

Original Research

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Powerless in the Virgin Islands: Emergency Department and Wound Care Clinic Utilization Following the 2017 Hurricanes Irma and Maria on St. Thomas, U.S. Virgin Islands

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Abstract

Objective: The main objective of this work was to characterize the prevalence of acute medical needs by examining emergency department (ED) and outpatient wound care clinic (WCC) visits before, during, and after the 2017 Hurricanes Irma and Maria, in St. Thomas, United States (U.S.) Virgin Islands.

Methods: Descriptive statistics and logistic regression were used to assess associations between the occurrence of the storms and visits due to injuries and chronic conditions presented to the ED and WCC from September 1, 2016 to May 31, 2018.

Results: ED visits increased and the rate of injury care was higher during the storms (12 patient visits per day) than before or after the storms (9 patient visits per day). WCC visits increased during (12%) and after the storms (45%), and were associated with patients 60 years and older. The odds of ED and WCC visits due to injury during the storms were significantly higher (odds ratio [OR]: 1.28, 95% confidence interval [CI]: 1.17, 1.40) than prior to the storms. The odds for visits due to injuries were 1.19 (95% CI: 1.12, 1.28) times higher after the storms.

Conclusions: Increases occurred in ED and WCC visits for injury care during the storms and in WCC visits after the storms. Public health preparedness mandates understanding how major hurricanes impact the prevalence of acute medical needs, and the factors that influence decisions to seek medical care, in their wake.

Introduction

Hurricanes Irma and Maria, 2 of the most powerful storms of the 2017 Atlantic hurricane season, struck the United States (U.S.) Virgin Islands as category 5 storms on September 6, 2017, and on September 20, 2017, respectively.^{1–3} Hurricane Irma caused catastrophic damage to St. Thomas and St. John and devastated St. Croix.^{1,3} Hurricane Maria arrived 2 weeks later, devastating St. Croix and exacerbating the damage inflicted by Hurricane Irma on the 3 islands.^{2,3}

All residents on the islands of St. Thomas, St. John, and St. Croix were affected by the hurricanes.³ The storms caused an estimated 10.8 billion dollars in infrastructure, property, and economic damage.³ An estimated 52% of the territory's housing units were destroyed, with about 12% sustaining catastrophic damage.^{3,4} The storms demolished more than 90% of the power lines, engendering electrical and telecommunication outages for months.^{3,5} Numerous residents waited up to 5 months for power and telecommunication services to be restored.^{3,5} Some residents did not have access to the territory's 911 system for several weeks due to the loss of power and telephone services.³ The loss of electrical power also created a health risk from floodwater contaminated with sewage.³ Most residents were also without running water, fresh food, and transportation.³ Roads were inaccessible due to flooding and debris from the hurricanes, and gas stations, seaports, and airports were closed for several weeks.³ The storms displaced countless residents, causing many to be placed in shelters, others to double up and cohabitate with friends or family, and numerous individuals to relocate to the U.S. mainland.^{3,6}

Prior to Hurricane Irma and within days after landfall, several residents and patients from the St. Thomas/St. John district were evacuated to St. Croix. When Hurricane Maria subsequently posed a threat to St. Croix, several of the St. Thomas/St. John evacuees and the most vulnerable populations from St. Croix were subsequently evacuated to Puerto Rico and the Continental U.S.⁷ In the days after the storms, numerous patients from the hospitals on St. Croix and on St. Thomas had to be evacuated to the U.S. mainland because of damage to the 2 hospitals' infrastructure, including the loss of power and water.^{3,7} Despite efforts to shield the vulnerable and

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prevent loss of life, 5 fatalities were directly attributed to the hurricanes, and the storms were indirectly responsible for several additional deaths.^{1–3}

Impact of storms on public health and healthcare infrastructure

In the St. Thomas/St. John district, the Roy Lester Schneider Hospital and Regional Medical Center (SRMC), a 159-bed hospital serving a population of over 48000, lost portions of its roof and windows and an entire in-patient ward.³ The hospital's cancer center and its community health clinic on St. John were deemed inoperable due to storm damage.³ In the wake of the storms, the hospital (including its emergency department [ED] and dialysis center) operated for days (and sporadically over 6 months) with only supplementary power from its emergency generator and limited water supplies. Power outages caused closure of outpatient facilities, pharmacies, and assisted-living centers, triggering an increased demand for healthcare services and utilization of SRMC's ED.

Power outages pose major public health concerns due to their substantial impacts on the delivery of healthcare services and on various health conditions. Substantial evidence shows the effects of power outages on healthcare delivery, home healthcare services, the public health infrastructure, and adverse health outcomes.^{8–13} The effects of hurricanes on the increased utilization of EDs in New York,^{14–19} New Jersey,^{20–22} and Texas²³; across 9 U.S. states,²⁴ among Caribbean islands,^{25–30} and the impact of a category 5 tropical cyclone on disaster related wounds,³¹ have been recently investigated. The hurricane studies attributed the increased ED visits to disrupted access to care for a range of chronic diseases and conditions, including cardiovascular disease, diabetes, cancer, chronic obstructive pulmonary disease (including ventilator dependence), renal disease, dementia, and mental disorders; disaster-related conditions (such as hypothermia or environmental exposures); carbon monoxide-related accidents; and a lack of prescription refills.^{15–20,22,28,32–34} The tropical cyclone study provided evidence of post-disaster wound infections and chronic wound conditions associated with poor wound management and the disruption of access to care.³¹

