and the existence of disaster preparedness plans in radiation oncology clinics, with the objective of identifying opportunities for future preparedness and adaptation efforts.

Methods and Materials

Survey design and development

A 39-question comprehensive online survey was designed to understand providers' perceptions of the effect of the 2017 to 2022 California wildfire events on the delivery of radiation therapy services and their preparedness for such events. The survey consisted of both open-ended and multiple-choice questions that elicited information for the following 6 categories: (1) general information, (2) physical/operational effects on clinic(s), (3) effects on physicians, (4) effects on clinic personnel, (5) effects on patients, and (6) resilience/disaster preparedness.

The survey was designed and reviewed by the study team members who had expertise in the fields of radiation therapy, environmental health, and disaster preparedness, to ensure that the questions were relevant and appropriate. The survey was validated using established methods for survey development, including semistructured interviews and pilot testing.[23] Pilot testing was performed in October 2022 to ensure that the survey was clear and easy to understand and that it covered all relevant topics within the scope of this study. A pilot test was conducted with a small sample of providers (n = 10) who provided feedback on the survey's format and content. The survey was subsequently modified based on this feedback.

Survey distribution

In total, 415 radiation oncologists in California were identified using the American Society for Radiation Oncology (ASTRO) member directory and invited to participate in the survey. Responses were collected using Qualtrics Survey Software (Qualtrics) during a 6-week period, from November 2022 to December 2022, with 3 automated reminders. Partially completed surveys were not included in the final data analysis. To determine rurality, self-reported clinic addresses were deassociated from clinic respondent data, and the United States (US) Department of Agriculture Rural-Urban Continuum Codes (RUCC) were calculated. A RUCC score of 1 to 3 was considered to be "urban/metropolitan," and a clinic with a score of 4 to 9 was determined to be "rural."[24]

Data visualization and mapping

The data for wildfires that occurred in California between 2017 and 2022 (Fig. 1) were obtained from the California Department of Forestry and Fire Protection registry in comma-separated values format.[25] The data included basic information about each wildfire, such as its name, date of start and extinction, acres burned, responding firefighter units, and information on containment, as

