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Acute post-disaster medical needs of patients with diabetes: emergency department use in New York City by diabetic adults after Hurricane Sandy

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ABSTRACT

Objective: To evaluate the acute impact of disasters on diabetic patients, we performed a geospatial analysis of emergency department (ED) use by New York City diabetic adults in the week after Hurricane Sandy.

Research design and methods: Using an all-payer claims database, we retrospectively analyzed the demographics, insurance status, and medical comorbidities of post-disaster ED patients with diabetes who lived in the most geographically vulnerable areas. We compared the patterns of ED use among diabetic adults in the first week after Hurricane Sandy’s landfall to utilization before the disaster in 2012.

Results: In the highest level evacuation zone in New York City, postdisaster increases in ED visits for a primary or secondary diagnosis of diabetes were attributable to a significantly higher proportion of Medicare patients. Emergency visits for a primary diagnosis of diabetes had an increased frequency of certain comorbidities, including hypertension, recent procedure, and chronic skin ulcers. Patients with a history of diabetes visited EDs in increased numbers after Hurricane Sandy for a primary diagnosis of myocardial infarction, prescription refills, drug dependence, dialysis, among other conditions.

Conclusions: We found that diabetic adults aged 65 years and older are especially at risk for requiring postdisaster emergency care compared to other vulnerable populations. Our findings also suggest that there is a need to support diabetic adults particularly in the week after a disaster by ensuring access to medications, aftercare for patients who had a recent procedure, and optimize their cardiovascular health to reduce the risk of heart attacks.

INTRODUCTION

On 29 October 2012, Hurricane Sandy made landfall on the East Coast of the USA, causing severe storm surges and immense destruction.1 In New York City alone, 305 000 homes were destroyed, and the city sustained 19 billion dollars in damage including to critical health facilities and infrastructure.2 There were 159 deaths; of which, 72 were directly attributed to the storm and 87 were indirectly due to the storm’s impact, ie, extended power outages which led to hypothermia, falls in the dark by the elderly, or carbon monoxide poisoning from improperly used generators and cooking devices.3 Although the acute impact on mortality and cost of destruction was well estimated for Hurricane Sandy, less is known about the acute impact this disaster had on patients with chronic diseases such as diabetes.3 4 Patients with diabetes are a particularly vulnerable population during a disaster. Disrupted access to care, inability to monitor glucose, poor nutrition, limited physical activity, damaged or lost medications, inability to safely store insulin due to power loss, and lack of prescription refills all place diabetic adults at increased risk for developing acute postdisaster medical needs, and potential morbidity or mortality in the days following a disaster.5 6

There is a paucity of information on the acute impact of disasters on diabetic patients, specifically following Hurricane Sandy. Longer term studies in the literature from other disasters have demonstrated poor glycemic control as measured by HbA1c months later and poorer quality of life both thought to be attributable to the increased physical and emotional stress experienced by diabetic patients.7 8

However, in our recent
study, screening for conditions that demonstrated increased postdisaster use of emergency care, we found that there was also a statistically significant increase in the number of New York City emergency department (ED) patients presenting with a primary or secondary diagnosis of diabetes even in the first week after Hurricane Sandy. These findings require additional investigation as to which characteristics make certain diabetic patients at higher risk for needing acute medical care after a disaster.

The goal of this study was to identify salient patient characteristics that increase the likelihood that a diabetic patient will develop acute medical needs after a disaster such as Hurricane Sandy. We analyzed data on patients over the age of 18 years focusing on those who lived in the highest risk evacuation zone in New York City. We investigated patient demographics, insurance status, and medical comorbidities that were associated with increased ED use among these diabetic adults. This study provides insight into how to support diabetic populations in future disasters and to develop a framework for targeted interventions and deployment of disaster response resources.

RESEARCH DESIGN AND METHODS

Study design

Using an all-payer claims database of ED visits in New York City for 2012, we compared the demographic characteristics, insurance status, geographic distribution, and health conditions of ED patients with a primary versus secondary diagnosis of diabetes before and after landfall of Hurricane Sandy. To evaluate post-disaster ED utilization by diabetic adults that occurred in geographically vulnerable regions, we compared ED use for the first week after the disaster to baseline ED use in 2012 prior to 29 October the day on which Hurricane Sandy struck the East Coast of the USA.