Purpose of study and significance

The costs of the impact of Hurricanes Irma and Maria on mortality, property, and the economy have been estimated for the U.S. Virgin Islands,^{1–3} however, less is known about the indirect effects of extended power outages, lack of running water, fresh food items, potable water, and flooding on the health of territorial residents, especially those with chronic medical conditions. Individuals with chronic medical conditions, access and functional needs, the elderly, pregnant or post-partum women, and infants are particularly vulnerable during hurricane disasters.^{18–20,32–36} Interrupted access to medical care and treatment, damaged or lost medications, and an inability to replenish prescription medications, all place vulnerable populations at increased risk for morbidity and developing acute medical needs in the days following a hurricane disaster, thus impacting ED inflow.^{16,18–20,22,28,32–36} Moreover, disruptions to essential community lifeline support and services, including primary healthcare services rendered by skilled clinicians, could increase demands for alternative care at EDs. Accordingly, evidence is required to inform and enable preparedness, including personnel and medical resource requirements in

EDs, for future hurricane disasters of the breadth and magnitude of Hurricanes Irma and Maria.

Understanding the profile of hurricane-related visits presenting to the ED is essential to discerning the health consequences of hurricanes and the resources that are needed for response to these disasters. Limited research is available describing how category 5 hurricanes and the downstream effects of power outages and other storm-related complications affect population health. As the U.S. Virgin Islands are highly prone to hurricanes, awareness of the immediate post-hurricane reality on ED visits is imperative to advance hurricane preparedness and response in the territory. To our knowledge, the literature on victims of Hurricanes Irma and Maria treated within the U.S. Virgin Islands healthcare system is scarce.²⁶ Given the scope and severity of destruction to the territory consequential to the 2 category 5 storms, we aimed to quantitatively characterize the prevalence of acute medical needs by examining patient visits to the SRMC ED and to the outpatient wound care clinic (WCC) in St. Thomas before, during, and after these major storms. Moreover, we specifically sought to describe the characteristics of patients correlated with the number of ED and WCC visits, and with the incidence of injuries and chronic conditions treated in the ED and WCC in each of the 3 time periods.

Methods

Study design, setting and sample

This study was a retrospective review of electronic health records from the SRMC ED and outpatient WCC visits. The ED serves approximately 20000 patient visits annually, with 17 beds available to manage patients from St. Thomas and St. John.³ The WCC provides advance care for acute and chronic wounds and ulcerations caused by diabetes, vascular disease, trauma, and other health conditions. It serves a population of roughly 48000 residents in the St. Thomas/St. John district.³ Physicians in the ED, outpatient clinics, and private medical practices refer patients to the WCC for specialized treatments including, debridement, skin grafts, advanced wound dressings and wound therapy, and coordinated individualized care facilitated by physical therapists, nutritionists, and diabetes educators. Data were extracted from the Medical Information Technology (MEDITECH) Electronic Health Records System. The study included the analysis of all patient visits to the ED and WCC during the period of September 1, 2016 to May 31, 2018. The ED data file consisted of 26141 visits for 15182 patients, and the WCC data consisted of 474 visits for 133 patients. Missing data were minimal in both files, ranging from 0.67% to 0.92%.

Measures

The variables in this study included patient demographic information such as age, gender, and race. Both ED and WCC data contained information on admission and discharge dates, as well as primary diagnosis codes (coded to *International Classification of Diseases, Tenth Revision* [ICD-10]), which allowed for the construction of variables related to time periods and to injuries and chronic medical conditions. Only primary diagnosis codes were used since some of the data files did not contain more than 1 ICD-10 primary diagnosis codes.

Time periods

A total of 3 time periods were defined as before-storms (baseline-reference point), during-storms (study period), and after-storms (downstream effect), based on the dates Hurricanes Irma and

Maria struck the U.S. Virgin Islands. The before-storms period (the reference point), ranged from September 1, 2016, to September 5, 2017, and included 15982 visits. The during-storm period (study period) ranged from September 6, 2017, to November 6, 2017, and included 2928 visits, while the after-storms period (downstream effect) was from November 7, 2017, to May 31, 2018, and included 7705 visits.

Injuries and chronic conditions

The primary diagnosis codes in both ED and WCC data files were parsed to divide the total number of visits in the sample into 3 categories: (1) visits due to injuries, (2) visits due to chronic medical conditions, and (3) all other visits. The *injuries* category was constructed to capture injury classifications as determined by the primary diagnosis code for patient encounters associated with the ICD-10 injury codes (ICD-10 code range: S00-T98). Similarly, the *chronic conditions* category was constructed to indicate whether a patient suffered from a chronic condition (ICD-10 codes: B15-B24; C00-D49; E08-E78; F10-F84; G30; I10-I63; J09-J99; M00-M99; N18). All remaining visits that were neither due to an injury or a chronic condition were classified as *other reasons*.

Demographic variables of the study

In this study, descriptive trends of ED and WCC visits during the 3 time periods were performed according to age, gender, number of patient visits, healthcare coverage of the patient such as self-pay, Medicaid, Medicare, and private insurance, and disposition of ED patients.