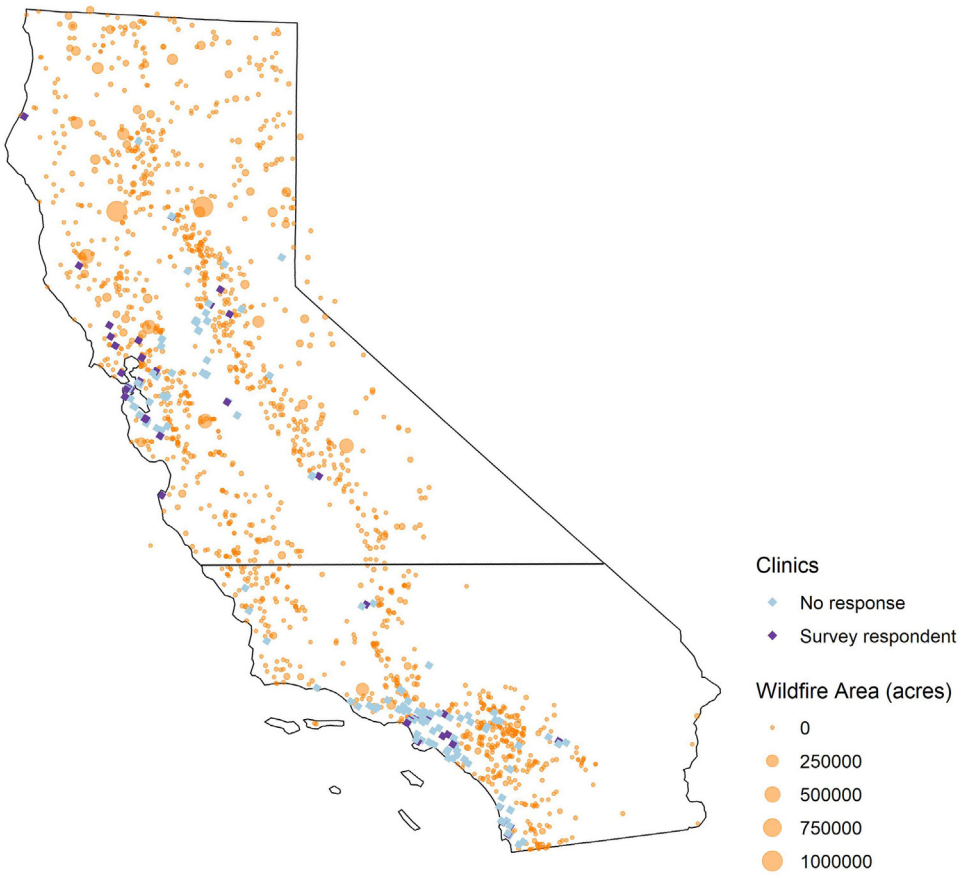

Figure 1 Approximate locations of California radiation oncology clinics in relation to the 2017 to 2022 wildfires per California Department of Forestry and Fire Protection registry data. The black line is located at latitude of 35.8° north, which is the accepted dividing line between Northern and Southern California.

well as location details, such as the name of the county, latitude, and longitude. The specific data used in the analysis included the number of acres burned, the latitude and longitude of each wildfire, and the dates of the start and extinction of each fire. RStudio version 4.1.1 (RStudio) was used to overlay the distribution of 2017 to 2022 wildfires on a map of California created using the usmap package. To ensure that the wildfire points were plotted with geographic accuracy, the latitude and longitude of each fire were transformed using the usmap_transform function, which applies the same projection (Albers projection) as the map of California generated by usmap. The wildfires were plotted in red using the ggplot2 package, and the magnitude of each fire (ie, the size of the point) was determined by the number of acres it burned.

To obtain data on the locations of clinics in California, addresses were anonymized from survey data, and nonrespondent clinic addresses were obtained using Google Maps. Addresses were verified via the ASTRO database and transformed using the usmap_transform function. Survey respondents (clinics where at least 1 physician completed the survey) and nonrespondents (clinics where no physician completed the survey) were grouped by location and then plotted using their transformed latitude and longitude and the ggplot2 package. RUCC scores were calculated for all the distinct 176 California radiation oncology clinic addresses in the ASTRO database and plotted in proximity to the 2017 to 2022 wildfire locations reported in the publicly available California Department of Forestry and Fire Protection registry.

The proximity of clinics to wildfires was calculated using the haversine distance formula, which takes in 2 latitude and longitude coordinates, converts them to radians, and then calculates the distance in miles between the 2 coordinates. A function was created on RStudio and then applied to a data frame that consisted of 5 columns: clinic number (unique to each clinic), clinic latitude, clinic longitude, wildfire latitude, and wildfire longitude. Each clinic was repeated for 1587 rows to match with each wildfire. A new column containing the calculated distances was added. The minimum distance of each clinic to a wildfire was then calculated by filtering the data frame by each clinic number and then finding the minimum distance value.

Statistical analysis

Provider demographics and clinic characteristics (eg, staff size) were summarized with descriptive statistics, including frequencies and percentages. Small clinics were defined as 25 clinical personnel or less. Pearson's χ^2 tests were performed to investigate potential associations between provider characteristics, practice settings, geographic location, urban/rural settings, and academic/private clinics, and their perceptions of the effect of wildfire events on the delivery of radiation therapy services and preparedness for such events. GraphPad Prism9 and RStudio Desktop 2022.7.2 were used for all statistical analyses. A $P < .05$ was considered statistically significant.

