

Surveillance of Injuries in Eastern North Carolina Following Hurricane Irene Using Emergency Department Data

James A. Miller, Gregory D. Kearney, Scott K. Proescholdbell

OBJECTIVE Our objective was to characterize nonfatal injuries, by age groups, that were seen in emergency departments (EDs) in 29 selected counties in Eastern North Carolina following Hurricane Irene.

METHODS A descriptive evaluation using data from the North Carolina Disease Event Tracking and Epidemiologic Collection Tool (NC DETECT) was performed to identify the numbers and types of nonfatal injuries among individuals who sought treatment at hospital EDs. Percentages of reported ED visits related to external injuries in the 7 most severely impacted counties were compared with results in the entire 29-county region and with data from a reference period in 2010.

RESULTS The total number of individuals who sought treatment at an ED for an external cause of injury was 22.3% greater during the week following Hurricane Irene than during the 2010 reference week. In the 29-county region, the increases were primarily due to falls; in the 7-county region, they were primarily due to cutting and piercing incidents. Following the storm, injuries related to falls, adverse effects of health care, or being struck by an object accounted for higher proportions of injury-related ED visits in the 7-county disaster region than in the 29-county region.

LIMITATIONS The inability to identify the patient's home address and the county where treatment was sought was a spatial limitation. Furthermore, data for urgent care visits, primary care doctor visits, and injuries treated at home were not included. Additionally, cautious inference should be made to distinguish between injuries that occurred as a direct result of the storm and those that occurred incidentally.

CONCLUSION Data from NC DETECT can be used to estimate the most common types of injuries seen in EDs following a natural disaster.

On August 27, 2011, Hurricane Irene, a storm with sustained winds of 85 miles per hour, made landfall on the Outer Banks of North Carolina, producing floods and causing property damage totaling approximately \$71 million dollars [1]. Following the storm, Beaufort, Carteret, Craven, Dare, Hyde, Pamlico, and Tyrrell Counties were recognized as the most severely affected counties in the state, and they received federal disaster declarations [2]. Thousands of individuals throughout Eastern North Carolina had to deal with destroyed homes, power failures, fallen trees and limbs, flooded roads, and other adversities. Many residents engaged in cleanup activities, thereby increasing their risk of being physically harmed or even killed. As a result, individuals experiencing acute injury or illness sought treatment from health care providers, including hospital emergency departments (EDs). Individuals living in rural, isolated areas or areas with limited access to care may have cared for their injuries at home or sought care at a doctor's office or urgent care clinic. Nevertheless, characterizing the types of injuries seen in EDs following a natural disaster is important and may aid in developing strategies for targeted prevention efforts in the future [3]. Previous studies that have evaluated injuries and illnesses following hurricane events have reported an increase in the number of hospital ED visits [4-7]. Primary injuries reported following Hurricane Katrina (2005) included falls, bites or stings, motor vehicle crashes, toxic exposures, and poisonings [8]. In a study in Eastern North

Carolina following Hurricane Floyd, 20 hospitals reported that they had treated orthopedic and soft tissue injuries as well as respiratory and gastrointestinal illnesses [9].