Statistical approach

The data were categorical, consisting of frequencies (counts and percentages) of ED and WCC patient visits classified into specified groups (age, gender, healthcare coverage, disposition, injury types, and chronic condition). We performed descriptive statistics (percentages, and bar graphs) to assess the characteristics of patients correlated with the visits during each time period and to quantify the number of visits due to injuries and chronic conditions in each of the 3 time periods. The proportions of patient visits within each category, the number of ED patient visits per day, and the number of WCC visits per month (rounded to the nearest whole number) were compared across the 3 time periods. The frequencies of injuries and chronic conditions observed in the ED per day and in the WCC per month were assessed across the 3 time periods. The level of statistical significance for each Z-test statistic was adjusted using the Bonferroni correction ($\alpha = 0.05/k$, where $k =$ number of paired comparisons in 1 test). Binary logistic regression analyses were conducted to assess the effects of the storms/study period on visits associated with injuries and chronic conditions, adjusting for demographic characteristics. Odds ratios (ORs), 95% confidence intervals (95% CIs), and associated *P*-values were calculated to estimate the effect of the storms/study period on visits associated with injuries and chronic conditions after controlling for patient age, gender, and race. The data were analyzed using IBM SPSS version 24 (SPSS Inc., Chicago, Illinois).

Results

Healthcare utilization trends and characteristics of patient visits in the ED and WCC are presented in [Table 1](#). There were 26615 patient visits, of which 60% ($n = 15982$) occurred prior to the storms, 11% ($n = 2928$) were during the storms, and 28.9%

($n = 7705$) after the storms ([Table 1](#)). Most of these patient visits (total $n = 19037$, 72.9%) were classified as self-pay, Medicaid, and Medicare. The average number of daily ED patient visits prior to the storms was 43. The total daily ED patient visit volume increased to 47 during the storms study period, then declined by about 37 patient visits in the period after the storms ([Table 1](#)). An examination of the 3 time periods shows the proportion of visits among patients aged 40 years and older was greatest during the storms, whereas the percentage of visits for patients aged 39 years and younger declined during and after the storms. Overall, there was not a statistically significant difference by sex, before and after the storms, but a higher proportion of ED visits was associated with male patients during the storms (51.0%) than with females (49.0%); and the daily volume of self-pay patient visits was slightly higher after the storms than before and during the storms.

The majority of WCC visits were associated with patients 60 years and older ($n = 304$, 64.1%). The average monthly volume of WCC patient visits increased from 17 before the storms, to 28 during the storms, and 31 after the storms. More male visits at the WCC occurred during the storms (55.4%) and after the storms (51.6%), than female visits (44.6% and 48.4%, respectively). However, more WCC female visits (59.5%) occurred before the storms, than male visits (40.5%).

The 10 most common primary diagnoses of injuries and chronic conditions associated with ED visits that occurred across the 3 time periods are presented in [Table 2](#). The top 5 primary diagnoses (72.1%), accounted for about 3 to 12 patient visits per day. The rate of injury care, including poisoning and other consequences of external causes, was higher during the storms (12 patient visits per day) than before or after the storms (9 patient visits per day). Patient visits for chronic conditions associated with ICD-10 diagnoses of signs, symptoms, and abnormal clinical and laboratory findings remained relatively constant across the 3 time periods (5 or 6 patient visits per day). The rate for diseases of the respiratory system, digestive system, and musculoskeletal system/connective tissue also remained constant (3 or 4 patient visits per day). Injuries of the ankle and foot, head, wrist and hand, and knee and lower leg were prevalent during the storms period ([Figure 1](#)). A higher proportion of visits was related to injuries of the wrist and hand, ankle and foot, knee and lower leg, abdomen/lower back/spine/pelvis, and thorax during the period after the storms, compared with the other time periods.

A ranking of the primary diagnoses of injuries and chronic disease conditions for WCC visits for each time period is provided in [Table 3](#). The proportion of the top 3 primary diagnoses (82.7%) accounted for roughly 2 to 15 patient visits per month. Visits associated with diseases of the skin and subcutaneous tissue, were more frequent during and after the storms (9 to 15 visits per month) than before the storms (5 visits per month). Injury, poisoning, and consequences of external causes increased from 1 patient encounter per month before the storms to 2 patient visits per month during and after the storms. Chronic disease conditions of the circulatory system (5 to 6 visits per month) and endocrine, nutritional, and metabolic diseases (2 visits per month), remained constant across the 3 time periods. A spike in the number of visits due to burns and poisoning occurred during the period of the storms and in the period after the storms, and another was due to a prevalence of knee, lower leg, ankle, and foot injuries after the storms ([Figure 2](#)).

