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Impacts of Hurricane Matthew Exposure on Infections and Antimicrobial Prescribing in North Carolina Veterans

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Abstract

The impact of hurricane-related flooding on infectious diseases in the US is not well understood. Using geocoded electronic health records for 62,762 veterans living in North Carolina counties impacted by Hurricane Matthew coupled with flood maps, we explore the impact of hurricane and flood exposure on infectious outcomes in outpatient settings and emergency departments as well as antimicrobial prescribing. Declines in outpatient visits and antimicrobial prescribing are observed in weeks 0–2 following the hurricane as compared with the baseline period and the year prior, while increases in antimicrobial prescribing are observed 3+ weeks following the hurricane. Taken together, hurricane and flood exposure appear to have had minor impacts on infectious outcomes in North Carolina veterans, not resulting in large increases in infections or antimicrobial prescribing

Introduction

The impact of hurricane-related flooding on infectious diseases in the US is not well understood. Hurricane Matthew made landfall in North Carolina in October, 2016 and caused extensive inland riverine flooding. Prior work examining hurricane impact in North Carolina suggests small but significant increases in emergency department (ED) visits for gastrointestinal illness immediately following hurricane exposure,¹ and in waterborne pathogen illness among Medicaid enrollees in the year following a hurricane,² for those living in flooded areas. Using health record data for infectious outcomes and antimicrobial prescribing, and linking patient residential address with high-resolution flood maps, we documented whether similar increases in infections and use of infection-related medications were observed among US veterans living in flood-exposed areas of eastern North Carolina following Hurricane Matthew.

Methods

Active users of the Veterans Health Administration (VHA) residing in the 45 counties declared disaster areas by FEMA following Hurricane Matthew were identified. Patients who died before the hurricane made landfall, resided in a nursing home or other care facility, or had an address that could not be geocoded to a specific location, were excluded.

Residential flood exposure based upon geocoded address was assessed using RIFT, a physics-based (shallow water equations) flood model developed by Pacific Northwest National Laboratory which used a 90-meter resolution digital elevation model data and spatiotemporally varying rainfall data. Additional patient characteristics included self-identified race, Charlson comorbidities,³ and rurality, defined by Rural-Urban Commuting Area (RUCA) codes based on patient residence census tract.

Infection-related outpatient and ED visits, and antimicrobial prescriptions were assessed on a weekly basis during 2016, as well as for the 2016 cohort in the year prior to Hurricane Matthew (2015) to account for seasonal trends in infectious outcomes and antimicrobial prescribing. No major hurricanes made landfall in North Carolina during 2015. Outpatient and ED visits included both VHA visits as well as VA-funded community care. Clinical Classifications Software CCS (US Department of Health and Human Services, Washington, USA) was used to identify diagnoses for infectious diseases of multiple systems with multiple causative organisms (Supplemental Table 1). A subset of relevant

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Table 1. Characteristics of the patient population

Variable	Overall (n = 62762)	Flooded (n = 6061)	Non-Flooded (n = 56701)	P - value
Gender				
Male	56693 (90.3%)	5442 (89.8%)	51251 (90.4%)	0.1324
Female	5369 (9.7%)	619 (10.2%)	5450 (9.6%)	0.1324
Age				
< 50	15935 (25.4%)	1538 (25.4%)	14397 (25.4%)	0.9787
50-59	13309 (21.2%)	1269 (20.9%)	12040 (21.2%)	0.5907
60-69	19245 (30.7%)	1862 (30.7%)	17383 (30.7%)	0.9186
70-79	9785 (15.6%)	982 (16.2%)	8803 (15.5%)	0.1675
> 80	4488 (7.2%)	410 (6.8%)	4078 (7.2%)	0.2195
Race				
White	33296 (53.1%)	2977 (49.1%)	30319 (53.5%)	< 0.0001
Black	25467 (40.6%)	2607 (43.0%)	22860 (40.3%)	< 0.0001
Other	3999 (6.4%)	477 (7.9%)	3522 (6.2%)	< 0.0001
Rurality				
Rural	31494 (50.2%)	2718 (44.8%)	28776 (50.8%)	< 0.0001
Urban	31268 (49.8%)	3343 (55.2%)	27925 (49.2%)	< 0.0001
Prior Hospitalizations				
30 Days Prior	430 (0.7%)	35 (0.6%)	395 (0.7%)	0.285
90 Days Prior	1290 (2.1%)	119 (2.0%)	1171 (2.1%)	0.5953
Charlson Comorbidity				
Myocardial infarction	3014 (4.8%)	305 (5.0%)	2709 (4.8%)	0.3785
Congestive heart failure	6910 (11.0%)	680 (11.2%)	6230 (11.0%)	0.5837
Peripheral vascular disease	7039 (11.2%)	688 (11.4%)	6351 (11.2%)	0.7243
Cerebrovascular disease	6609 (10.5%)	693 (11.4%)	5916 (10.4%)	0.0159
Dementia	2869 (4.6%)	280 (4.6%)	2589 (4.6%)	0.8493
COPD	14846 (23.7%)	1416 (23.4%)	13430 (23.7%)	0.5736
Rheumatic disease	1357 (2.2%)	146 (2.4%)	1211 (2.1%)	0.1647
Peptic ulcer disease	863 (1.4%)	85 (1.4%)	778 (1.4%)	0.8473
Mild liver disease	4731 (7.5%)	454 (7.5%)	4277 (7.5%)	0.8829
Diabetes	22899 (36.5%)	2222 (36.7%)	20677 (36.5%)	0.7657
Diabetes with complications	13432 (21.4%)	1308 (21.6%)	12124 (21.4%)	0.7206
Hemiplegia or paraplegia	775 (1.2%)	86 (1.4%)	689 (1.2%)	0.1721
Renal disease	9795 (15.6%)	1009 (16.6%)	8786 (15.5%)	0.0188
Malignancy	8145 (13.0%)	786 (13.0%)	7359 (13.0%)	0.9816
Moderate or severe liver disease	514 (0.8%)	47 (0.8%)	467 (0.8%)	0.6925
Metastatic solid tumor	1366 (2.2%)	127 (2.1%)	1239 (2.2%)	0.6489
AIDS	401 (0.6%)	53 (0.9%)	348 (0.6%)	0.0155