Results

Provider demographics and clinic characteristics

Fifty-one radiation oncologists based in California completed the survey, representing 25% (43/176) of the radiation therapy clinics in California, with the representation of 41% (24/58) of the counties in California. Respondents were from both Northern (69%, 35/51) and Southern (31%, 16/51) California-based clinics. Northern California was defined as any latitude above 35.8° north and Southern California by any latitude at or below 35.8° north. More than half of the clinics were hospital affiliated (52%, 27/51), and almost all respondents (96%, 49/51) practiced in clinics located in urban or metropolitan areas, according to the US Department of Agriculture RUCC (Table 1). Only 2 of the 176 distinct clinic locations were considered to be physically located in a rural county (RUCC 4-9) (Fig. 1).

Geographic distribution and proximity of wildfires to clinics

There were 1587 reported wildfires from 2017 to 2022, with 1056 wildfires in Northern California and 531 in Southern California (Table E1). Wildfire severity was classified by size,[26] with almost half the fires covering more than 100 acres (Table E1). Every clinic (100%, 176/176) listed in the ASTRO database in California was located within a 25-mile radius of a wildfire that occurred in the past 5 years. The clinics were ranked based on their proximity to the wildfires, revealing that 7 clinics were located within 1 mile, 69 clinics within 5 miles, 60 clinics within 10 miles, and the remaining 40 clinics were still within a 25-mile distance from a wildfire (Table E2).

Table 1 Respondent and clinic characteristics

Variable	n (%)
Total respondents	51
Age	
30-39	13 (25%)
40-49	13 (25%)
50-59	9 (18%)
60-69	8 (16%)
70+	3 (6%)
Prefer not to say	5 (10%)
Gender	
Male	35 (69%)
Female	14 (27%)
Prefer not to say	2 (4%)
Rurality (RUCC code)	
Metropolitan (RUCC 1-3)	49 (96%)
Rural (RUCC 4-9)	2 (4%)
Self-described clinic characteristics (could select more than 1)	
Hospital affiliated	35 (52%)
Academic center	25 (37%)
Academic satellite	6 (9%)
Privately owned center	11 (16%)
Community-based center	17 (25%)
Urban	13 (19%)
Suburban	16 (24%)
Rural	5 (7%)
Clinic size (per number of personnel)	
<10	6 (12%)
10-25	19 (37%)
25-50	11 (22%)
>50	15 (29%)

Abbreviation: RUCC = Rural-Urban Continuum Codes.

Clinical effect of wildfires

Among the radiation oncologists who completed the survey, 61% (31/51) reported being affected by a wildfire between 2017 and 2022. Those who were affected were an average of 6.25 miles from a recorded wildfire, whereas those who reported no effect were located an average of 7.22 miles from a wildfire. Respondents from both rural (100%, 2/2) and metropolitan (59%, 29/49) areas experienced the effects of a wildfire in the last 5 years.

Table 2 summarizes physician responses regarding the effects of wildfires on patients, clinic staff, and themselves.

Table 2 Effect of 2017 to 2022 California wildfires on radiation oncology patients and staff

Variable	Patients (n, %)	Clinical staff (n, %)	Radiation oncologists (n, %)	*P* value*
Home evacuation	28 (55%)	14 (27%)	5 (10%)	< .001
Clinic or patient rescheduled appointment(s)	27 (53%)	-	-	-
Patient(s) missed appointments	27 (53%)	-	-	-
Community/regional evacuation	27 (53%)	18 (35%)	8 (16%)	< .001
Physical/mental health burdens	23 (45%)	14 (27%)	5 (10%)	< .001
Home/property damage	23 (45%)	7 (14%)	0 (0%)	< .001
Interruption of transportation	22 (43%)	19 (37%)	5 (10%)	< .001
Financial burdens	19 (38%)	8 (16%)	0 (0%)	< .001
School/childcare closures	18 (35%)	18 (35%)	7 (14%)	.02
Loss of communication with medical team	17 (33%)	12 (24%)	3 (6%)	.003
Patient relocation and transfer of care to an alternate treatment facility	12 (24%)	-	-	-
Relocation to another region/state	11 (22%)	3 (6%)	0 (0%)	.002
Reduced access to medical supplies/devices/pharmaceuticals	11 (22%)	-	-	-
Limited/no access to clean water	11 (22%)	5 (10%)	2 (4%)	.02
Loss of medical records	4 (8%)	-	-	-
Considered early retirement/retired early	-	2 (4%)	0 (0%)	-