Findings from binary logistic regression are shown in [Table 4](#) for the ED and WCC data combined. These results indicate the adjusted odds of visits due to injury for the period during the storms were significantly higher (OR: 1.28, 95% CI: 1.17, 1.40) than

Table 1. Healthcare utilization trends and characteristics of patient populations in the emergency department and wound care clinic

Emergency Department (ED) Utilization Trends		Before Storms: Comparison Period (Sept 1, 2016 to Sept 5, 2017)		During Storms: Study Period (Sept 6, 2017 to Nov 6, 2017)		After Storms: Downstream Effect (Nov 7, 2017 to May 31, 2018)		Total
		n	% of Total	n	% of Total	n	% of Total	Total
Number of patient visits		15777	60.4*	2872	11.0*	7492	28.7	26141
Number of days		369	58.1*	61	9.6*	205	32.3	635
Average visits/day		43		47		37		41
Characteristics	n	% within period	n	% within period	n	% within period	n	%
Age								
< 18 years	2986	18.9*	411	14.3*	1231	16.4*	4628	17.7
18 to 39 years	4597	29.1*	723	25.2*	2110	28.2*	7430	28.4
40 to 59 years	4324	27.4*	890	31.0*	2209	29.5*	7423	28.4
≥ 60 years	3870	24.5*	84	29.5*	1942	25.9*	6660	25.5
Gender								
Female	8760	55.5*	1407	49.0*	3883	51.8*	14050	53.7
Male	7017	44.5*	1465	51.0*	3609	48.2*	12091	46.3
Healthcare Coverage								
Self-pay	3950	25.0*	856	29.8*	2344	31.3*	7150	27.4
Medicaid	4400	27.9*	608	21.2*	1792	23.9*	6800	26.0
Medicare	2971	18.8*	655	22.8*	1461	19.5*	5087	19.5
CIGNA	2232	14.1*	421	14.7*	970	12.9*	3623	13.9
Commercial	1251	7.9*	197	6.9*	490	6.5*	1938	7.4
Blue Cross	532	3.4*	65	2.3*	217	2.9*	814	3.1
Other	441	2.8*	70	2.4*	218	2.9*	729	2.7
Disposition								
Hospital discharged	14778	94.4*	2303	96.7*	6758	96.1*	23839	95.1
Self-discharged	732	4.7*	46	1.9*	175	2.5*	953	3.8
Transferred	68	0.4*	20	0.7*	77	1.0*	165	0.6
Expired	38	0.2*	5	0.2*	18	0.3*	61	0.2
Admitted as inpatient	25	0.2*	2	0.1*	7	0.1*	34	0.1
Outpatient Wound Care Clinic (WCC) Utilization Trends		Before Storms: Comparison Period		During Storms: Study Period		After Storms: Downstream Effect		Total
		n	% of Total	n	% of Total	n	% of Total	Total
Number of patient visits		205	43.2*	56	11.8*	213	44.9*	474
Number of months		12.3	58.1	2.0	9.6	6.8	32.3	21.1
Average visits/month		17		28		31		23
Characteristics	n	% within period	n	% within period	n	% within period	n	%
Age								
18-39 years	15	7.3*	4	7.1*	10	4.7*	29	6.1
40-59 years	53	25.9*	19	33.9*	69	32.4*	141	29.8
≥ 60 years	137	66.8*	33	58.9*	134	62.9*	304	64.1
Gender								
Female	122	59.5*	25	44.6*	103	48.4*	250	52.7
Male	83	40.5*	31	55.4*	110	51.6*	224	47.3

Note. * indicates that these proportions were significant at P -value ≤ 0.05 .

the period prior to the storms. The odds for visits due to injuries were 1.19 (95% CI: 1.12, 1.28) times higher during the period after the storms compared with the period during the storms. The adjusted odds of a visit due to chronic conditions in the period during the storms were 0.83 (95% CI: 0.77, 0.91) lower than the period prior to the storms. No significant effect was detected for chronic conditions in the period after the storms.

Discussion

Hurricanes pose a dynamic and prominent threat to the public's health.^{37,38} These storms perpetrate a substantial public health burden on impacted populations by causing deaths, injuries, and diseases that engender disability and compromise the capacity and delivery of local public health and human services.³⁷⁻⁴⁰ Given the high probability of a hurricane making landfall in the U.S.

Table 2. Ranking of primary diagnoses of injuries and chronic conditions based on visits in the emergency department for each time period

Rank	Primary Diagnosis	Before Storms: Comparison Period (Sept 1, 2016 to Sept 5, 2017)			During Storms: Study Period (Sept 6, 2017 to Nov 6, 2017)			After Storms: Downstream Effect (Nov 7, 2017 to May 31, 2018)			Total	
		n	% within period	n/day	n	% within period	n/day	n	% within period	n/day	n	%
1	Injury, poisoning and other consequences of external causes	3305	20.7*	9	717	24.5*	12	1807	23.5*	9	5829	27.4
2	Symptoms, signs and other abnormal clinical findings	2383	14.9*	6	356	12.2*	6	995	12.9*	5	3734	17.5
3	Diseases of the respiratory system	1456	9.1*	4	233	8.0*	4	679	8.8*	3	2368	11.1
4	Diseases of the musculoskeletal system/connective tissue	1090	6.8*	3	190	6.5*	3	517	6.7*	3	1797	8.4
5	Diseases of the digestive system	1017	6.4*	3	166	5.7*	3	450	5.8*	2	1633	7.7
6	Diseases of the genitourinary system	1004	4.0*	3	140	4.8*	2	459	6.0*	2	1603	7.5
7	Factors influencing health status and contact with health services	820	5.1*	2	188	6.4*	3	387	5.0*	2	1395	6.6
8	Diseases of the circulatory system	635	4.0*	2	90	3.1*	1	283	3.7*	1	1008	4.7
9	Certain infectious and parasitic diseases	667	4.2*	2	54	1.8*	1	268	3.5*	1	989	4.6
10	Diseases of the skin and subcutaneous tissue	525	3.3*	1	151	5.2*	2	250	3.2*	1	926	4.4
Total		12902	60.6*	35	2285	10.7*	37	6095	28.6*	30	21282	100.0

