Advances in Radiation Oncology (2024) 9, 101491

advances in radiation oncology

www.advancesradonc.org

Research Letter

Impact of Severe Winter Weather on Operations of a Radiation Oncology Department

Fatemeh Fekrmandi, MD, MSc,[a,b] Jasmin Gill,[a] Siddharth Suresh,[a] Sarah Hewson, BS, RT,[c] and Varun K. Chowdhry, MD, MBA[a,b,c,*]

[a]*University at Buffalo, Buffalo, New York;* [b]*Roswell Park Comprehensive Cancer Center, Buffalo, New York; and* [c]*Southtowns Radiation Oncology, Orchard Park, New York*

Received 24 October 2023; accepted 26 February 2024

Purpose: During winter 2022, western New York faced 2 major storms with blizzard conditions and record-breaking snowfall. The severe weather resulted in power outages and travel bans. This study investigates the impact of these conditions on patient adherence to radiation therapy. Combining data from a large academic center and its satellite clinic, this single-center study sheds light on the challenges faced by cancer care facilities during severe weather and proposes suggestions to prevent and mitigate harm done by severe weather.

Methods and Materials: In this study, data were collected using the MOSAIQ Record and Verify system (v. 2.81) to generate deidentified reports of scheduled and treated patients. The treatment adherence rate was calculated by dividing the number of patients treated by the total number of patients scheduled. Data were specifically collected for patients undergoing treatment on linear accelerators at a primary academic center and a satellite facility. The study focused on working days from November 1, 2022, to March 31, 2023, excluding weekends and holidays (as treatments are not routinely scheduled). Severe weather days were identified using advisories from the National Weather Service and the local institution, including specific periods in November, December, and January.

Results: In the study, 15,010 scheduled treatment visits were recorded across the academic center and the satellite clinic. The mean daily treatment adherence rate was 91.7%. Severe weather conditions led to a significant reduction in adherence, with rates dropping to 77.8%. Adherence rates during nonsevere weather days were notably higher at 93.9%. Statistical analysis confirmed the substantial influence of severe weather on adherence ($P < .001$). Severe weather had a more pronounced impact on the satellite clinic during periods of severe weather, with absolute reduction in adherence rates of 21.9% versus 15% in the primary hospital. Moreover, adherence at the satellite clinic was lower than at the primary hospital site even under standard operating conditions (92.2% vs 94.0%, $P < .001$).

Conclusion: As a part of operational planning, it is important to be aware how severe weather can impact treatment adherence. Study findings underscore the importance of proactive measures to ensure patient access to health care services during adverse weather events and highlight the broader significance of incorporating consideration of social determinants of health into contingency planning for maintaining treatment continuity.

Introduction

In winter 2022-23, western New York encountered 2 major storms that resulted in blizzard conditions and unprecedented snowfall. For the first storm, in November 2022, the region encountered a snowstorm that surpassed

Sources of support: None.

Data sharing statement: Research data are stored in an institutional repository and will be shared upon request to the corresponding author.

*Corresponding author: Varun K. Chowdhry, MD, MBA; Email: varun.chowdhry@roswellpark.org

https://doi.org/10.1016/j.adro.2024.101491

previous records, yielding an impressive 36.9 inches of total snowfall.[1] Slightly over a month later, western New York underwent one of its most catastrophic snowstorms to date. The direct impact of the severe weather claimed the lives of 39 Erie County residents and left about 20,000 buildings without power for up to 4 days. The storm was associated with widespread power outages. A report from New York University's Graduate School of Public Service indicated the city was unprepared to clear roadways, communicate with residents, and restore utilities, further aggravating the effects of the storm in subsequent days.[2]

Although much of the focus on severe weather events is on the direct impact of the storm, severe weather has the potential to result in secondary harm as a result of delayed medical care. A study using Medicare data on hospitalizations for acute myocardial infarction found that road closures and other infrastructure disruptions associated with marathons resulted in longer ambulance transport times and higher hospital mortality compared with nonmarathon days.[3] In the same way, we sought to understand the impact of severe weather on radiation treatment adherence rates to help guide contingency plans for the future.