Data source

The New York State Department of Health collects claims data from hospitals on ED visits and inpatient hospitalizations. The Statewide Planning and Research Cooperative System (SPARCS) is the most comprehensive resource for ED utilization in New York State. It includes privately insured, Medicare, Medicaid, and uninsured patients. In addition, to patient demographic data and insurance status, SPARCS includes diagnosis codes and patient addresses that can be used to identify health conditions and the exact location of a patient's residence.

Study population

Our study included all adult patients aged 18 years and older who visited a New York City ED in 2012, had a home address located in New York City, and had either a primary or secondary diagnosis of diabetes. We excluded patients from correctional facilities and nursing homes, and patients who visited an ED associated with a specialty hospital (ie, surgical subspecialty, oncological, or Veterans Administration facilities). These exclusions were performed so that we studied non-institutionalized New York City adults with diabetes who visited a 911-receiving ED based at a general acute care hospital in New York City.

ICD-9 diagnosis codes

To identify ED patients with a primary or secondary diagnosis of diabetes, we scanned International Classification of Diseases, 9th Edition (ICD-9) codes for a prefix of 250 (ie, 250.00–250.93), which includes diabetes diagnoses with and without complications. In a study of patients at the University of Pittsburgh Medical Center, the presence of a diabetes diagnosis code in ED records was 95% sensitive and 99% specific for identifying diabetic adults among ED patients. In fact, ED data had higher accuracy than outpatient records (79% sensitive, 98% specific), inpatient records (84% sensitive, 97% specific), and identification methods based on scanning pharmacy records for diabetes medications and laboratory tests for elevated HgbA1c or blood glucose concentrations.

In addition, to identify health conditions associated with ED visits for patients with a primary or secondary diagnosis of diabetes, we also evaluated the frequency of other ICD-9 codes based on the first three-digit and/or letter prefix. For patients who had an ED visit with a primary diagnosis of diabetes, we evaluated the other secondary diagnosis codes to evaluate other conditions and comorbidities that may have contributed to increases in ED use after the storm. For patients who had a secondary diagnosis of diabetes, we evaluated the primary diagnosis code associated with the ED visit to evaluate the presenting cause of ED visits among patients who have a history of diabetes, but came to the ED for other conditions.

Evacuation zones

In our prior study of ED utilization patterns, we had found that adults with a history of diabetes presented in significantly increased numbers in the level 1 evacuation zone. In this study, we focused on this subset of diabetic adults by studying diabetic patients located in the level 1 evacuation zone (at the highest risk). These revised evacuation zones were developed by the New York City Office of Emergency Management in response to Hurricane Sandy's impact and were generally areas of the city most impacted by the storm. To identify these patients, we geocoded the addresses of diabetic adults in New York City and analyzed the sample of patients whose address was located in the level 1 evacuation zone based on a publicly available geographic shapefile called "Atomic Polygons" (Release 15B, April 2015), which is available from the New York City Department of City Planning.

Statistical analyses

We first evaluated the geographic distribution of ED patients from any part of New York City who presented...
with a primary or secondary diagnosis of diabetes by comparing the number of ED visits for the week after the storm compared to weekly baseline ED use in 2012 prior to landfall of Hurricane Sandy.\textsuperscript{13} We analyzed this geographic distribution by postal ZIP code to identify areas of significant changes in ED use. We calculated a Z-score for the number of ED visits for the week after the storm’s landfall using an average and SD from the pre-disaster weeks in 2012. Then, we identified areas with significant changes in ED use by mapping ZIP codes with a Z-score of 1.645, 1.96, and 2.545, which we noted as a 90%, 95%, and 99% confidence of an increase or decrease in postdisaster ED use.

