RESEARCH BRIEF

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Estimating Emergency Department Utilization of Select Drugs during Extreme Heat Events

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KEY POINTS

- We modeled the excess utilization of three commonly used drugs that treat heat-related illness in emergency departments during extreme heat events, using literature-derived estimates of emergency department visit rates for heat-related illness on extreme heat days and drug utilization rates from medical claims data.
- We estimate that extreme heat is associated with an average of 34,251 excess emergency department visits for heat-related illness in the contiguous United States per year, or roughly 6 percent of the baseline number of visits for heat-related illness in June through September. The number of excess emergency department visits for heat-related illness varies heavily from year to year (estimated range: 6,433–62,854) based on the length and frequency of heatwaves.
- Of the 34,251 excess emergency department visits per year, we estimate an average of 12,677 excess visits require saline solution infusions, 5,963 excess visits require ondansetron injections, and 2,226 excess visits require ceftriaxone injections.
- Using recent heatwaves as illustrative examples, we show that this type of model can be used to predict local surges in drug utilization, inform drug acquisition and supply chain resilience strategies, and ultimately improve health outcomes. This is particularly important given that a heatwave can cause sudden spikes in drug utilization of more than 60 percent for an entire affected state, according to our modeling.

INTRODUCTION

Extreme heat is the leading cause of weather-related fatalities in the United States [1]. Extreme heat also has a high morbidity burden as it triggers acute health conditions and worsens a range of chronic conditions like diabetes and renal disease [2] [3] [4]. Heat-related illness (HRI) occurs when the body becomes too hot and cannot cool properly, resulting in heat exhaustion, rhabdomyolysis, heat syncope, heat cramps, heat rash and heat stroke [5]. These adverse health effects occur across the United States, from densely populated cities to rural communities, with heatwaves sometimes covering wide-ranging areas at once. Even in regions with cooler climates (e.g., Alaska or parts of the northwestern United States), unusually high temperatures can have detrimental effects on human health. Overall, extreme heat is estimated to cost over $100 billion annually in the United States [6]. In addition to its adverse effects on human health, extreme heat events can also disrupt global supply chains [7]. For example, extreme heat is associated with reduced manufacturing output [8] and can cause damage to energy

systems, leading to power outages that can impact drug manufacturing facilities [9] [10]. While supply-side vulnerabilities have been researched extensively, studies on demand-side vulnerabilities are more limited. When healthcare systems experience an influx of emergency department (ED) visits, a sudden increase in utilization of intravenous (IV) fluids, respiratory therapies, cardiovascular drugs, or other medications could strain local supply chains beyond the available stock. These challenges require a better understanding of how large these utilization surges may be.

In this research brief, we estimate the excess number of ED visits for HRI during extreme heat events and the associated increase in utilization of three drugs (saline solution, ondansetron, and ceftriaxone) commonly used in treating HRI. We also model recent heatwaves in the U.S. Northeast, Midwest, and South and discuss these results in the context of the medical product supply chain. Examining the relationship between natural hazards such as extreme heat and drug utilization provides important evidence to support preparedness, enhance the resilience of drug supply chains, and improve human health.

METHODS AND DATA SOURCES

Model Overview

Our model is described in the sections that follow. As a brief overview, we combined the HRI incidence rates from Visaria et al. [11], a recent large, national study, with present-day demographic and health information to estimate the number of excess HRI-related ED visits on a typical extreme heat day in each U.S. county.* From Medicare Part B claims data, we identified the types of drugs used in treating HRI in hospital EDs and calculated the percentage of ED visits at which each drug was administered (which we define as the drug's "utilization rate"). From these data, we selected three drugs that are commonly used in treating HRI—saline solution, ondansetron, and ceftriaxone. Combining the estimates of excess ED visits per extreme heat day with these drugs' utilization rates, we estimated the excess utilization of these drugs due to HRI-related ED visits on an extreme heat day for each U.S. county. We aggregated these county-level results to estimate the impact of extreme heat both nationally and for specific recent heatwaves.

Estimating the Burden of an Extreme Heat Day by U.S. County

Using findings reported in Visaria et al. [11], we estimated how often people visit the ED for HRI on extreme heat days and non-extreme heat days, which we define as the 95–100th percentiles and 0–94th percentiles, respectively, of the historical local daily mean temperature during warm months (June through September). Visaria et al. [11] reports the number of HRI-related ED visits per 1,000 people per year separately for extreme heat days and non-extreme heat days. These ED visit rates are based on data from a wide range of U.S. counties, years, and types of extreme heat events with varying severities and durations. To estimate the excess ED visit rate for HRI attributable to extreme heat, we calculated the difference between the ED visit rate on extreme heat days and non-extreme heat days. Next, we multiplied this excess ED visit rate by 2023 county-level population estimates from the American

* In this context, "excess" refers to the difference between the number of ED visits during an extreme heat event and the "baseline" expected number of ED visits if extreme heat had not occurred.