* Pearson χ^2 values

Radiation oncologists reported that their patients experienced home evacuations (55%, 28/51), missed/rescheduled appointments (53%, 27/51), community/regional evacuations (53%, 27/51), and home/property damage (45%, 23/51) due to wildfire events. Additionally, 23% (12/51) of radiation oncologists reported their patients needed their care plan transferred to another radiation oncology facility as a result of a wildfire. A significant proportion (45%, 23/51) of radiation oncologists reported that their patients experienced physical and mental health complications resulting from wildfires, which was higher than the reported incidence of physical and mental health complications among physicians (5/51, 10%, $P < .001$). Patients were also perceived to be more likely to be affected by home evacuations ($P < .001$), home/property damage ($P < .001$), and financial burdens ($P < .001$) compared with clinical personnel and radiation oncologists (Table 2).

Table 3 summarizes physician responses regarding the effects of wildfires on clinic operations. Clinical operations were reported to be most affected by staffing shortages (30%, 15/51) and power outages (22%, 11/51), with staffing shortages lasting less than 1 month in most cases for those experiencing staffing shortages (87%, 13/15). Two radiation oncologists reported staffing changes lasting months. Almost one-third of respondents whose clinics experienced a wildfire (29%, 9/31) also reported a clinic closure, with a median closure time of less than 1 month (8/9). Small clinics that experienced a wildfire were equally likely to experience staffing shortages (50%, 8/16) compared with larger practices (47%, 7/15), but twice as likely to experience clinic closures (38%, 6/16) compared with larger practices (20%, 3/15; $P = .283$). There was no reported physical destruction of building infrastructure, loss of potable water access, or loss of medical records. Nevertheless, a respondent expressed their apprehension regarding the lack of a disaster preparedness plan to handle radioactive substances, specifically those related to high-dose-rate (HDR) brachytherapy treatment. They highlighted the occurrence of "significant smoke damage in the building" and the absence of contingency measures in case the building and the HDR device were compromised due to a fire.

Climate disaster preparedness plans

Table 4 summarizes responses regarding clinic emergency preparedness plans. Only half (47%, 24/51) of the respondents reported that their workplace had a wildfire emergency preparedness plan, and half of these plans accommodated patient transfers for treatment if needed. Few physicians (25%, 13/51) reported that patients are counseled on emergency preparedness planning related to climate-driven disasters, including wildfires. Interestingly, only 51% (26/51 respondents) said they were prepared for dealing with wildfires.

Table 3 Effect of 2017 to 2022 California wildfires on clinical operations

Variable	n (%)
Outcomes (select all that apply)	
Staffing shortages	15 (30%)
Power outages	11 (22%)
Clinic closures	9 (18%)
Other: Poor air quality	5 (10%)
Financial burdens	4 (8%)
Interruption of communication systems	3 (6%)
Other: Patients displaced	3 (6%)
Unavailable medical supplies	1 (2%)
Other: Staff home evacuations	1 (2%)
Other: Patient cancellations	1 (2%)
Other: Paused follow-ups, nonessential services	1 (2%)
Other: Transportation interruptions	1 (2%)
Longest clinic closure due to wildfire	
Permanently closed	0 (0%)
>3 mo	0 (0%)
1-3 mo	1 (2%)
<1 mo	8 (16%)
My clinic has not been closed	42 (82%)
Longest period of staffing shortages	
>12 mo	0 (0%)
6-12 mo	0 (0%)
1-6 mo	2 (4%)
<1 mo	13 (25%)
My clinic did not experience staffing shortages	36 (71%)