We then examined the demographic characteristics and insurance status of ED patients with a primary or secondary diagnosis of diabetes focusing on patients living in the level 1 evacuation zone. To compare these characteristics for the week after the storm’s landfall to baseline utilization patterns, we analyzed the average weekly proportion of elderly (aged 65 years and older), female, non-Hispanic black, and Hispanic patients, in addition to the proportion of privately insured, Medicare, Medicaid, and uninsured patients in 2012 prior to Hurricane Sandy’s landfall. For these weeks in 2012 prior to the disaster, we computed an average and SD and then calculated Z-scores for patient characteristics the week after the storm to determine statistically significant changes using a p value of $<0.05$.

Finally, to analyze the other primary and secondary diagnoses, we determined the most common primary diagnoses among ED patients with a secondary diagnosis of diabetes and also the most common secondary diagnoses among ED patients with a primary diagnosis of diabetes. This analysis also focused on patients from the level 1 evacuation zone. We compared the top 10 of these primary and secondary diagnoses before and after the disaster, and we also evaluated which of these diagnoses had the highest absolute increases in the number of ED patients in the week following Hurricane Sandy’s landfall compared to the pre-disaster weekly average. To be considered, the increase in ED visits for a given primary or secondary diagnosis had to be statistically significant, meaning that the Z-score for the number of ED visits for the week after storm’s landfall had to be above 2.81, correlating to a p value of at least 0.005 based on a Bonferroni adjustment for comparisons among the top 10 diagnoses.

Statistical analyses were performed using Stata V.12.1 (StataCorp: College Station, Texas, USA, 2011). Geographic analysis was performed using ArcGIS Desktop 10.2 (ESRI: Redlands, California, USA, 2013).

**RESULTS**

**Study population**

In evacuation zone level 1 in New York City, there were an average of 30.9 ED visits with a primary diagnosis of diabetes and 258.8 ED visits with a secondary diagnosis of diabetes during the weeks in 2012 before Hurricane Sandy’s landfall (table 1). For the week after the landfall, there were statistically significant increases with 60 ED visits for a primary diagnosis of diabetes and 420 ED visits for a secondary diagnosis of diabetes in the level 1 evacuation zone ($p<0.01$).

Comparing the proportion of these patients to the average weekly baseline in New York City in 2012, there was a statistically significant increase in the proportion of Medicare patients presenting to an ED with a primary diagnosis of diabetes (from 41% to 55%, $p=0.04$). Among ED patients with a secondary diagnosis of diabetes, the proportion of Medicare patients also increased (from 56% to 66%, $p<0.01$). In addition, there was an increase in the proportion of elderly patients presenting with a secondary diagnosis of diabetes (from 50% to 60%, $p<0.01$).

We did not find evidence of any statistically significant changes in the proportion of female, non-Hispanic black, Hispanic, privately insured, or uninsured patients presenting with a primary or secondary diagnosis of diabetes. However, among ED patients with a secondary diagnosis of diabetes, there was a statistically significant decrease in the proportion of Medicaid patients (from 26% to 18%, $p=0.02$) (figure 1).

**Geographic distribution**

In our evaluation of ED patients from all regions of New York City, we identified ZIP codes with a statistically significant change in the number of ED visits by diabetic adults comparing the week after the landfall of Hurricane Sandy to the average weekly baseline prior to disaster in 2012 (figures 2 and 3). There were significant increases in ED use for a primary diagnosis of diabetes, especially, in flood-prone areas. These regions included the Rockaways (11693, 11694), Howard Beach (11414), Coney Island (11224), eastern Staten Island (10306), and parts of Brooklyn (11201) and the Bronx (10454, 10461). For a secondary diagnosis of diabetes, there was similarly a statistically significant increase in ED use in the Rockaways (11691, 11694) and Coney Island (11224), but also some increases in flood-prone areas of Manhattan (10002, 10011).