Community Survey (ACS) to estimate the excess number of HRI-related ED visits per county on a given extreme heat day [12].[†]

Estimating ED Utilization Rates for Drugs that Treat HRI

Drugs used to treat HRI in an ED setting were identified from 2024 Medicare Part B claims where HRI was listed as the primary diagnosis code.[‡] We defined a drug's utilization rate for HRI as the percentage of HRI visits at which the drug was administered. We selected three drugs to model, which all have relatively high utilization rates in ED settings for HRI patients. Table 1 presents these drugs, along with their main therapeutic uses, utilization rates, and recent shortage history. The selection also reflects several therapeutic purposes—rehydrating, antiemetic, and antibiotic—to address the range of clinical needs that may be associated with HRI. All three drugs are essential medicines according to the Food and Drug Administration (FDA) [13] and have a history of being in shortage according to the FDA and/or the American Society of Health-System Pharmacists (ASHP).[§] After estimating these drugs' utilization rates, we multiplied those rates by the county-level excess number of HRI-related ED visits per day of extreme heat.[**]

Table 1. Drugs Selected for Modeling

Drug	Therapeutic Uses	HCPCS Code(s)	Recent Shortage History	Utilization Rate [a]
Saline solution infusion	Dehydration, electrolyte imbalance, reduced blood volume	J7030, J7040, J7050	2 shortages on FDA list: December 2021–August 2025 [14] and December 2014–November 2019 [15]. Additionally, a manufacturer reported in June 2025 that it will discontinue this product [16]. 3 shortages on ASHP list: June 2015–June 2019 [17], February 2022–July 2024 [18], and October 2024–present [19]	37.0%
Ondansetron injection	Nausea, vomiting	J2405	1 shortage on FDA list: April 2018–April 2022 [20] 2 shortages on ASHP list: June 2015–May 2017 [21] and March 2018–January 2025 [22]	17.4%
Ceftriaxone injection	Infection from physical injuries resulting from HRI,	J0696	1 shortage on ASHP list: June 2015–November 2019 [23]	6.5%

[†] To account for county-level variations in age, we performed this calculation separately for the two age groups analyzed by Visaria et al. [13] (< 65 years and ≥ 65 years) and then summed the excess ED visits from those two groups. The 2023 ACS population estimates were the most recent available at the time of analysis.

[‡] Medicare Part B covers drugs and biological products used in outpatient settings (including EDs) and related to physician services. They are usually administered by a healthcare practitioner (not self-administered) and often are infused or injected, for example, by an oncologist, rheumatologist, or urologist [53].

[§] The FDA drug shortage list is focused on medically necessary drugs, or those that prevent serious diseases or medical conditions and for which there is no alternative available; the ASHP drug shortage list includes all reported drugs with a supply issue that impacts how the drug is dispensed/administered or that requires an alternative to be used [53].

[**] We assumed the drug utilization rates from the Medicare Part B data were representative of all age groups.

Drug	Therapeutic Uses	HCPCS Code(s)	Recent Shortage History	Utilization Rate [a]
	weakened immunity from sustained heat exposure			

Notes: HRI = heat-related illness. HCPCS = Healthcare Common Procedure Coding System. FDA = U.S. Food & Drug Administration. ASHP = American Society of Health-System Pharmacists. All three drugs are essential medicines according to Executive Order 13944 List of Essential Medicines, Medical Countermeasures, and Critical Inputs [13].
[a] Utilization rates were calculated using 2024 Medicare Part B outpatient facility claims from emergency departments where heat-related illness was the primary diagnosis [24]. For the Medicare Part B population in 2024, we estimate that there were 86,745 total ED visits listing HRI as the primary diagnosis.

Estimating the National Excess Drug Utilization per Annum

After estimating the average burden of a single day of extreme heat on each county in the United States, we then estimated the total excess drug utilization per year at the national level associated with extreme heat. To do this, we multiplied each U.S. county's excess drug utilization per day of extreme heat by that county's average number of extreme heat days per year, which we calculated using 1999–2023 temperature data from the Parameter-elevation Regressions on Independent Slopes Model (PRISM) model [25] [26]. Estimating the number of extreme heat days per year in a given county requires the county's historical 95th percentile of daily mean temperature, which serves as the extreme heat threshold. We calculated county-specific 95th percentiles from 1981–2010 PRISM temperature data [25] [26], which is consistent with the date range used in Visaria et al. [11].[††] Because PRISM data are only available for the 48 contiguous states, our national estimates only apply to the contiguous United States.