Table 4 Summary of survey responses regarding workplace wildfire emergency preparedness plans

Variable	n (%)
Does your workplace have an emergency preparedness plan in the event of a wildfire?	
Unsure	21 (41%)
Yes, plan was instituted	12 (24%)
Yes, but my workplace did not experience a wildfire	7 (14%)
My workplace does not have an emergency preparedness plan	6 (12%)
Yes, but plan was not instituted	5 (9%)
Yes, but I was unaware of the plan at the time	0 (0%)
Does this plan accommodate patient transfers for treatment, if needed?	
Unsure	17 (33%)
Yes, but this was not implemented	16 (31%)
No, there are no such provisions	11 (22%)
Yes, and this was implemented	7 (14%)
Perceptions of workplace preparedness	
Very prepared	8 (16%)
Somewhat well prepared	18 (35%)
Neither prepared nor unprepared	9 (18%)
Somewhat unprepared	2 (4%)
Very unprepared	2 (4%)
Did not implement emergency procedures	12 (24%)
Are patients counseled on emergency preparedness planning?	
No	22 (43%)
Unsure	16 (31%)
Yes	13 (25%)

Discussion

This study captures data from practicing radiation oncologists to characterize the effect of wildfires on California radiation oncology clinics and patients. The survey represents experiences from 24 out of 58 California counties and 43 out of 176 radiation oncology clinics. A key finding of this survey was that a majority (61%, 31/51) of practicing radiation oncology respondents reported that a wildfire event affected their clinic(s) in the past 5 years, consistent with the finding that 100% of California radiation oncology clinics were located 25 miles or less from a recorded wildfire. Furthermore, many patients were reportedly forced to evacuate from their homes or communities, resulting in interruptions to radiation treatment delivery and the need to transfer their radiation plans to alternate cancer centers. Almost half of the cancer patients were perceived to have experienced physical or mental health complications related to wildfire events, which is significantly higher than what radiation oncologists reported with regard to their own mental and physical health complications. This difference may be partially explained by the higher level of home evacuations and home or property damage in comparison to the radiation oncologist population. In addition, physician respondents reported that patients were more likely than clinical staff to experience financial burdens and property damage resulting from wildfire events. Clinical operations were mainly affected by staffing shortages and power outages, with smaller clinics (<25 clinical personnel) often experiencing clinic closures as a result.

In our survey findings, practicing radiation oncologists reported a higher incidence of perceived adverse effects of wildfires on patients, including physical and mental health burdens, in comparison to treating physicians and clinical personnel. Although the providers' perceptions

limit these data, it is crucial to highlight the possible disproportionate effect of climate-driven disasters on patients with cancer undergoing radiation therapy treatment. There is growing evidence to suggest that medically vulnerable and historically marginalized populations bear a higher burden of cumulative environmental effects from climate-driven disasters.[27,28] Individuals living with cancer, particularly those undergoing treatment, are especially susceptible to both disease and treatment-related side effects, which may make them vulnerable to climate-related health complications, such as those arising from wildfire smoke and poor air quality.[29,30] Furthermore, our data suggest wildfire exposure may compound the mental and physical challenges frequently experienced by patients with cancer.[31,32] In addition to the physical and mental health effects, the financial burden was also reported to be higher for patients in this study, which may further exacerbate the financial stress that patients undergoing cancer treatment are known to experience.[33,34] As a result, the physical, psychological, and financial needs of patients with cancer need to be prioritized in emergency preparedness and response plans. This may include providing contact info for mental health support, working with local health departments to facilitate access to special needs shelters, and working with policymakers to lessen the financial burden of evacuating or safely sheltering in place, which might include purchasing special air filters.