**Primary diagnoses**

Among patients in the level 1 evacuation zone, the top 10 primary diagnoses among ED patients with a secondary diagnosis of diabetes for the week after Hurricane Sandy’s landfall and the pre-Hurricane Sandy average weekly baseline in 2012 are shown in table 2. Comparatively, the lists are relatively similar with over half of the diagnoses appearing before and after Hurricane Sandy’s landfall. Notable exceptions included a statistically significant increase in the number of myocardial infarctions (an increase from 4 to 12 cases per week in evacuation zone level 1), hypertension (an increase from 4 to 15 cases per week), chronic bronchitis (an increase from 4 to 12 cases per week), and hypertensive kidney disease (an increase from 2 to 10
In addition, we also found statistically significant increases in the number of ED visits with a primary diagnosis for chronic kidney disease, prescription refills, drug dependence, dialysis dependence, and electrolyte disorders (p<0.005).

**Secondary diagnoses**

We also analyzed the top 10 secondary diagnoses among ED patients in the highest level evacuation zone with a primary diagnosis of diabetes to assess associated health conditions and comorbidities (see table 3). Comparing

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**Table 1** Characteristics of ED users with diabetes in New York City evacuation zone level 1 before and 1 week after Hurricane Sandy’s landfall in 2012

<table>
<thead>
<tr>
<th>Patient characteristics</th>
<th>Before Hurricane Sandy landfall</th>
<th>After Hurricane Sandy landfall</th>
<th>p Value for difference</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Weekly average 2012</td>
<td>Proportion of patients (%)</td>
<td>One week after the landfall</td>
</tr>
<tr>
<td><strong>Primary diagnosis of diabetes</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>30.9</td>
<td>100</td>
<td>60</td>
</tr>
<tr>
<td>Demographics</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Elderly (aged 65 years and older)</td>
<td>9.8</td>
<td>32</td>
<td>26</td>
</tr>
<tr>
<td>Female</td>
<td>12.8</td>
<td>41</td>
<td>36</td>
</tr>
<tr>
<td>Black</td>
<td>12.7</td>
<td>41</td>
<td>4</td>
</tr>
<tr>
<td>Hispanic</td>
<td>6.1</td>
<td>20</td>
<td>13</td>
</tr>
<tr>
<td>Insurance</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Private</td>
<td>3.6</td>
<td>12</td>
<td>4</td>
</tr>
<tr>
<td>Medicare</td>
<td>12.7</td>
<td>41</td>
<td>33</td>
</tr>
<tr>
<td>Medicaid</td>
<td>10.7</td>
<td>35</td>
<td>17</td>
</tr>
<tr>
<td>Self-Pay</td>
<td>3.9</td>
<td>12</td>
<td>6</td>
</tr>
<tr>
<td><strong>Secondary diagnosis of diabetes</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>258.8</td>
<td>100</td>
<td>420</td>
</tr>
<tr>
<td>Demographics</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Elderly (aged 65 years and older)</td>
<td>128.4</td>
<td>50</td>
<td>250</td>
</tr>
<tr>
<td>Female</td>
<td>143.5</td>
<td>55</td>
<td>238</td>
</tr>
<tr>
<td>Black</td>
<td>73.9</td>
<td>29</td>
<td>101</td>
</tr>
<tr>
<td>Hispanic</td>
<td>50.9</td>
<td>20</td>
<td>81</td>
</tr>
<tr>
<td>Insurance</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Private</td>
<td>32.0</td>
<td>12</td>
<td>37</td>
</tr>
<tr>
<td>Medicare</td>
<td>145.9</td>
<td>56</td>
<td>279</td>
</tr>
<tr>
<td>Medicaid</td>
<td>67.8</td>
<td>26</td>
<td>75</td>
</tr>
<tr>
<td>Self-Pay</td>
<td>13.1</td>
<td>5</td>
<td>29</td>
</tr>
</tbody>
</table>

ED, emergency department.