Methods and Materials

The Record and Verify System (MOSAIQ, v. 2.81, Sunnyvale, California) was used to generate deidentified reports of total scheduled and treated patients. We calculated the treatment adherence rate by dividing the number of patients treated by the total number of patients scheduled. The number of patients treated was determined by subtracting those on breaks, no-shows, cancellations, and equipment downtime-related cancellations from the total number of scheduled patients. Data were evaluated from patients being treated on linear accelerators, either at a primary hospital-based academic center or a nearby satellite facility. Patients being treated with modalities other than linear accelerator-based therapy such as brachytherapy and GammaKnife radiosurgery were excluded. Data were collected for all working days between November 1, 2022, to March 31, 2023. Weekends and scheduled holidays (Christmas and New Years) were excluded. Classification of severe weather days (Winter Weather Watch, Advisories, or Warnings) was based on information from the regional office of the National Weather Service. The periods of November 14, 2022 through November 22, 2022; December 23, 2022 through December 30, 2022; and January 25, 2023 through January 27, 2023 were classified as the periods of severe weather events on the basis of continuous winter weather advisories by the local chapter of the National Weather Service and/or institutional notifications of severe weather for a duration of 2 or more days.

Results

During the study period, we recorded a total of 15,010 scheduled individual treatment visits across both the primary academic center as well as the affiliated satellite clinic. Analysis revealed a mean daily treatment adherence rate of 91.7% across both facilities across all weather conditions. We identified 15 severe weather days based on criteria discussed above. The satellite clinic experienced a total of 3 days of closure, whereas the academic center ceased operations for 1 day due to a travel ban.

Aggregate data regarding treatment adherence rates is shown in Table 1. During nonsevere weather days, we noted an adherence rate of 93.9%, and we noted 77.8% on severe weather days. When removing dates of facility closure, treatment adherence rate was 84.8% on severe weather days. The reduced rate of treatment adherence during severe weather was highly statistically significant with or without facility closure days ($P < .001$). Treatment adherence rates by month are shown in Fig. 1.

The difference in adherence rate between the satellite location and the hospital-based facility is shown in Fig. 2. Even under standard operating conditions, we noted lower adherence rates at the satellite compared with the hospital-based facility (92.2% vs 94.0%, $P < .0001$). Moreover, the difference between the lower adherence rates seen between these 2 facilities during severe weather was statistically significant (70.3% vs 79.0%, $P < .001$), and the absolute reduction in adherence rates at the satellite clinic was higher than that of the hospital-based facility (21.9% vs 15%).

We attempted to ascertain the impact of storms on overall treatment time. Unfortunately, a limitation of our record and verify system prohibited understanding of how overall treatment time was impacted by the storm. Furthermore, the 2 major storms during the weather event occurred during the Thanksgiving and Christmas

Table 1 Treatment adherence rates during nonsevere and severe weather days

	Scheduled treatments	Actual treatments delivered	% adherence	*P* value
Nonsevere weather	12,917	12,133	93.9%	-
Severe weather	2093	1629	77.8%	$P < .001$
Severe weather (excluding dates of closure)	1922	1629	84.8%	$P < .001$
Total	15,010	13,762	91.7%	