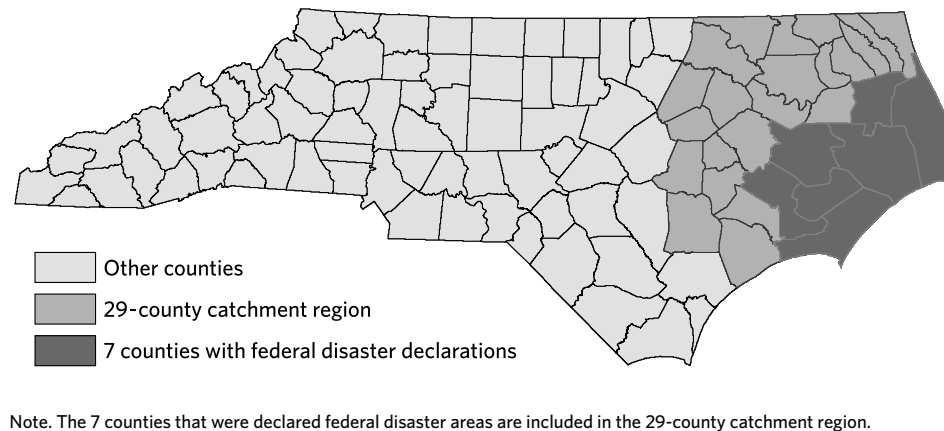
As public health researchers and practitioners from East Carolina University and the North Carolina Department of Health and Human Services, we decided to study the impact of Hurricane Irene on our state. Given the vast amount of physical destruction and potential for human harm created by Hurricane Irene, we chose to investigate ED visits associated with injuries surrounding the landfall date of the hurricane—August 27, 2011. Our study focuses on the affected area of the 29-county catchment region, which consists of counties located primarily in the extreme eastern part of North Carolina (see Figure 1). This area is predominantly rural and impoverished, and a large majority of the inhabitants have limited access to common services, including health care facilities [10]. Several counties within the 29-county region rank as having the highest mortality and morbidity rates in North Carolina. The region has therefore been targeted by the Brody School of Medicine at East

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FIGURE 1.
Map Showing the 29 Counties in Eastern North Carolina That Were Most Affected by Hurricane Irene and the Subset of 7 Counties That Were Declared Federal Disaster Areas



Carolina University as a primary service area for health and medical improvement.

Given the breadth and severity of damage to the region, the objective of our project was to characterize the nonfatal patient injuries reported by EDs in Eastern North Carolina following the storm. ED data was stratified by age groups and by types of injuries to detect any unique patterns or trends. Results and information from this assessment can be used to evaluate additional health impacts of the storm and may offer health care providers and county emergency managers more specific information that can help them to appropriately staff EDs and to issue precautionary safety advisory statements before or during a natural disaster.

Materials and Methods

This study received approval (UMCIRB 11-001137) from the University and Medical Center Institutional Review Board at East Carolina University in December 2011. Data used for this project were obtained using the North Carolina Disease Event Tracking and Epidemiologic Collection Tool (NC DETECT). NC DETECT is a surveillance data and reporting system that captures records of EDs affiliated with acute-care civilian hospitals in North Carolina. The ED data in NC DETECT are all secondary data. Hospitals extract their data in near real-time from their respective administrative and clinical electronic databases to allow timely statewide public health surveillance. Medical coding is done by each hospital for its own operational purposes. Each hospital standardizes the data elements using Data Elements for Emergency Department Systems (DEEDS) guidelines prior to transmission to a data aggregator. Data files are received securely by NC DETECT every 12 hours in Health Level Seven (HL7)-like format. HL7 is a widely recognized and implemented standard for the exchange and transmission of health care data. Studies that have used NC DETECT have consistently shown that the data is accurate and reliable for public health surveillance purposes

[11-17]. Of the 114 acute-care civilian hospital-affiliated EDs in North Carolina that are open 24 hours per day and 7 days per week, 113 (99%) were reporting data to NC DETECT on a daily basis as of 2010, with data validation every 12 hours [18].

Data from NC DETECT were evaluated for ED visits related to external injuries in all 29 counties in the catchment area, including the 7 aforementioned counties with federal disaster declarations. Topographically, those 7 counties are situated in coastal or tidally influenced areas, making them physically vulnerable to flooding, particularly from heavy rainfall events. Larger increases in the number of injuries relative to the 2010 reference week and relative to the week before the storm were expected in this area. Therefore injuries reported in the entire 29-county region were compared with injuries in the 7 disaster counties. All 29 counties in the catchment area were approved for federal financial assistance to help recover costs of emergency protective measures provided by local governments [2]. This provided confirmation that individuals in these counties had a higher probability of being affected by the hurricane. Those 29 counties, which are shaded on the map in Figure 1, are Beaufort, Bertie, Camden, Carteret, Chowan, Craven, Currituck, Dare, Duplin, Edgecombe, Gates, Greene, Halifax, Hertford, Hyde, Jones, Lenoir, Martin, Nash, Northampton, Onslow, Pamlico, Pasquotank, Perquimans, Pitt, Tyrrell, Wayne, Wilson, and Washington. The 7 counties with the darkest shading are those that received the federal disaster declarations.