* = p-value < 0.05
the week after Hurricane Sandy’s landfall to the pre-disaster average weekly baseline for 2012, a majority of the secondary diagnoses overlap before and after the storm. Notable exceptions included a statistically significant increase in the number of ED patients presenting primarily with diabetes who also had a secondary diagnosis code for a postprocedural state (an increase from 3 to 10 cases per week in evacuation zone level 1) and a secondary diagnosis code for overweight or obesity (an increase from 2 to 7 cases per week). In addition, we also found statistically significant increases in the number of ED visits with a secondary diagnosis for cardiac dysrhythmia, chronic airway obstruction, and osteomyelitis.
CONCLUSIONS

Prior literature has documented the longer term impact of disasters on diabetic adults. Hurricane Sandy was the second most destructive hurricane in US history, only surpassed by Hurricane Katrina in 2005.14 After Hurricane Katrina, there was evidence of long-term effects of the disaster on diabetic patients when glycemic control was measured by HbA1c and quality of life was assessed.7 8 15 16 In studies of international disasters, there has similar been evidence of disruptions in glycemic control and worse quality of life among individuals affected by events like earthquakes in Japan, Italy, and Turkey.17–22 The presumed mechanism of impact is thought to be mediated by the stress caused by the disaster, which has also been seen in other non-natural disasters.23–25 Our study expands this body of literature by specifically analyzing the acute impact of disasters on diabetic patients by evaluating ED use by diabetic adults after Hurricane Sandy.

Figure 3 Significant changes in ED visits among patients with a secondary diagnosis of diabetes. ED, emergency department.
In our geographic analysis, we found that diabetic adults in evacuation zone level 1 were more likely to have increased the need for post-disaster emergency care. We also found that elderly diabetic adults aged 65 years and older and Medicare patients are particularly at risk for requiring postdisaster emergency care compared to other vulnerable diabetic populations. Finally, through our analysis of diagnosis codes, we found that certain coexisting medical conditions and comorbidities place diabetic patients at higher risk for requiring acute medical care in the week immediately following a disaster such as Hurricane Sandy.

There are a unique constellation of factors that combine to increase vulnerability among elderly patients to the negative effects of catastrophic events. Many elderly patients depend on complex medication regimens or medical equipment. Some are dependent on caregivers to help manage their lives, and with disaster-related disruptions, these caregivers may be unable to care for this population. Complicating these risk factors, these patients may not be adequately prepared for disasters as at least one study shows that only 31% of elderly had a disaster plan in place. Finally, the intersection between multiple chronic diseases and advanced age can push those at the margins of compensated chronic disease into decompensated states.

We analyzed the coexisting medical conditions and comorbidities to identify those that were associated with increased ED use the week after Hurricane Sandy’s landfall compared to the pre-disaster average weekly baseline in 2012 among diabetic patients from the highest risk evacuation zone. For patients presenting to the ED for a primary diagnosis of diabetes, a majority of the most common secondary diagnoses were no different from those conditions noted before the storm. However, there were a substantial number of patients with a secondary diagnosis of postprocedural status. This finding suggests that diabetic patients who recently had a significant surgical or medical procedure experienced difficulty in accessing appropriate follow-up aftercare, and better planning is required for these patients in the face of a pending disaster. In a post hoc analysis, we did not find that there was a statistically significant increase in the number of emergency visits for a primary diagnosis of diabetic ketoacidosis or hyperglycemic hyperosmolar syndrome. However, this subanalysis was limited by a small number of events in the highest risk evacuation zone.

### Table 2
Most common primary diagnoses of patients with a secondary diagnosis of diabetes who presented for emergency care before and 1 week after Hurricane Sandy’s landfall in 2012