Note. * indicates that these proportions were significant at P -value ≤ 0.05 ; ^a Some Emergency Department data files contained 2 primary diagnoses codes

Virgin Islands annually, the risk for hurricane-related injuries and deaths remains a significant public health concern. Previous studies implicate hurricanes with an increase in ED visits, largely attributed to substantial disruptions in essential community lifeline support services, including a heavily distressed healthcare system.^{16-20,22,27,28,33,34,41} Although the U.S. Virgin Islands are frequently impacted by hurricanes, category 5 storms are uncommon. Thus, to enhance public health preparedness, it is important to understand how major hurricanes (category 4 and 5 storms) impact the prevalence of acute medical needs, and the factors and circumstances that influence decisions to seek medical care in their wake. We examined ED and WCC patient visits before, during, and after Hurricanes Irma and Maria to describe the incidence of injuries and chronic medical conditions and thereby define the prevalence of acute medical needs.

ED visits

Our analysis shows that the total rate of daily ED visits increased by 9.3% during the storms' study period. The increase in the rate of visits was observed among the distribution of visits by age, gender, and primary diagnosis codes. ED visits among the elderly and middle-aged individuals were more likely during and after the storms than among those 39 years of age and younger. It is plausible that these visits were due to the closure of outpatient clinics and private medical practices as a result of the storms. Our finding of increased ED utilization among the elderly is consistent with previous hurricane studies, which attributed such upsurges to exacerbations of chronic diseases and disrupted access to care.^{14,17-20,22,24-28,34} An intriguing finding was the escalation of ED visits by middle-aged persons. The U.S. Virgin Islands population has higher rates of chronic diseases, such as diabetes and cardiovascular disease, than the national averages.^{42,43} The increase in visits among this population may represent the prevalence of hypertension, diabetes, asthma, chronic obstructive pulmonary disease, and allergy cases, which were reported in previous studies to be aggravated by the storms,^{6,14,26,27,44} and may also reflect visits among a population more likely engaged in home repairs and outdoor activities in the period between and after the storms. Previous studies show patients with respiratory complications,^{17-19,24,26,27,30,45,46} and allergies,⁴⁷ were at an increased risk during hurricanes, and the risks were closely associated with environmental exposures.⁴⁵ In a study examining ED utilization rates associated with 7 hurricanes across 9 states, respiratory conditions and injuries accounted for the increased ED visits among middle-aged individuals.²⁴ This finding suggests a plausible new pattern of ED utilization among a cohort that has not been extensively examined in the context of hurricane disasters.

Although there was not a statistically significant difference in visits by gender before and after the storms, there was a higher percentage of ED visits by males during the storms. Other studies have shown a gender-linked difference in ED utilization.^{17,19,28,30} This variance may be correlated with more males remaining in their damaged homes and engaging in activities that engender trauma-related cases,^{17,19,28} and possibly inequitable access to and utilization of social support systems to moderate the effect of the disaster.^{6,19,26} The storms disturbed many social networks and family cohesion.⁶ Numerous individuals departed the territory before landfall,³ and this mass exodus continued between the storms and increased after the storms,³ likely undermining the robust social networks and support systems enjoyed by many