We used this same range of temperature data to account for variation in extreme heat frequency and duration and estimate the full distribution of number of extreme heat days per year. Quantifying the distribution allowed us to calculate ranges in excess ED visits and excess drug utilization due to year-to-year variation in extreme heat exposure. To estimate the average national annual burden, we summed the county-level average annual totals across all U.S. counties. Similarly, the ranges in national annual burden were calculated by summing the minimum annual values and the maximum annual values.

Estimating the Excess Drug Utilization for Recent Heatwaves

We also used our county-level per-day estimates of excess drug utilization to calculate the associated extreme heat burden for two recent heatwaves. We selected heatwaves that were notable for their severity, duration, and geographic extent: (1) the Midwest and South heatwave lasting from June 12 through June 26, 2022 and (2) the Midwest, Northeast, and South heatwave lasting from June 20 through June 27, 2025. Using weather and news reports, we identified the dates of each heatwave and the affected counties [27] [28] [29] [30]. To facilitate comparison with the national, annual results, we used the same 5-year 2023 ACS population estimates for all heatwave scenarios for the number of people affected by each heatwave. We then used PRISM temperature data [25] [26] to estimate the number of days during the heatwave when each affected county exceeded its historical 95th percentile. For each affected county, we multiplied the number of extreme heat days by that county's excess utilization for each of the three drugs (saline solution, ondansetron, and ceftriaxone) per extreme heat

[††] PRISM is a high-resolution gridded climate dataset widely used for modeling localized temperature patterns across the United States. We only used data for warm months (June through September). We used county-level area-weighted estimates [25].

day. Then, we summed these county-level totals to estimate the overall excess drug utilization associated with the heatwave, for each of the three drugs. The heatwaves we analyzed are described in detail below.

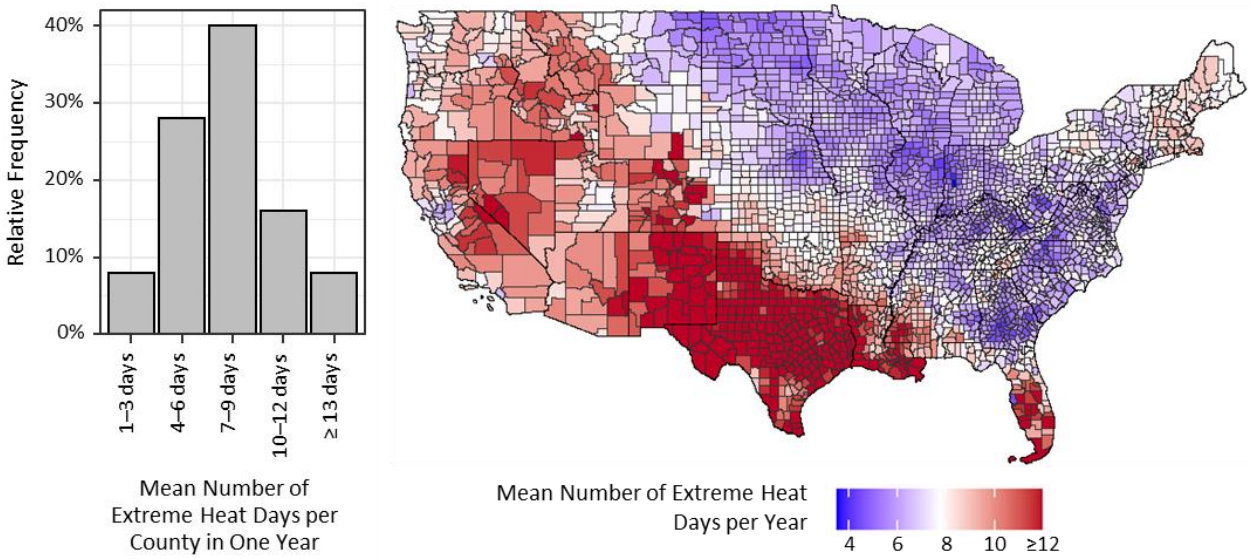
RESULTS

Estimated National, Annual Excess ED Visits and Drug Utilization

From 1999 to 2023, the average number of extreme heat days per county and per year ranged from 3.6 to 18.4. The overall average (across all 25 years from 1999–2023) is 7.8 extreme heat days per year, and the overall median is 7.0 extreme heat days per year (see left panel of Figure 1), across all counties in the contiguous United States.