Health systems must respond to the growing threat of wildfires and climate change by developing both adaptation and disaster preparedness plans[35] that take into account the complex needs of patients with cancer and establish resiliency.[36,37] Adaptation is defined by the United Nations as "adjustments in ecological, social, or economic systems in response to actual or expected climatic stimuli and their effects," and adaptation solutions should "respond to current and future climate change impacts." Urgent efforts and research are required to support the development of risk and vulnerability assessments specific to oncology and radiation therapy to establish best practices for adaptation to protect patients. Importantly, radiation oncology clinics have the additional risk of radiation exposure in wildfire events if technology (eg, HDR brachytherapy machine or Gamma Knife) is suboptimally shielded and damaged in the fire. Building climate resiliency within oncology will require the implementation of appropriate adaptation and disaster preparedness plans that recognize the unique needs of this vulnerable patient population and takes into consideration safety pertaining to the clinics' onsite radioactive sources (eg, HDR and Gamma knife radiation sources).

Furthermore, it is critical to capture data pertaining to the experiences of rural radiation oncology practices in regard to climate-driven disasters in order to reduce urban-rural health disparities. Historically, rural communities have been found to be more likely to experience socioeconomic disadvantages, worse health outcomes, and worse access to health care resources than their urban counterparts.[38] In this study, visual mapping shows that the effects of wildfires in California were distributed geographically across both metropolitan and rural communities; however, the majority of California radiation oncology centers are located in metropolitan areas. Only 2 respondents in our study reported practicing in clinics physically located in rural counties, and statewide, only 6 clinics are located in rural counties as defined by the RUCC. This distribution of respondents is consistent with national data demonstrating a higher density of physicians in metropolitan cities compared with rural areas.[39]

Although wildfires affected both rural and metropolitan practices in our study, meaningful comparisons between the 2 are elusive because of power limitations. However, it is reasonable to assume that rural clinics, patients, and providers face unique challenges and may be particularly vulnerable to climate-driven disasters because of their remote geographic locations, wider clinic catchment areas, smaller clinic sizes, and limited resources compared with centers located in metropolitan areas. National data suggest that patients undergoing radiation therapy travel an average of 12.5 miles each way daily, but data suggest that this distance may be higher in rural communities, leading to increased opportunities for adverse climate effects on access to care for rural patients who already face numerous barriers to care (including transportation).[40,41] This is important to address considering that every radiation oncology clinic in California has been within 25 miles of a wildfire event in the past 5 years, with the majority of clinics being within 10 miles of a wildfire. Wildfires have the potential to pose serious interruptions to treatment and the ability of patients to travel to nearby or distant clinics. Rural patients may especially benefit from further investigations to identify opportunities to establish and implement climate-resilient oncologic care, as our data suggest that climate-driven disasters threaten to widen already existing urban-rural health care disparities.[42]

Lastly, our study aligns with previous research demonstrating that wildfires have a multifaceted effect on health care systems, personnel, patients, and communities, resulting in damage to infrastructure and clinical operations.[35,43] These disruptions can lead to power outages, transportation interruptions, and staff shortages that directly affect care delivery. Our findings affirm that health care providers are susceptible to work interruptions, displacement, and financial hardship, consistent with previous investigations.[44,45] The cancer control continuum is particularly vulnerable to climate-related disruptions, potentially affecting screening, prevention, diagnosis, treatment, survivorship, and ultimately oncologic outcomes.[3,4,6,46] Alarmingly, only 47% of respondents in our study reported knowledge of their workplace having a wildfire emergency preparedness plan in place.