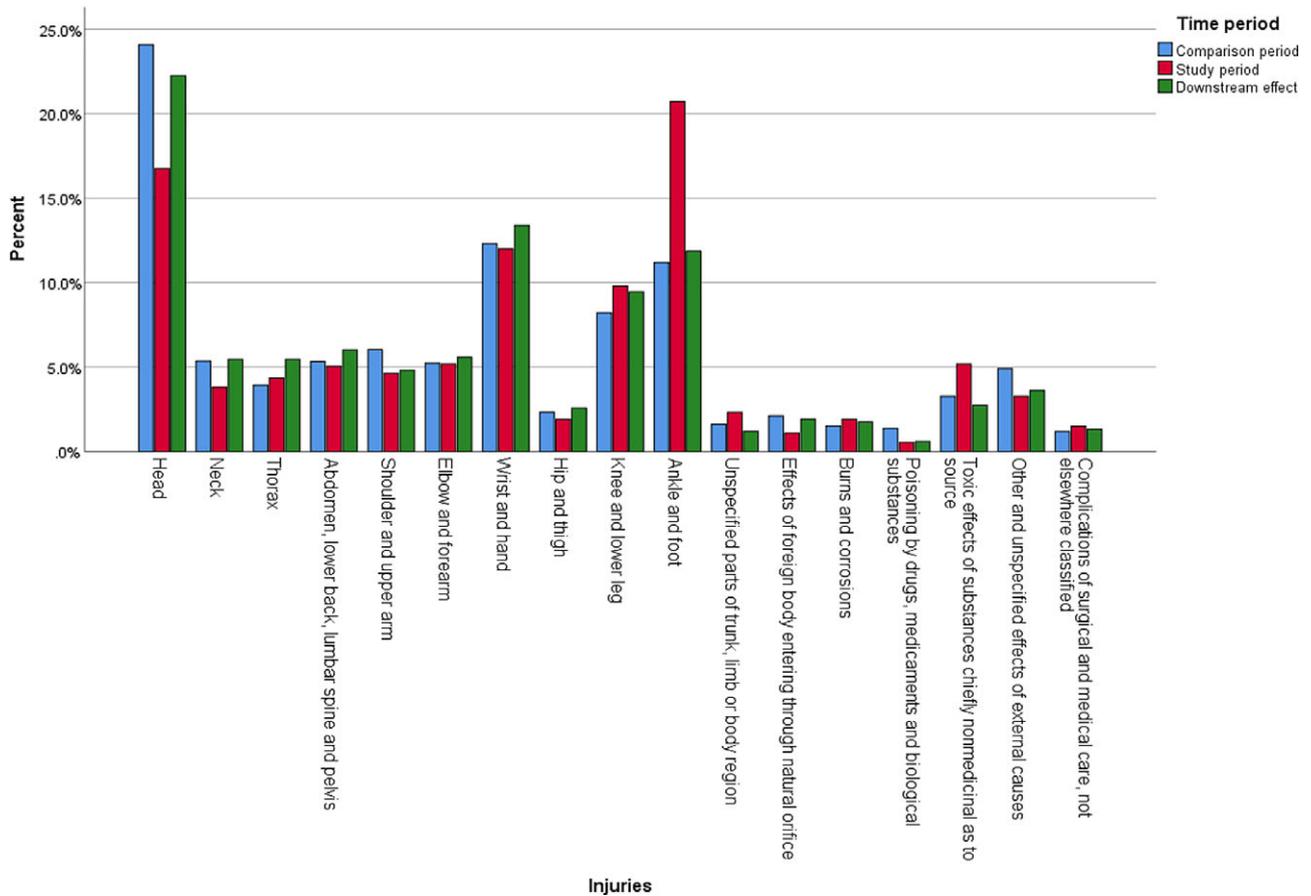


Figure 1. Types of injuries based on emergency department visits by study period.

residents.^{6,26} A valuable mitigation strategy may be to employ human services in the ED to provide for a range of disaster social work, including psychological first aid, case management, and social services support, during and after the storm. Social workers and staff that provide services to enhance individual and family welfare may be needed to support early interventions in EDs and facilitate appropriate follow-on services.

Overall, proportionately more ED visits were related to injuries, poisoning, and external causes. This upsurge became more profound in the analysis of daily visits during the storms and the period after the storms. Significantly, more visits after the storms were among patients with a primary diagnosis of injuries to the head, wrist and hand, ankle and foot, knee and lower leg, abdomen/lower back/spine/pelvis, neck, thorax, and elbow/forearm (Figure 1). This finding is consistent with prior studies,^{17,20,24,26–30} and is possibly because residents devoted considerable time attending to their damaged homes between storms and engaged in recovery activities known to produce injuries and health conditions in the aftermath of the hurricanes.^{17,28,48}

WCC visits

The rate of WCC visits increased during (12%) and after the storms (45%). Proportionately more visits were by males, which likely increased with age among those 60 years and older, and by those with injuries related to burns and poisoning, knee and lower limb damages, and diseases of the skin and subcutaneous tissue. The differences by gender are similar to other studies showing that

males have a higher risk for hurricane-related injuries and are more likely than females to seek medical care in the hurricane aftermath.^{17,19,28,30} Remarkably, a higher proportion of female WCC visits occurred before the storms compared with male visits. This was an unexpected finding and suggests a probable correlation with gender-associated risk to hurricane-related injuries, exacerbations of pre-existing wounds/injuries, and poor wound management linked to a lack of electricity, running water, and disruptions in access to care.

An amplification in visits occurred among the elderly, correlated with advancing age and pattern of injury, including skin, and subcutaneous tissue diseases, burns, and poisoning. Among the various types of injury-related visits, burns, poisoning, knee, lower leg, ankle, and foot injuries were the most prevalent (Figure 2). The increased incidence of visits for knee and lower limb injuries and wounds is consistent with other findings.^{28,29} It is possible these visits may account for case presentations by those with previous wounds associated with underlying medical conditions that were exacerbated by the stress of the hurricane. The amplified visits may also represent cases of acute injuries connected with debris during inter-storm and post-storm activities,^{28,30,48} that led to persistent wound conditions among those with chronic diseases, such as diabetes and peripheral vascular disease. Although empirical evidence is lacking correlating this profile and a suspected pattern of illness and injury, previous research has shown an increase in medical needs among the elderly for hurricane related injuries and exacerbated chronic medical conditions.^{17,18,20,24} Trends in burn-related injuries have been reported

Table 3. Ranking of primary diagnoses of injuries and chronic conditions based on visits in the wound care clinic for each time period