Patients were included in this study if their visit to an ED at an acute-care civilian hospital resulted in a diagnosis that was related to an external cause of injury. Specifically, the diagnosis needed to have an International Classification of Disease, 9th Revision, Clinical Modification (ICD-9 CM) E-code in the grouping E000 through E030 or E800 through E999. The listed E-code grouping framework for codes E800 through E999 was based on the Web-Based Injury Statistics Query and Reporting System (WISQARS) injury matrix cod-

ing. WISQARS is an interactive online database maintained by the Centers for Disease Control and Prevention; injury codes assigned to each category are publicly available [19]. Causes of injury that accounted for less than 1% of the total number of injuries were added to a category labeled “other/unspecified” and are not reported. These causes included drowning and submersion, injuries caused by firearms, injuries caused by machinery, injuries to pedestrians not involving motor vehicles, suffocation, self-inflicted injuries and suicide, and injuries resulting from activities related to maintenance and hygiene. ICD-9 CM codes E000 through E030 are not included in the WISQARS framework. These codes accounted for injuries resulting from activities related to maintenance and hygiene at home or in the workplace and accounted for less than 1% of the total number of injuries. These injuries were included in the “other/unspecified” category.

To determine which types or causes of injury were associated with the greatest increases in ED visits following Hurricane Irene, descriptive statistics were generated separately for the 29-county region and for the 7-county region for the period August 1, 2010, through September 30, 2011. After generating descriptive statistics for the entire 14-month period, additional analysis was performed to determine whether the types of injuries reported by EDs differed immediately before and after the storm. Methods characterizing the number and types of ED visits following natural disasters have included descriptive evaluations of morbidity and mortality using comparative time frames of days, weeks, or months prior to the disaster, with similar earlier reference periods [8-9, 20-23]. For this analysis, data were extracted for the week immediately preceding the storm (August 20 through August 26, 2011) and for the week beginning on the date the storm made landfall (August 27 through September 2, 2011). These data were used to compare the proportion of ED visits relating to a specific type of injury during that week with the proportion relating to that type of injury during the reference period, which was the week of August 28 through September 3, 2010. (That week was chosen as the reference period because the dates encompassed the same days of the week—Saturday through Friday—as the 2011 post-storm week.) To determine whether age was a factor in the distribution of injuries, the 5 most commonly reported injuries for the 2011 post-storm week in the 29-county region and in the 7-county region were stratified using age groups (0-11 years, 12-19 years, 20-29 years, 30-39 years, 40-49 years, 50-59 years, 60-69 years, and older than 69 years). ED data were analyzed using IBM SPSS Statistics software (version 19). Pearson's chi-square test and Fischer's exact test were used to evaluate the relative changes in the proportions of various injury types during the post-storm week compared with the 2010 reference week. The 2010 reference week was used for comparison rather than the 2011 pre-storm week because activities performed in preparation for Hurricane Irene during the 2011 pre-storm week could have affected injuries dur-

ing that time period. Significance was determined at a level of $P < .05$, and Fischer's exact test was used when counts were below 10 with 1 degree of freedom.

Results

During the 14-month study period, the sample consisted of a total of 112,751 ED visits in the 29-county region. As shown in Table 1, the 5 most common types or causes of injury resulting in ED visits in the 29-county region were falls (40.1%); injuries involving motor vehicles (21.5%); injuries resulting from recreational activities (12.2%); adverse effects of health care, which includes drug side effects and injuries sustained during surgeries or medical procedures (7.3%); and being struck by or against an object (5.9%). In the 7-county disaster region, the most common types or causes of injury were falls (41.9%), injuries involving motor vehicles (16.3%), recreational activities (8.3%), adverse effects of health care (7.5%), and overexertion (6.6%).