Table 5 Key elements to consider for inclusion in establishing emergency preparedness plans for radiation oncology clinics

Identification of referral centers	Ensuring clear and well-defined procedures to identify and coordinate with appropriate referral centers for patients requiring urgent or specialized care during emergencies
Patient/staff evacuation plans	Developing robust evacuation plans that prioritize the safety and well-being of both patients and staff, considering different emergency scenarios and ensuring smooth and timely evacuations when needed
Backup plans for clinic infrastructure and energy support	Establishing contingency measures to address potential infrastructure failures and ensuring continuous access to vital utilities, such as power and water, to sustain critical operations during emergencies
Communication with local and state emergency management organizations	Facilitating seamless communication channels with relevant local and state emergency management organizations to exchange vital information, seek assistance, and collaborate effectively during crisis situations
Routine practice of alternative information sharing	Regularly practicing alternative methods of information sharing among health care providers and patients, such as employing digital platforms or backup communication systems, to maintain essential lines of communication when primary channels are disrupted

Furthermore, 41% of respondents reported being unsure if their clinic had a plan, highlighting the need for improving awareness among physicians, staff, and patients. The existence of effective emergency preparedness plans for increasing climate events is critical to cancer care delivery. The US Department of Health and Human Services has recognized the importance of developing adequate emergency preparedness plans, and the Office of the Assistant Secretary for Preparedness and Response created the 2017 to 2022 Health Care Preparedness and Response Capabilities to help prepare health care delivery systems to have an appropriate response to emergencies, including climate-driven disasters.[47] Medicare and Medicaid providers were also given emergency preparedness requirements in 2016 by the Center for Medicare and Medicaid—a federal agency within the US Department of Health and Human Services —to ensure an adequate response to disasters, which included meeting the needs of patients.[48] Briefly, emergency preparedness plans for radiation oncology clinics may include identification of referral centers, planning for patient/staff evacuation, backup plans for clinic infrastructure and energy support, supporting communications with local and state emergency management organizations, and routine practice of alternative information sharing (Table 5).[49] Despite the potential role of physicians in counseling patients on emergency preparedness planning related to climate disasters,[50] our study shows that only a minority of patients receive such counseling (25% of physicians reported providing emergency preparedness information to patients). Thus, significant opportunities exist to expand appropriate disaster preparedness planning and patient education tailored to the specific needs of clinics and the patients they serve.

This study has several limitations that should be considered. First, the reported effects on patients were subject to physician perceptions based on their clinical insights and experiences rather than first-hand patient accounts. Obtaining patient perspectives will help tailor future development of adaptation and climate resiliency efforts. Further, the study may be affected by recall bias, in which physicians recall perceptions regarding fires that occurred a few years ago and not necessarily in the last year. Additionally, geographic representations were limited to clinic addresses alone and did not account for patient or physician home addresses. A key limitation of this study is the low response rate, contributing to nonresponse bias. We speculate sample size and selection bias to be significant in this study, with an assumed higher response rate among those affected by a wildfire compared with those who were not. However, we sought to address this through sensitivity analyses. Although we captured a quarter (25%) of operating California radiation oncology clinics, only 51 physician respondents completed the survey (51/415 = 12%). Additionally, this study is limited to radiation oncologist perspectives only but we look forward to expanding to additional clinical staff in the future, including but not limited to physicists and radiation therapists. Finally, because radiation therapy centers tend to be located in centralized urban and metropolitan areas, it is difficult to draw conclusions about the challenges faced by patients living in rural areas who may travel long distances for treatment and may be more vulnerable to climate-driven travel interruptions.

Conclusion

In summary, this study underscores the detrimental effect of wildfires on radiation oncology clinics and patients, as reported by health care providers. Given that radiation oncology depends on electrical power and timely execution of the treatments, it is a particularly sensitive component of the oncologic treatment pathway to

climatic disruption and in urgent need of emergency preparedness planning that accounts for the unique needs of this vulnerable patient population to mitigate future effects. Overall, this study contributes to the growing body of evidence that climate change and associated disasters pose a significant threat to health care delivery. Future research should focus on conducting risk and vulnerability assessments specific to oncology and radiation therapy, to identify those who may be particularly susceptible to climate-driven disasters, and to establish best practices for adaptation and climate resiliency.

Disclosures

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Supplementary materials

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