At the county level, there is wide variation in extreme heat exposure, with southwestern parts of the United States experiencing higher than average numbers of extreme heat days per year (see right panel of Figure 1). Among the 10 percent of counties (n = 311 counties) that experienced the most extreme heat days from 1999 to 2023, 67.5 percent (n = 210 counties) were in Texas, 9.3 percent (n = 29 counties) were in Louisianna, 8.0 percent (n = 25 counties) were in New Mexico, 4.8 percent were in Colorado (n = 15 counties), and 3.5 percent were in Florida (n = 11 counties). The most extreme heat days experienced by a county in a single year was 89 extreme heat days in Jefferson County, Texas, followed by 81 extreme heat days in Cameron Parish, Louisiana and 75 extreme heat days both in Fort Bend County, Texas and Harris County, Texas.[‡‡]

Figure 1. Year-to-year and Geographic Variations in Annual Extreme Heat Exposure Across Counties in the Contiguous United States



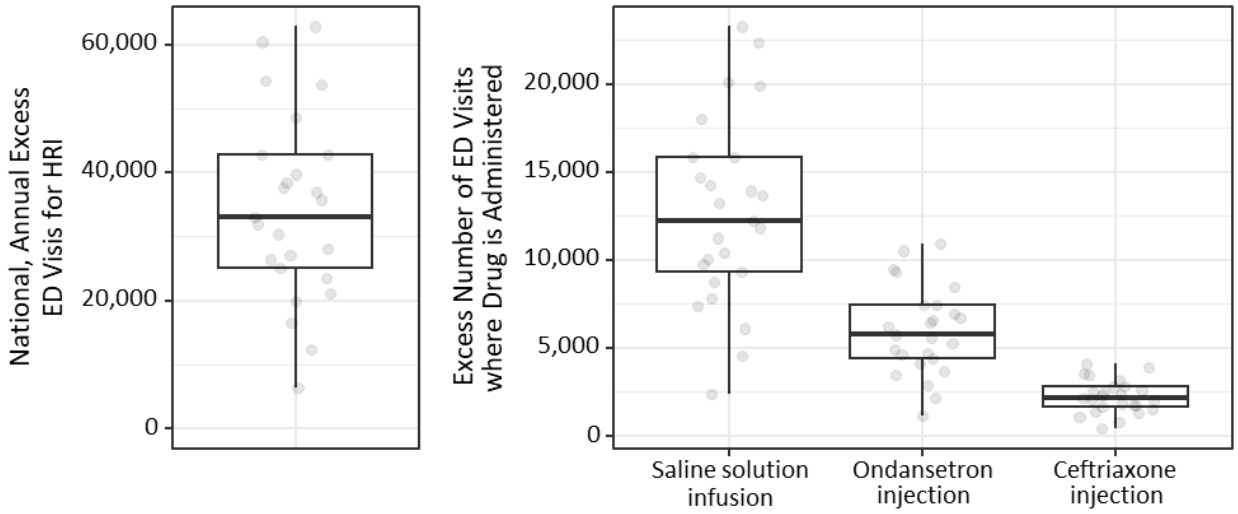
Notes: Left panel shows variation in the average number of extreme heat days per county in one year, based on 1999–2023 PRISM data. Right panel shows geographic variation in average number of extreme heat days per county, using each county's

[‡‡] All four counties experienced these extreme heat exposures in 2023.

25-year average from 1999–2023, relative to the national average. Counties in red experienced more extreme heat days than the national average; counties in blue experienced fewer extreme heat days than the national average. Counties in white experienced a similar number of extreme heat days as the national average.

These extreme heat days are associated with a substantial public health burden. Annually, in the United States, we estimate that there are 6,433 to 62,854 excess ED visits for HRI on extreme heat days, with an average of 34,251 and a median of 33,014 (see left panel of Figure 2). For comparison, the estimated national baseline incidence is 547,045 HRI-related ED visits during the months of June through September.[§§] Figure 2 shows the distributions of the national, annual excess ED visits for HRI, along with the associated excess utilization of the three drugs. We estimate that an average of 12,677 excess visits (range: 2,381–23,263) require saline solution infusions, an average of 5,963 excess visits (range: 1,120–10,942) require ondansetron injections, and an average of 2,226 excess visits (range: 418–4,084) require ceftriaxone injections.

Figure 2. Estimated National, Annual Number of ED Visits for HRI and Excess Utilization by Drug Across Counties in the Contiguous United States



Note: Estimates are based on 2023 ACS population data. Ranges show the variation in number of extreme heat days per year, based on the 1999–2023 PRISM data. In the box-and-whiskers plots, the solid black line shows the median value, the lower and upper edges of the box show first and third quartiles (respectively), and the whiskers extend to the minimum and maximum values. Points show the 25 individual estimates, each based on a single year of temperature data from 1999–2023.