antimicrobials, from the National Healthcare Safety Network's standardized list, was identified based upon clinical expertise (Supplemental Table 2). For each year of data, flags were set to indicate a baseline period (calendar weeks 1-40), weeks 0-2 after Hurricane Matthew (weeks 41-43), and 3 or more weeks after Hurricane Matthew (weeks 44-52).

Binomial regression models with logit link functions were used to assess changes in infection-related outcomes during weeks 0-2 and 3 or more weeks after Hurricane Matthew, relative to the baseline period. Models included an exchangeable working correlation matrix with robust standard errors to account for the multiple weeks per patient. Interactions between year and the indicators for baseline, weeks 0-2 and weeks 3+ were used to assess changes in outcomes associated with the hurricane. Models were generated separately for patients residing in flood-exposed and unexposed neighborhoods. All models adjusted for race, Charlson comorbidities, and rurality.

Statistical analysis was completed in SAS version 8.2 (SAS Institute, Cary, NC, USA), residential flood assignment was done in ArcMap version 7.1 (ESRI, Redlands, CA, USA). The study was approved by the Institutional Review Board at the University of Iowa.

Results

Of the 62762 eligible patients, 6061 (9.7%) experienced residential flooding during Hurricane Matthew (Table 1). Residential flooding did not differ by age but did differ by race, rurality, and some comorbidities.

When controlling for race, comorbidities, and rurality, significant declines in outpatient visits for infectious diseases and antimicrobial prescriptions in weeks 0-2 versus the baseline period relative to the non-Matthew years were observed in both the overall and the non-flooded cohort, and in prescriptions for the flooded

Table 2. Model results representing relative change versus baseline in Matthew year versus the same period in the year prior to the hurricane

	Overall		Flooded		Non-Flooded	
	0-2 weeks	3+ weeks	0-2 weeks	3+ weeks	0 - 2 weeks	3+ weeks
Outpatient	0.90 (0.84, 0.97)	1.03 (0.97, 1.10)	0.80 (0.64, 1.00)	1.13 (0.91, 1.40)	0.91 (0.85, 0.98)	1.03 (0.97, 1.09)
Emergency Department	0.85 (0.61, 1.17)	0.96 (0.79, 1.16)	0.52 (0.15, 1.85)	0.67 (0.30, 1.51)	0.89 (0.63, 1.25)	0.99 (0.82, 1.21)
Antimicrobials	0.86 (0.81, 0.91)	1.06 (1.01, 1.12)	0.79 (0.65, 0.96)	1.07 (0.91, 1.27)	0.87 (0.82, 0.92)	1.06 (1.01, 1.12)

cohort (Table 2). Significant increases in antimicrobial prescriptions were observed in weeks 3+ for the overall cohort and in prescribing in the non-flooded cohort. No significant changes in ED visits for infections were observed.

Discussion

These findings contradict other studies that found slightly increased ED visits for flood-related acute gastrointestinal infections in weeks 0-2 following Hurricane Matthew, for residents of highly flooded ZIP codes.¹ The current analysis used a more specific determination of flood exposure and a broader set of infections. The increase in antimicrobial prescribing observed in weeks 3+ could be due to an onset of less acute infections resulting from hurricane exposure or reflect a delay and then rebound in healthcare seeking behavior as the hurricane disrupted typical activities, as has been previously observed in VHA users.⁴ The delayed healthcare seeking behavior is also potentially responsible for the relative decline in outpatient visits for infections in weeks 0-2 versus the baseline period. Taken together, hurricane and flood exposure appear to have had minor impacts on infectious outcomes in North Carolina veterans, not resulting in large increases in infections or antimicrobial prescribing.

Supplementary material. To view supplementary material for this article, please visit <https://doi.org/10.1017/dmp.2023.9>

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