Rank	Primary Diagnosis	Before Storms: Comparison Period (Sept 1, 2016 to Sept 5, 2017)				During Storms: Study Period (Sept 6, 2017 to Nov 6, 2017)				After Storms: Downstream Effect (Nov 7, 2017 to May 31, 2018)				Total	
		% within period		n/month		% within period		n/month		% within period		n/month		n	%
		n	%	n	%	n	%	n	%	n	%	n	%	n	%
1	Diseases of the skin and subcutaneous tissue	57	32.6*	5	18	46.2*	9	100	52.4*	15	175	43.2			
2	Diseases of the circulatory system	67	38.3*	5	9	23.1*	5	39	20.4*	6	115	28.4			
3	Endocrine, nutritional and metabolic diseases	27	15.4*	2	3	7.7*	2	15	7.9*	2	45	11.1			
4	Injury, poisoning and consequences of external causes	11	6.3*	1	4	10.3*	2	15	7.9*	2	30	7.4			
5	Factors influencing health status and contact with health services	3	1.7*	<1	1	2.6*	1	13	6.8*	2	17	4.2			
6	Neoplasms	1	0.6*	<1	1	2.6*	1	6	3.1*	1	8	2.0			
7	Diseases of the blood and blood-forming organs and the immune mechanism	3	1.7*	<1	1	2.6*	1	1	0.5*	<1	5	1.2			
8	Diseases of the genitourinary system	2	1.1*	<1	1	2.6*	1	1	0.5*	<1	4	1.0			
9	Congenital malformations, deformations and chromosomal abnormalities	2	1.1*	<1	0	0.0*	<1	1	0.5*	<1	3	0.7			
10	Diseases of the musculoskeletal system and connective tissue	2	1.1*	<1	1	2.6*	1	0	0.0*	<1	3	0.7			
Total		175	43.2	14	39	9.6	20	191	47.2	28	405	100.0			

Note. * indicates that these proportions were significant at P-value ≤ 0.05; ^a Wound Care Clinic data files contained 1 primary diagnosis code

in hurricane disasters,^{27,29,49} and linked to heat and lighting apparatuses utilized by individuals affected by the loss of electrical power.^{29,49} Given the extended period of time that residents were without electricity, these proxies for power and light generation may account for the increased pattern of burn-related injuries.^{29,49}

Limitations of the Study

The findings in this investigation are subject to several limitations. First, this was a retrospective geographic analysis of ED and WCC visits. Data was extracted from SRMC electronic health records without individual medical record reviews. For the times during the study period when the MEDITECH Electronic Health Records System was inoperable due to storm-related damages and power outages, paper charts were used and subsequently added to the MEDITECH Electronic Health Records System. Thus, the data may be subject to coding errors, missing data, or incomplete diagnoses (ICD-10 codes). However, electronic health records' data have been used in several studies to examine ED utilization and assess hurricane disaster-related morbidity and mortality.^{16,25-29,34} In this study, primary and secondary diagnoses, medical procedures, and discharge disposition from the visits were considered to inform our analysis. Accordingly, it was assumed that the dataset was accurate and representative. Second, this investigation focused on ED and WCC visits; thus, the proportion of individuals who received treatment elsewhere (such as Federally Qualified Health Centers, walk-in clinics, and private physician practices), were not included in the analyses. The study also did not examine ED and WCC visits associated with amputated limbs due to wound infections nor codify wounds as acute or chronic or wound types (such as chronic venous stasis ulcer or diabetic foot wound). Third, upsurges in ED visits during the interval between storms and in the aftermath of Hurricane Maria may have occurred as a result of patients arriving from damaged assisted living facilities, nursing homes, and residential behavioral health facilities requiring transfers to an equivalent off-island facility. This may have confounded the precision of our estimates in the number of morbidity-related ED visits associated with the storms. Finally, this study was limited to visits at the only tertiary hospital serving the St. Thomas/St. John district, and was limited to Hurricanes Irma and Maria. Therefore, the findings from this investigation cannot reflect the characteristics of all ED and WCC visits in the U.S. Virgin Islands and may not be generalizable to other Caribbean islands, regions of the U.S., or other types of disasters.