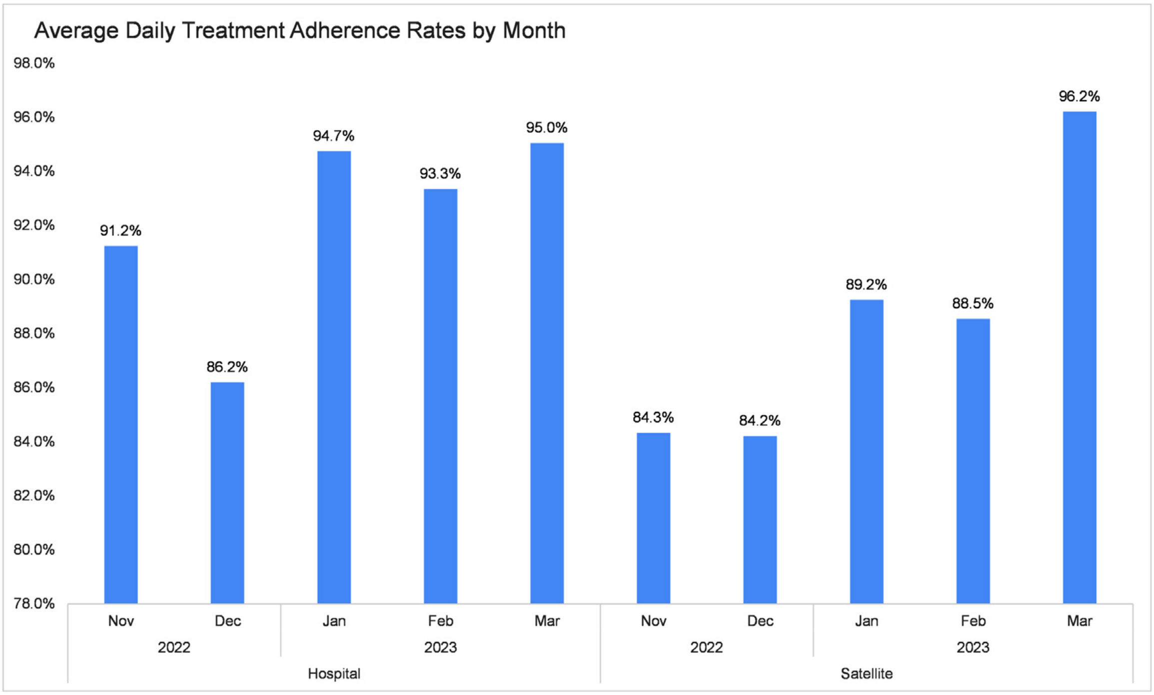

Figure 1 Treatment adherence rates by month.

holidays, a time of year when there are typically fewer new scheduled patient starts. Therefore, any estimate would be an underestimate of the actual impact of the storm.

Nevertheless, it is possible to mathematically estimate changes in aggregate treatment because of the storms using Little's Law, which states that the average time a patient would spend within a system (L) is equal to the arrival rate (λ) multiplied by the average time a patient spends within the system (W), formulaically represented as $L = \lambda W$. If we assume that 100 patients are treated per day, and the average number of fractions is 20 per treatment course. Little's Law would estimate that there is a steady state of 5 patients completing and starting treatment each day. Assuming that a severe weather event reduces treatment compliance to 75%, we can implement a weighted average of Little's Law to understand the systematic impact of the storm. Data from these calculations are shown in Table 2 and graphically depicted in Fig. 3.

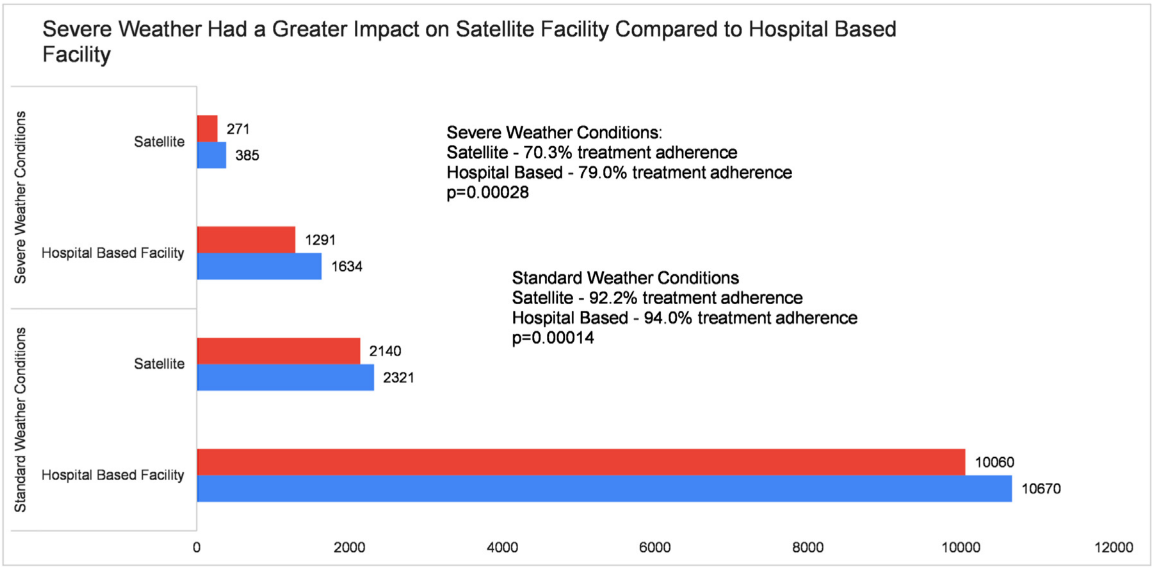

Figure 2 Severe weather Impact on satellite facility compared with hospital based facility.