During the 2011 post-storm week, there were 2,252 ED visits related to injuries in the 29-county region, resulting in a 22.3% overall increase in the number of injury-related ED visits compared with the 2010 reference week. In the 7-county region, 648 ED visits related to injuries were reported in the post-storm week, compared with 463 such visits in the 2010 reference week, representing an increase of 45% in the number of injury-related ED visits.

When the number of reported injury-related ED visits in the 29-county region in the week preceding Hurricane

TABLE 1.
Types and Causes of Injuries Reported by Emergency Departments in Eastern North Carolina Between August 1, 2010, and September 30, 2011

Type or cause of injury	29-county region ^a Number of injuries (%)	7-county region ^b Number of injuries (%)
Falls	45,183 (40.1%)	11,604 (41.9%)
All motor vehicles	24,264 (21.5%)	4,504 (16.3%)
Recreational activities	13,748 (12.2%)	2,307 (8.3%)
Adverse effects of health care	8,279 (7.3%)	2,085 (7.5%)
Struck by or against an object	6,673 (5.9%)	1,707 (6.2%)
Overexertion	5,459 (4.8%)	1,816 (6.6%)
Cut/pierce	3,796 (3.4%)	1,053 (3.8%)
Natural/environmental	3,176 (2.8%)	858 (3.1%)
Poisoning	2,780 (2.5%)	966 (3.5%)
Transport: other	2,078 (1.8%)	517 (1.9%)
Pedal cyclist: other	1,343 (1.2%)	408 (1.5%)
Burns	1,271 (1.1%)	295 (1.1%)
Other/unspecified	34,810 (30.9%)	4,744 (17.1%)
Total	112,751 (100%)	27,692 (100%)

Note. The numbers and percentages of the 5 most prevalent types or causes of injury in each region are in boldface type.

^aThe counties in the 29-county region are Beaufort, Bertie, Camden, Carteret, Chowan, Craven, Currituck, Dare, Duplin, Edgecombe, Gates, Greene, Halifax, Hertford, Hyde, Jones, Lenoir, Martin, Nash, Northampton, Onslow, Pamlico, Pasquotank, Perquimans, Pitt, Tyrrell, Wayne, Wilson, and Washington.

^bBeaufort, Carteret, Craven, Dare, Hyde, Pamlico, and Tyrrell are the 7 counties that were declared federal disaster areas following Hurricane Irene.

TABLE 2.
The Top 5 Types or Causes of Injuries Resulting in Emergency Department Visits in Eastern North Carolina During the Week Following Hurricane Irene, by Age Group