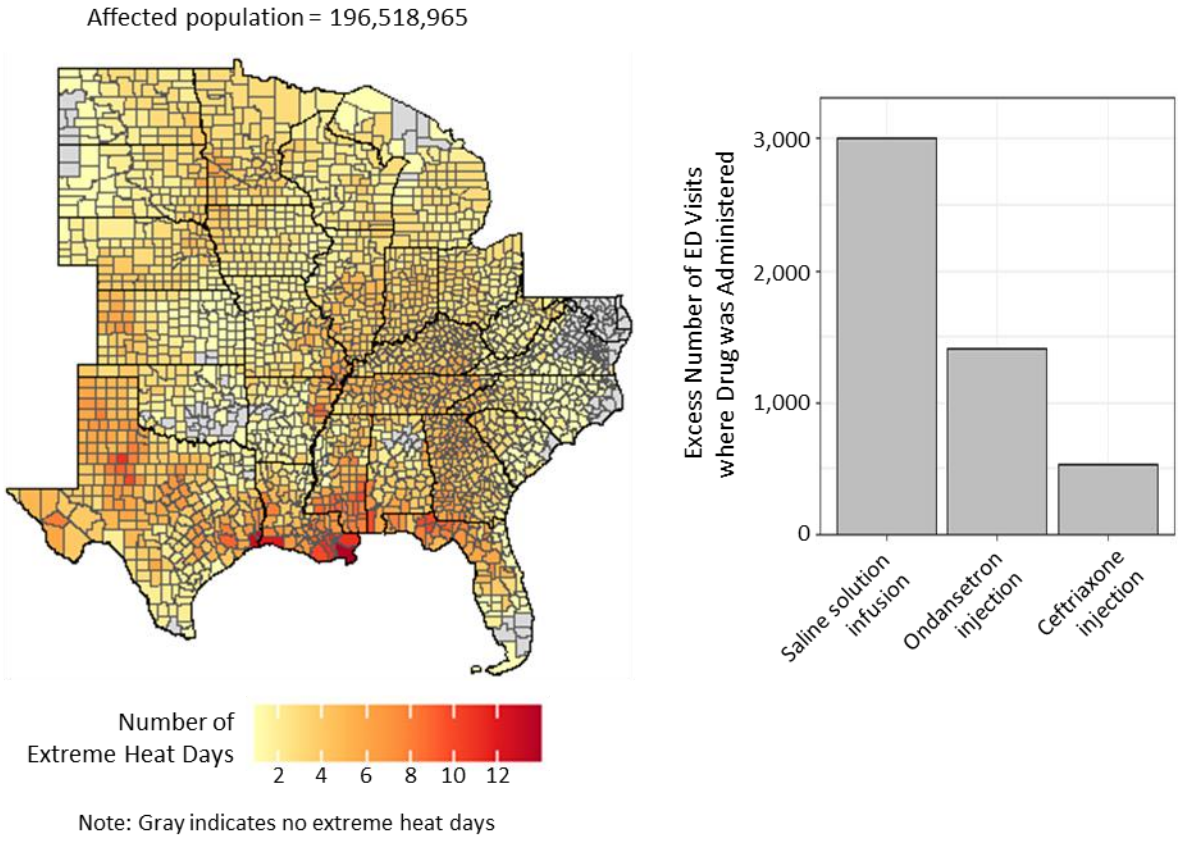
[§§] This baseline incidence is the estimated total number of ED visits with HRI as the primary diagnosis under the scenario where there are no extreme heat days between June and September. The baseline incidence estimate is using the current U.S. population (i.e., 2023 ACS data) and the weighted average incidence rate in Visaria et al. [13] for warm days below the 95th percentile (i.e., non-extreme heat days).

Recent Heatwaves

Midwest and South Heatwave, June 12th to June 26th, 2022

An early-season heatwave affected the Midwest and South in June 2022, with several southern states experiencing record temperatures that month [27]. Some cities also experienced record daily temperatures, and over 125 million people in the United States were under excessive heat warnings or heat advisories [28]. As shown in Figure 3, multiple counties in Louisiana, Texas, Mississippi, Alabama, and Florida experienced over ten days of extreme heat. Based on our model, the heatwave resulted in an estimated 8,120 excess ED visits for HRI, with 1,866 excess visits in Texas alone and over 500 excess ED visits each in Georgia (743), Florida (695), and Illinois (536). Of these excess ED visits for HRI, we estimate that there were 3,005 visits where saline solution infusions were administered, 1,414 where ondansetron injections were administered, and 528 where ceftriaxone injections were administered. Over the same period and geographic area, we estimate that there would have been 39,766 ED visits for HRI if a heatwave had not occurred. Compared to this baseline, the heatwave is associated with a 20.4 percent increase in ED visits for HRI across the entire Midwest and South, and increases of over 30 percent in some Southern states, including Louisiana (44.2 percent), Georgia (33.8 percent), and Mississippi (32.1 percent).