Table 2 Weighted average of Little's Law to understand the systematic impact of the storm

Total patients (L)	100	100	100	100	100
Average time through the system (W or total fractions)	20	20	20	20	20
Patients completing (starting) treatment per day (λ)	5	5	5	5	5
Arrival rate during storm	75%	75%	75%	75%	75%
Number of days of storm	0	1	2	3	4
λ storm (new arrival rate during the storm)	3.75	3.75	3.75	3.75	3.75
Average time through system for nondelayed Patients (W)	20	20	20	20	20
Average time for delayed patients (W)	20	21	22	23	24
Weighted average (days)	20	20.25	20.5	20.75	21

Discussion and Conclusion

Our experience adds to the existing literature regarding the impact of natural disasters on oncological outcomes.[4] To our knowledge, this is the first study that analyzes the impacts of snowstorms on radiation-oncology treatment adherence rates. Given that we noted up to 20% absolute reduction in adherence rates associated with weather advisories, we recommend that departmental operation plans should incorporate contingency plans to ensure patient safety from natural conditions while considering the long-term detriment associated with delayed care.

Although establishing a definitive threshold may be somewhat arbitrary, our suggestion would be to at least consider weekend openings when adherence rates are less than 85% for greater than 3 days or for 2 or more days of facility closure. A systematic review examining the impact of natural disasters on cancer care by Man et al also recommended maintaining the overall duration of radiation therapy with weekend treatments without breaks,[5] as was implemented in the aftermath of Superstorm Sandy in the radiation oncology department at New York University.[6]

Another noteworthy finding of our study was that the observed impact of severe weather on adherence rates was more pronounced at our community-based satellite clinic compared with the hospital-based facility, which is a National Cancer Institute Comprehensive Cancer Center (NCICCC). One likely explanation of this that severe weather tends to differentially impact the satellite facility, which is located in a part of the region with higher snowfall total as a result of lake effect snowbands.[7] The differential impact could also be attributed to inherent differences in patient populations being treated at the satellite clinic, with potentially greater transportation challenges and longer travel times, warranting further investigation into the role of social determinants of health in treatment adherence. A study of about 70,000 newly diagnosed adult-onset cancer patients treated at NCICCCs suggested improved survival rates compared with patients at non-NCICCC facilities. However, barriers to care at NCICCCs were identified, including factors such as race/ethnicity, insurance, socioeconomic status (SES), and geographic distance.[8] A retrospective study from Montefiore Medical Center showed treatment

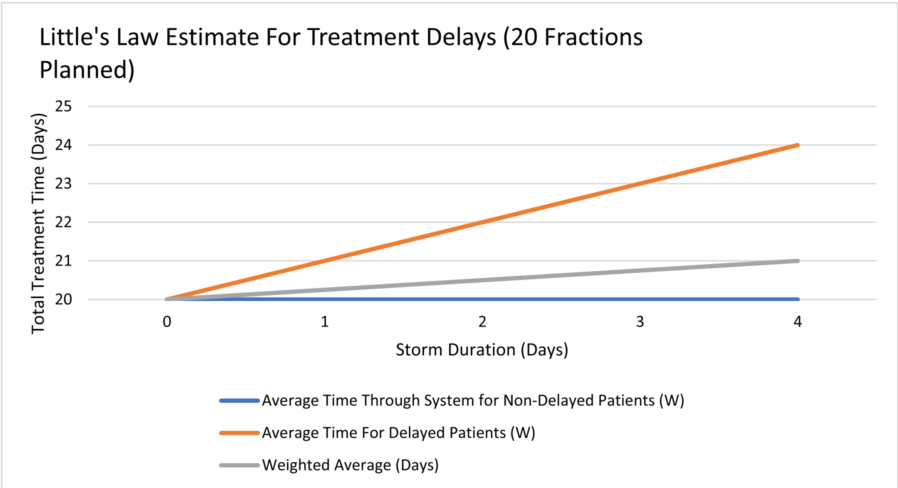

Figure 3 Little's Law estimate of treatment delays for a 20 fraction course of treatment.

during winter months (Nov-Feb) and low socioeconomic status (based on household income, housing unit values, education level, and occupation statistics) were independent factors predicting radiation treatment nonadherence (all $P < .05$).[9] Residential distance to cancer treatment center (average 59 miles) correlated significantly with nonadherence to first radiation treatment, particularly for rural individuals who also experienced increased risk of unfavorable outcomes ($P < .05$).[10]

It is beyond the scope of this study to understand the potentially detrimental impact on patient outcomes as a result of missed appointments. Nevertheless, it would be reasonable to assume that these delays would result in detriment to patient outcomes when extrapolated over populations of patients.[11] We estimate that by increasing the storm duration, the average delay of patients across department would increase to up to 1 day. It is important to note that the storm would likely impact certain groups of patients to a greater extent compared with others.