29-county region Beaufort, Bertie, Camden, Carteret, Chowan, Craven, Currituck, Dare, Duplin, Edgecombe, Gates, Greene, Halifax, Hertford, Hyde, Jones, Lenoir, Martin, Nash, Northampton, Onslow, Pamlico, Pasquotank, Perquimans, Pitt, Tyrrell, Wayne, Wilson, and Washington Counties								
Type or cause of injury	Age group							
	0-11 years Number of injuries (%)	12-19 years Number of injuries (%)	20-29 years Number of injuries (%)	30-39 years Number of injuries (%)	40-49 years Number of injuries (%)	50-59 years Number of injuries (%)	60-69 years Number of injuries (%)	>69 years Number of injuries (%)
Falls	165 (7.3)	163 (7.2)	263 (11.7)	200 (8.9)	149 (6.6)	157 (7.0)	100 (4.4)	106 (4.7)
MVR injuries	42 (1.9)	49 (2.2)	96 (4.3)	66 (2.9)	57 (2.5)	47 (2.1)	22 (1.0)	21 (0.9)
Recreational activities	29 (1.3)	45 (2.0)	28 (1.2)	22 (1.0)	13 (0.6)	25 (1.1)	11 (0.5)	25 (1.1)
Adverse effects of health care	8 (0.4)	3 (0.1)	11 (0.5)	13 (0.6)	11 (0.5)	21 (0.9)	21 (0.9)	37 (1.6)
Struck by or against an object	15 (0.7)	24 (1.1)	25 (1.1)	21 (0.9)	16 (0.7)	16 (0.7)	9 (0.4)	7 (0.3)
All injuries	297 (13.2)	220 (9.8)	349 (15.5)	292 (13.0)	265 (11.8)	269 (11.9)	207 (9.2)	352 (15.6)
7-county disaster region ^a Beaufort, Carteret, Craven, Dare, Hyde, Pamlico, and Tyrrell Counties								
Type or cause of injury	Age group							
	0-11 years Number of injuries (%)	12-19 years Number of injuries (%)	20-29 years Number of injuries (%)	30-39 years Number of injuries (%)	40-49 years Number of injuries (%)	50-59 years Number of injuries (%)	60-69 years Number of injuries (%)	>69 years Number of injuries (%)
Falls	42 (6.5)	36 (5.6)	68 (10.5)	55 (8.5)	48 (7.4)	54 (8.3)	35 (5.4)	73 (11.3)
MVR injuries	8 (1.2)	4 (0.6)	19 (2.9)	10 (1.5)	16 (2.5)	17 (2.6)	8 (1.2)	8 (1.2)
Recreational activities	8 (1.2)	12 (1.9)	6 (0.9)	0 (0.0)	3 (0.5)	4 (0.6)	4 (0.6)	2 (0.3)
Adverse effects of health care	0 (0.0)	0 (0.0)	3 (0.5)	2 (0.3)	3 (0.5)	8 (1.2)	6 (0.9)	14 (2.2)
Struck by or against an object	4 (0.6)	1 (0.2)	7 (1.1)	8 (1.2)	5 (0.8)	5 (0.8)	3 (0.5)	4 (0.6)
All injuries	73 (11.3)	52 (8.0)	95 (14.7)	79 (12.2)	83 (12.8)	87 (13.4)	70 (10.8)	108 (16.6)

Note. ED, emergency department; MVR, motor vehicle-related.

Types or causes of injury are ranked as a percentage of total ED visits. Data are for ED visits from August 28 through September 2, 2011. Percentages were calculated by dividing the number of ED visits related to injuries in that category and age group by the total number of ED visits in that region during that week. (There were 2,251 total ED visits in the 29-county region and 647 total ED visits in the 7-county region.) The bottom row represents the total number of ED visits for external injuries in each region for the listed week, including those for types of injuries that are not separately reported in this table; thus, the sum of the data in the first 5 rows does not equal the total in the bottom row.

^aThese 7 counties received federal disaster declarations.

Irene was compared with the number of such visits in the 2010 reference week, an 18% overall increase in the number of injury-related ED visits was identified. In the 7-county disaster region, 488 injury-related ED visits were reported during the 2010 reference week, compared with 475 injuries during the 2011 pre-storm week, representing a decrease of 2%. Comparing the pre-storm week with the 2010 reference week showed that residents' preparations for the storm did not significantly affect the rate of injury-related ED visits; thus the pre-storm week could be used as a baseline for comparison with the post-storm week.