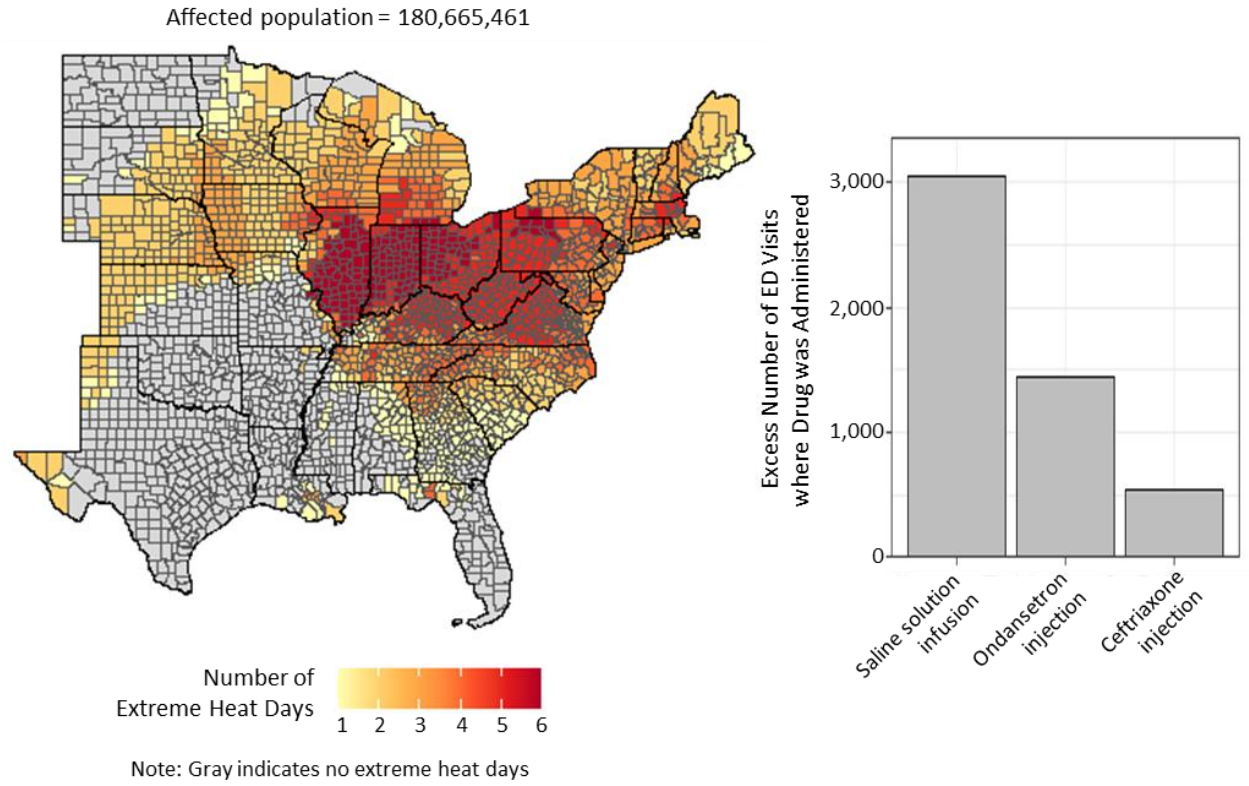
Figure 3. Midwest and South Heatwave between June 12th and June 26th, 2022



Midwest, Northeast, and South Heatwave, June 20th to June 27th, 2025

Extreme heat caused by a large heat dome in June 2025 broke temperature records across the Midwest, Northeast, and some of the South [29] [30]. Many states were under heat advisories, and several Northeastern states broke or tied all-time record highs. The map in Figure 4 shows the spread of extreme heat days by county, with the majority of counties in Illinois and Indiana experiencing six days of extreme heat. We estimate that this heat event was associated with 8,264 excess ED visits for HRI in the Midwest, Northeast, and South, with 3,059 of those excess visits using saline solution infusions, 1,439 using ondansetron injections, and 537 using ceftriaxone injections (Figure 4). Over the same period and geographic area, we estimate there would have been a baseline of 19,484 ED visits for HRI if extreme heat had not occurred.*** The heatwave therefore is estimated to be associated with a 42.4 percent increase in ED visits for HRI across both regions, with the greatest impacts in Indiana (67.6 percent increase), Ohio (62.2 percent increase), Illinois (57.1 percent increase), and West Virginia (56.9 percent increase).

Figure 4. Midwest, Northeast, and South Heatwave between June 20th and June 27th, 2025



*** As this heatwave only affected certain parts of the Midwest and South, the baseline ED visit incidence is restricted to counties that experienced at least one day of extreme heat during the heatwave. Similarly, the affected population corresponds to those living in counties that experienced at least one extreme heat day.