One important limitation of this study is that we used the record and verify system as the only source to understand missed appointments. For example, a patient deleted from the schedule without formal cancellation might not be captured, and this could have resulted in an underestimation of missed appointments. Nevertheless, we do not believe that this limitation would have impacted study results. Given the higher pretest probability that a patient would not arrive for treatment during a severe weather day, it is likely that we are underestimating the impact of severe weather. Additionally, this study does not account for weather-unrelated reasons (family events and holidays) or prior delays and the associated detrimental impact at earlier phases in treatment.

At the 2023 American Society for Radiation Oncology conference, the keynote address[12] described how external phenomena can result in disruptions to medical care and how understanding the impact of such events can prompt operational planning to mitigate their adverse impact. In conclusion, this study demonstrates the substantial impact of severe weather on treatment adherence rates in cancer care settings in an era of increased weather extremes. In addition to the causal impacts of climate change on cancer, there is a foreseeable disruption of the intricate health care systems necessary for cancer diagnosis, treatment, and care. Extreme weather events can damage healthcare infrastructure, leading to a decline in quality and accessibility. It is possible that climate change could differentially impact those most influenced by social determinants of health. Thus, we may consider advocacy about these issues to be an essential component of health care.[13]

The disparities observed between the satellite clinic and the hospital-based facility raise the possibility that impact of severe weather can be associated with social determinants of health. These findings underscore the importance of proactive measures to ensure patient access to healthcare during adverse weather events and consideration of alternative scheduling processes during such events to minimize patient harm from the perspective of missed cancer treatments.

Disclosures

None.

References

1. WGRZ.com. November 2022 ranks as one of the snowiest on record in Buffalo. https://www.wgrz.com/article/weather/november-2022-ranks-one-of-the-snowiest-on-record-buffalo/71-dec16705-6f0f-4454-86af-247e66d6339d. Accessed September 27, 2023.
2. Meko H, Fadulu L. Buffalo leaders weren't ready for blizzard that killed 31, report says. *The New York Times*. 2 June 2023.. https://www.nytimes.com/2023/06/02/nyregion/buffalo-blizzard-emergency-response.html. Accessed 27 September 2023.
3. Jena AB, Mann NC, Wedlund LN, Olenski A. Delays in emergency care and mortality during major U.S. marathons. *N Engl J Med*. 2017;376:1441-1450.
4. Roach MC, Robinson CG, Bradley JD. Natural disasters and the importance of minimizing subsequent radiation therapy interruptions for locally advanced lung cancer. *Int J Radiat Oncol Biol Phys*. 2018;100:836-837.
5. Man RX, Lack DA, Wyatt CE, Murray V. The effect of natural disasters on cancer care: A systematic review. *Lancet Oncol*. 2018;19:e482-e499.
6. Grew D, Vatner R, DeWyngaert K, Nicholas S, Formenti S. The impact of Superstorm Sandy on the care of radiation oncology patients. *Int J Radiat Oncol Biol Phys*. 2013;87:S490-S491.
7. National Weather Service. Buffalo climate narrative. https://www.weather.gov/buf/BUFclifo. Accessed October 13, 2023.
8. Wolfson JA, Sun CL, Wyatt LP, Hurria A, Bhatia S. Impact of care at comprehensive cancer centers on outcome: Results from a population-based study. *Cancer*. 2015;121:3885-3893.
9. Ohri N, Rapkin BD, Guha D, et al. Predictors of radiation therapy noncompliance in an urban academic cancer center. *Int J Radiat Oncol Biol Phys*. 2015;91:232-238.
10. Morris BB, Hughes R, Fields EC, Sabo RT, Weaver KE, Fuemmeler BF. Sociodemographic and clinical factors associated with radiation treatment nonadherence and survival among rural and nonrural patients with cancer. *Int J Radiat Oncol Biol Phys*. 2023;116:28-38.
11. McMillan MT, Ojerholm E, Verma V, et al. Radiation treatment time and overall survival in locally advanced non-small cell lung cancer. *Int J Radiat Oncol Biol Phys*. 2017;98:1142-1152.
12. Jena AB. Random acts of medicine. Paper presented at the American Society for Radiation Oncology Annual Meeting, October 3, 2023, San Diego, CA.
13. Hiatt RA, Beyeler N. Cancer and climate change. *Lancet Oncol*. 2020;21:e519-e527.