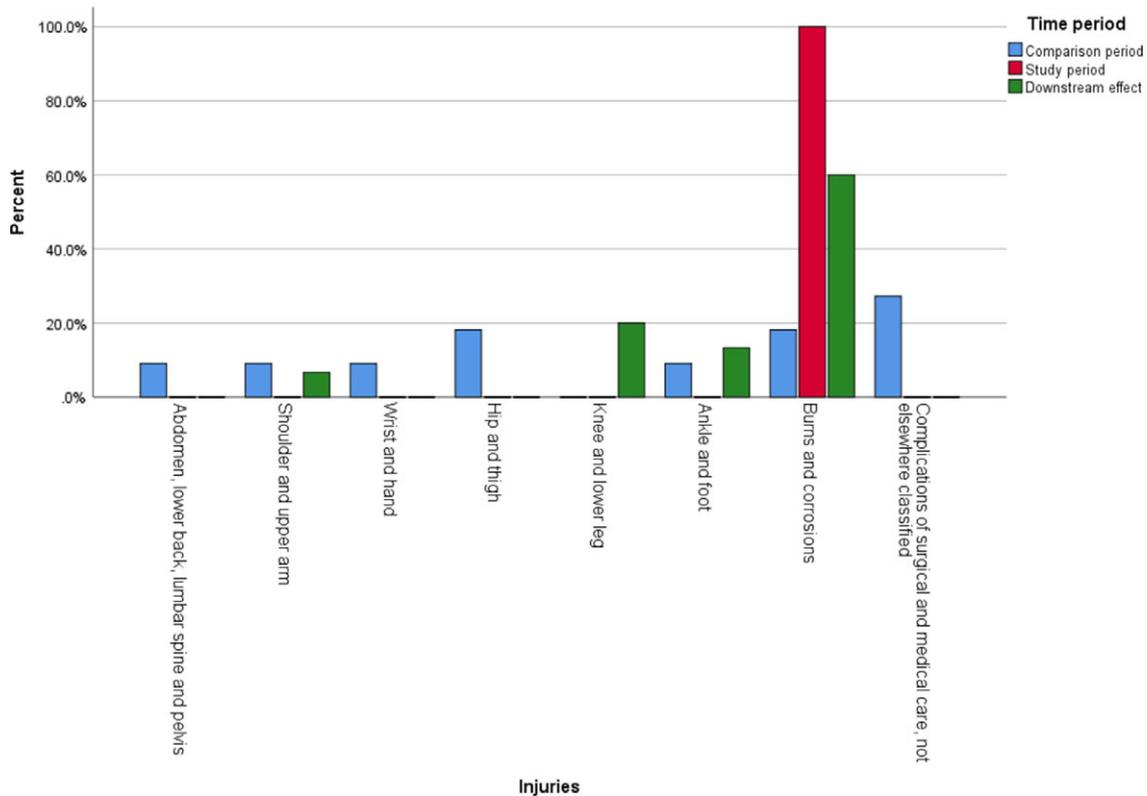
Future Directions

Several directions for future research emerge from our study, including examining the impact of caring for acute and chronic wounds during and after a disaster; assessing the proportion of patients that sustain amputated limbs due to infected wounds; exploring the long-term burden of managing post disaster care, such as for patients with amputations that become wheelchair bound and do not have access to wheelchair accessible housing; and understanding the mechanisms through which hurricane disasters influence ED utilization among middle-aged individuals. As this study analyzed data from the St. Thomas/St. John district, studies with comparisons from the St. Croix district may provide additional insights relative to the territory's population and inform public health preparedness for future storms. Studies comparing ED visits in Puerto Rico can also provide parallels or contrast

Table 4. The effect of storms on patient visits in the wound care clinic and emergency department related to injuries and chronic conditions

Time period	Visits due to Injuries		Visits due to Chronic Conditions	
	Unadjusted Odds Ratio (95% CI)†	Adjusted Odds Ratio (95% CI)†	Unadjusted Odds Ratio (95% CI)†	Adjusted Odds Ratio (95% CI)†
Before storms- Comparison period	Reference	Reference	Reference	Reference
During storms- Study period	1.26*** (1.15, 1.38)	1.28*** (1.17, 1.40)	0.87** (0.80, 0.95)	0.83*** (0.77, 0.91)
After storms-Downstream effect	1.18*** (1.10, 1.26)	1.19*** (1.12, 1.28)	0.01 (0.95, 1.06)	0.98 (0.93, 1.04)

Note. $n = 26,615$. Odds Ratio (OR) adjusted for age group, gender, and race. * $P < 0.05$, ** $P < 0.01$, *** $P < 0.001$
 †95% Confidence Interval

**Figure 2.** Types of injuries based on wound care clinic visits by study period.

among neighboring territories to help project resource needs during hurricane seasons.

Conclusions

This study supports prior research relative to surges in ED visits due to hurricane-related injuries and exacerbated chronic medical conditions, and suggests that facilities with WCCs should anticipate an upsurge in visits among patients with chronic wound conditions during and after severe hurricanes. Findings from this research confirm the need to understand patient trends and vulnerability profiles. This research highlights the need for an organized and unified strategy to provide healthcare services in alternate care settings during future hurricanes to prevent deterioration of vulnerable patients and mitigate a potential surge of ED visits. In light of these observations, federal resources should be made available to improve support for public health preparedness in

the territory. Preparedness funding should be increased to facilitate establishment of a Medical Reserve Corps unit and territorial healthcare coalition that includes assisted living and long-term care facilities, behavioral health and social services organizations, outpatient clinics and private medical practices, independent dialysis centers, the Virgin Islands Territorial Emergency Management Agency, and independently-owned rescue squads.⁵⁰

Given the risk of hurricane disasters in the U.S. Virgin Islands, the needs of individuals with health profiles that contribute to increased ED visits and chronic wound conditions should be anticipated prior to the annual hurricane seasons. Interdisciplinary workgroups should assess the health resource needs of high-demand facilities prone to resource limitations during hurricane disasters, such as the ED and the WCC. The workgroups should seek solutions, including providing care in alternative settings and utilizing multi-media messaging before storms, to decrease the number of added ED visits seen with hurricane disasters. Public health preparedness

for hurricanes must include significant attention to securing safe housing and chronic disease management for persons with chronic conditions to limit the need for ED visits.

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Ethical standards. The protocol for this study was reviewed and approved by the Institutional Review Board of George Mason University (No. 1243586-1). The research protocol and data use for this investigation was also approved by the SRMC. No personal identifiable information was included in the dataset. The data used in the analysis were aggregate de-identifiable data.

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