DISCUSSION

Overview and Implications

Our findings highlight the substantial burden of extreme heat on public health in the United States, with a focus on ED visits resulting from HRI. On average, there are about eight extreme heat days each year based on our definition, but this varies substantially across regions and over time, with some counties having experienced more than 80 extreme heat days in a single four-month period between June and September over the 1999–2023 period. Counties with the most extreme heat exposure between 1999 and 2023 are disproportionately located in Texas, Louisianna, New Mexico, Colorado, and Florida; Arizona and Nevada also have experienced a disproportionately large share of extreme heat. While many previous studies have quantified the effects of extreme heat on the number of HRI-related ED visits, this study translates those findings into an excess drug utilization for the current U.S. population, while accounting for year-to-year variation in extreme heat exposure and using recent heatwaves as case studies. By linking literature on ED visit rates, drug utilization rates, and current U.S. population data, we show that excess drug utilization can be estimated and anticipated using a set of reasonable assumptions for specific counties and heatwave lengths.

We find that extreme heat is associated with surges in ED visits, which can stress emergency services and hospital capacity—especially if extreme heat lasts for multiple days. Nationally, we estimate that extreme heat exposure translates into over 34,000 excess ED visits for HRI each year, which corresponds to roughly 6 percent of the baseline ED visits for HRI in June through September (n = 547,045). The 2022 and 2025 heatwaves further illustrate the acute health consequences of extreme heat, with thousands of excess ED visits estimated in each event and sudden increases in drug utilization of over 60 percent for entire states. These excess visits can strain local hospital inventories of saline solution, ondansetron, and ceftriaxone—all of which are used to treat patients with HRI at relatively high rates. Notably, these same drugs are heavily used for other conditions besides HRI [31], possibly expanding the impact of supply shortfalls during extreme heat to other patients. Of the three modeled drugs, saline solution experiences the highest spike in utilization during extreme heat, as we estimate that it is administered to over a third of ED patients with HRI.

Our findings suggest that regional preparedness and resource allocation must be tailored to the intensity and frequency of local heat events. As our heatwave case study analysis shows, the intense localized nature of extreme heat can cause drug utilization spikes that are high relative to typical regional needs, which emphasizes the need for public health strategies and infrastructure resilience to mitigate the strain on emergency medical services.

Chronic Diseases and Regional Variation

While this study focuses on HRI, our results have broader relevance. Extreme heat is also associated with a surge of ED visits for chronic diseases like kidney disease [32] [4], diabetes [33], respiratory disease [32] [34] [35], and mental health conditions [33] [4] [36]. All of these diseases require medications that overlap with those used for HRI, making our estimates of the excess drug utilization conservative. In addition to saline solution, ondansetron, and ceftriaxone, several other critical drugs may be at risk for similar utilization surges, including other IV fluids, dialysis treatment, insulin, and other antibiotics, as just a few examples.

The drug utilization surges we have quantified disproportionately affect communities with higher rates of chronic disease like diabetes, heart disease, asthma, and kidney disease, as these conditions increase susceptibility to HRI [37]. Many counties with the most extreme heat exposure are rural communities, which face high and growing incidence of chronic illness—in part due to limited access to healthcare and healthy food [38]. Many rural residents have long travel times to healthcare facilities, which have been worsened in recent years by hospital closures [39] [40]. Rural hospitals also face greater challenges quickly acquiring medicines when supplies run low [41]. As chronic disease rates continue to rise nationally, the heat-related drug burden will also increase.

Supply Chain Vulnerabilities

Our analysis highlights a critical intersection between increased drug utilization and existing supply chain vulnerabilities. All three drugs modeled—saline solution, ondansetron, and ceftriaxone—are prone to shortage as generic injectables and have experienced shortages in recent years [42] [43] [44]. Saline solution—which has the highest utilization spikes during extreme heat of all three modeled drugs—has been in shortage almost continuously from late 2014 through August 2025. These shortages have arisen for a number of reasons, including damage by Hurricane Maria and Hurricane Helene to manufacturing facilities in Puerto Rico [45] and North Carolina [46], respectively, and saline manufacturers exiting the market [17] such as Fresenius Kabi who announced discontinuation of its 1000-mL saline injection bags [16] in June of 2025.

While a single extreme heat event may be too concentrated to create a nationwide drug shortage, shortfalls in regional drug inventories may still have detrimental effects on a single county or hospital. ED patients are particularly vulnerable since they often require time-sensitive and sometimes life-saving care, and supply shortfalls force EDs to rely on substitutes that may be less effective or have less desirable adverse side effect profiles [47]. All three modeled drugs are essential medicines, meaning that patients may face serious health risks and treatment disruptions when access to these drugs is restricted or unavailable.