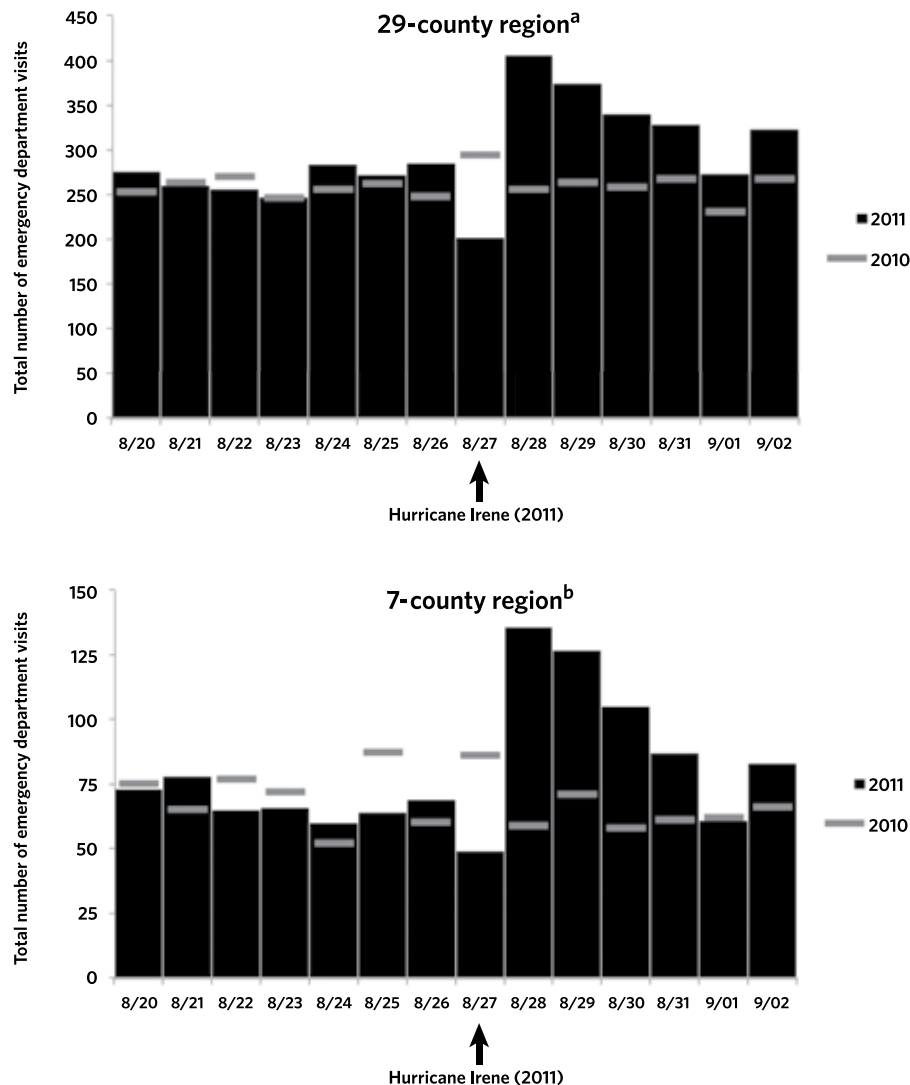
Both the 29-county region and the 7-county disaster region experienced a significant decrease in the number of injury-related ED visits on the day of the storm (August 27), followed by a substantial peak on the day after the storm (see Figure 2). Approximately 7-10 days after the storm, the number of injury-related ED visits gradually returned to baseline, with trends similar to those observed in 2010.

Pearson's chi-square test of independence was used to

evaluate the frequencies of injury types in the post-storm week compared with the 2010 reference week. For the 29-county region, statistically significant increases were noted in the proportion of injuries caused by falls ($P=.001$). For this region, there were decreases in the proportion of injuries caused by assault ($P=.038$) and the proportion of injuries resulting from recreational activities ($P=.001$). When the 7-county region was evaluated using the same method, a significant increase was detected in the proportion of injuries caused by cutting or piercing incidents ($P=.012$); decreases in the proportions of other causes or types of injury were not statistically significant.

When the data were stratified by age group (Table 2), falls were the most common cause of injury in all age groups, with individuals 20-29 years of age having the highest number of falls in the 29-county region. In the 7-county region, 27.4% of the total number of injuries occurred in individuals older than 69 years; in the 29-county region, only 15.6% of all injuries occurred in this age group.

FIGURE 2.
Injury-Related Emergency Department Visits in Eastern North Carolina Before, During, and After Hurricane Irene in 2011 and During the Week of August 28 through September 3, 2010



Note. Hurricane Irene made landfall on August 27, 2011. This day is denoted by an arrow on the above histograms.
^aThe counties in the 29-county region are Beaufort, Bertie, Camden, Carteret, Chowan, Craven, Currituck, Dare, Duplin, Edgecombe, Gates, Greene, Halifax, Hertford, Hyde, Jones, Lenoir, Martin, Nash, Northampton, Onslow, Pamlico, Pasquotank, Perquimans, Pitt, Tyrrell, Wayne, Wilson, and Washington.
^bThe 7 counties that were declared federal disaster areas following Hurricane Irene are Beaufort, Carteret, Craven, Dare, Hyde, Pamlico, and Tyrrell.

Discussion

Overall, the number of ED visits related to injuries was significantly higher following Hurricane Irene than during the 2010 reference week. This increase became more evident when data from the 7-county disaster region were analyzed and compared with data from the 29-county region. Observed increases in injuries due to cutting or piercing and injuries caused by falls during the week following Hurricane Irene were consistent with the findings of other studies that have assessed the types of injuries seen in EDs following a

natural disaster [21-23]. Nonfatal injuries and illnesses—including insect stings, dermatitis, diarrhea, and psychiatric conditions—increased following Hurricane Floyd, which caused a great deal of damage in North Carolina in 1999 [8].

Interestingly, our study found that the types of injuries most commonly seen in EDs during the 2010 reference period and during the 2011 pre-storm period were also commonly reported during the week following Hurricane Irene. This information could prove valuable for hospitals planning for the ED visits likely to occur after a natural disaster. Eastman and colleagues [5] found that injury-related

surges in patient loads at EDs have the potential to overwhelm local resources following a disaster; the use of alternative sources of medical care, including temporary clinics, after disaster events therefore needs to be considered to help manage this expected increase in need. Local EDs need to be prepared to accommodate their typical patient loads along with additional injuries following a disaster. Preparations could include stockpiling supplies, adding personnel (including physicians), and other measures. It is important to remember that many underserved individuals in Eastern North Carolina live in rural and isolated areas and have limited access to medical treatment. The health needs of individuals in these areas are a critical concern and should continue to be addressed through coordinated efforts on the part of state and local governments, physician residency programs, and the community—both before and after a natural disaster event.

Although we met the aims of our evaluation, there were several limiting factors. We were unable to obtain the patient's home address, the patient's treatment location, or information about the patient's underlying health conditions. Lacking these types of specific details may have resulted in our either overestimating or underestimating the number of storm-related injuries for selected counties. Having the patient's home address would have been useful for determining how far an individual traveled and where he or she sought treatment. More descriptive information about how the injury occurred might have helped us to better identify whether the injury was a result of the storm. For public health surveillance purposes, the doctor or a member of the admitting staff could make a special notation on the patient's medical record indicating whether the injury was a direct or indirect result of the storm. This type of increase in reporting could assist public health practitioners and health educators in targeting injury-prevention outreach when undertaking hurricane preparation and planning. In addition, the inability to account for individuals who sought health care from nonreporting medical facilities (such as walk-in clinics) was a limitation. These types of private providers are under no obligation to report injuries to NC DETECT, and therefore the patients they saw are not included in our estimates. Also, any increases in the number of ED visits during the week prior to the storm may have occurred as a result of preparations for the storm. This may have distorted the accuracy of our estimates of the number of injuries associated with the storm. However, the information we obtained about ED visits during the week before the storm may be useful for hospitals that are trying to predict the number and types of pre-storm ED visits.

In conclusion, the outcomes of a natural disaster can have multiple devastating effects on individuals and communities. However, public health surveillance using NC DETECT can serve as a vital resource for evaluating public health injuries and adverse health outcomes. We recommend continuous monitoring of ED visit data and enhanced communication

with the public regarding how to avoid injuries following natural disasters. In addition, other highly significant, but less immediately recognized types of impacts, such as effects on mental health, need to be considered. Studies with these types of focuses may prove important for underserved persons living in rural areas with limited access to health care facilities, who may suffer greater long-term effects from certain stress disorders. *NCMJ*

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Potential conflicts of interest. All authors have no relevant conflicts of interest.

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