Just as rising rates of chronic disease can exacerbate the effects of extreme heat, certain trends in pharmaceutical supply chains can amplify the public health impact of heat-related surges in drug utilization. A growing share of active pharmaceutical ingredients (APIs) are now produced overseas and imported into the United States [48], with only 24 percent of API manufacturing facilities serving U.S. drug markets located domestically as of 2024 [49]. The production of generic drugs has similarly shifted abroad: between 2011 and 2020, the proportion of U.S.-based generic drug manufacturers fell from 52 percent to 35 percent [50]. Because of this trend in outsourcing, many drug supply chains are spread across multiple countries and regulatory jurisdictions, reducing manufacturers' ability to respond quickly during heatwaves or other weather-related emergencies. Generic drug manufacturers often operate with minimal excess capacity and face particular challenges in ramping up production, which can require coordination between numerous different companies and regulatory bodies in a geographically distributed supply chain. To the extent that pharmaceutical supply chains continue to globalize and generic drug competition continues to create downward pressure on prices (lowering profit margins), hospitals may find it increasingly difficult to secure adequate drug supplies during prolonged periods of extreme heat.

Future Work

While this study modeled the utilization of three HRI drugs, further work should validate the model using real-world heatwave data and extend it to (a) a wider range of extreme heat severities and durations, (b) other drugs associated with HRI, (c) other illnesses like renal disease, diabetes, respiratory disease, and mental health conditions, and (d) medical devices or other medical products. Other natural hazards could also be considered, such as floods, hurricanes, or wildfires. While emergency departments often serve as the first point of contact for unplanned healthcare visits, ED visits often lead to hospital stays or primary care physician visits. Analyzing these other healthcare settings could help capture inpatient drug use or retail prescriptions that contribute to the total drug utilization but are not quantified by our model. Other data sources could improve the estimates, such as commercial claims data covering a wider range of ages. Over-the-counter drug utilization could also be captured from other data sources such as retail sales data sets.

Extending our model in these ways could help inform preparedness efforts and improve public health during weather-related emergencies. Improving the accuracy of regional estimates would be particularly useful to hospitals and healthcare networks when creating purchasing schedules, estimating peak seasonal drug utilization, and pursuing emergency drug acquisitions to cover near-term utilization surges. Beyond local healthcare operations, future versions of the model could also support state and federal public health policy and emergency preparedness by identifying specific drugs that need investments in supply chain resilience. Future versions of the model could also assist federal or state, Tribal, local, and territorial agencies in planning distribution strategies for extreme weather events. Integrating future models with existing real-time weather forecasts or heat alerts issued by the National Weather Service (NWS) could enable an automated system for triggering regional preparedness actions [51]. Ultimately, future versions of this model could be used by stakeholders at all levels (federal, state, local, hospital) to anticipate surges in drug utilization, maintain healthcare preparedness, and ultimately improve human health.

Study Limitations

Our study has several limitations that may be addressed by future work. First, our analysis did not capture ED visits resulting in hospitalization or trips to other outpatient facilities besides EDs (e.g., physician's offices, standalone clinics, urgent care facilities, renal facilities connected to a hospital), which likely contribute to drug utilization during an extreme heat event. ED visits that result in hospitalization may be particularly important to capture in future analyses because long inpatient stays could make large contributions to the excess drug utilization. Another limitation of this study is the sole reliance on Medicare Part B claims data to estimate drug utilization rates. As Medicare is designed primarily for individuals 65 years and older, the claims data we used in this analysis are skewed toward older individuals. Commercial claims contain information about a wider range of age groups and would provide more accurate drug utilization rates.

A third limitation of this work is that our analysis used only one extreme heat threshold (i.e., the 95th percentile). Modeling the effect of extreme heat as a continuous function of heat severity and exposure duration would be particularly important for future heatwave analyses, since extended exposure can have a compounding effect—even at thresholds below the 95th percentile. Because we only modeled excess ED visits treating HRI, our model underestimates the total excess drug utilization. Extreme heat is

known to affect other conditions that are treated with saline solution, ondansetron, and ceftriaxone; these other heat-triggered illnesses should also be modeled to yield a drug's total excess utilization during extreme heat.

Lastly, in the recent heatwave case study analysis, we applied the same ED visit rates from Visaria et al. [11] as we used for the national, annual results. Those ED visit rates are averages over extreme heat events lasting any number of days (i.e., including single-day events). The selected historical heatwaves, though, had higher-than-average durations and severities. Applying the results from Visaria et al. [11] thus likely underestimates the true impact of the historical heatwaves.

CONCLUSION

This study provides a novel model that estimates the excess utilization of three drugs (saline solution, ondansetron, and ceftriaxone) that treat HRI in the ED setting on extreme heat days in the United States. We demonstrate that extreme heat is associated with an increased number of HRI-related ED visits and a resulting increase in the use of the examined drugs. By estimating the heat-related excess drug utilization both nationally and for two recent heatwave events, this study highlights the substantial burden placed on emergency departments and the supply chain for these drugs during extreme heat events. Further research could improve the accuracy of our regional estimates and extend the model to a wider range of diseases, healthcare settings, medical products, and severities/durations of heatwaves. This could support emergency planning and preparedness by helping hospitals and healthcare networks assess short-term and long-term drug acquisition needs, and by helping state and local governments make informed investments in supply chain resilience.

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