<table>
<thead>
<tr>
<th>Weekly baseline in 2012 before Hurricane Sandy’s landfall</th>
<th>One week after Hurricane Sandy’s landfall</th>
<th>Highest increases before and after</th>
</tr>
</thead>
<tbody>
<tr>
<td>Respiratory symptoms (16)</td>
<td>General symptoms (25)</td>
<td>General symptoms (+13)</td>
</tr>
<tr>
<td>General symptoms (12)</td>
<td>Respiratory symptoms (19)</td>
<td>Hypertension (+11)</td>
</tr>
<tr>
<td>Heart failure (10)</td>
<td>Hypertension (15)</td>
<td>Myocardial infarction (+8)</td>
</tr>
<tr>
<td>Sepsis (7)</td>
<td>Heart failure (13)</td>
<td>Hypertensive kidney disease (+8)</td>
</tr>
<tr>
<td>Cellulitis or abscess (7)</td>
<td>Sepsis (9)</td>
<td>Chronic bronchitis (+8)</td>
</tr>
<tr>
<td>Urinary tract infection (7)</td>
<td>Ischemic heart disease (9)</td>
<td>Chronic kidney disease (+7)</td>
</tr>
<tr>
<td>Asthma (7)</td>
<td>Ischemic heart disease (9)</td>
<td>Prescription refills (+7)</td>
</tr>
<tr>
<td>Abdominal/pelvic symptoms (6)</td>
<td>Hyperglycemic ketoacidosis (5)</td>
<td>Drug dependence (+7)</td>
</tr>
<tr>
<td>Cardiac dysrhythmias (5)</td>
<td>Ischemic heart disease (10)</td>
<td>Dialysis dependence (+6)</td>
</tr>
<tr>
<td>Ischemic heart disease (5)</td>
<td>Hyperglycemic ketoacidosis (5)</td>
<td>Electrolyte disorder (+6)</td>
</tr>
</tbody>
</table>

Diagnoses in bold highlight the differences in categories before and after Hurricane Sandy’s landfall.

### Table 3
Most common secondary diagnoses of patients presenting for EDs for a primary diagnosis of diabetes before and 1 week after Hurricane Sandy’s landfall in 2012

<table>
<thead>
<tr>
<th>Weekly baseline in 2012 before Hurricane Sandy’s landfall</th>
<th>One week after Hurricane Sandy’s landfall</th>
<th>Highest increases before and after</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hypertension (13)</td>
<td>Hypertension (30)</td>
<td>Hypertension (+17)</td>
</tr>
<tr>
<td>Hyperlipidemia (7)</td>
<td>Post-procedural aftercare (17)</td>
<td>Post-procedural aftercare (+11)</td>
</tr>
<tr>
<td>Post-procedural aftercare (6)</td>
<td>Chronic skin ulcer (14)</td>
<td>Chronic skin ulcer (+9)</td>
</tr>
<tr>
<td>Electrolyte disorder (6)</td>
<td>Electrolyte disorder (13)</td>
<td>Electrolyte disorder (+7)</td>
</tr>
<tr>
<td>Ischemic heart disease (5)</td>
<td>Hyperlipidemia (11)</td>
<td>Post-procedural state (+7)</td>
</tr>
<tr>
<td>Chronic skin ulcer (5)</td>
<td>Post-procedural state (10)</td>
<td>Overweight or obese (+5)</td>
</tr>
<tr>
<td>Chronic kidney disease (4)</td>
<td>Ischemic heart disease (10)</td>
<td>Ischemic heart disease (+5)</td>
</tr>
<tr>
<td><strong>Hypertensive kidney disease (4)</strong></td>
<td>Drug abuse (8)</td>
<td>Cardiac dysrhythmia (+4)</td>
</tr>
<tr>
<td>Drug abuse (4)</td>
<td>Chronic kidney disease (7)</td>
<td>Chronic airway obstruction (+4)</td>
</tr>
<tr>
<td>Other health hazards (7)</td>
<td><strong>Overweight or obese (7)</strong></td>
<td>Osteomyelitis (+4)</td>
</tr>
</tbody>
</table>

Diagnoses in bold highlight the differences in categories before and after Hurricane Sandy’s landfall. ED, emergency department.
Epidemiology/health services research

In addition, when analyzing patients with a secondary
diagnosis of diabetes who presented in increased
numbers for care in the week following Hurricane Sandy’s landfall, we found that there was a substantial
increase in the number of patients who had a primary
diagnosis of myocardial infarction, hypertension, respira-
tory conditions, kidney disease, dialysis dependence,
and prescription refills. In prior studies, patients with
respiratory conditions and kidney conditions were
known to be at high risk during disasters as some are ven-
tilator dependent or dialysis dependent. Following
Hurricane Sandy’s landfall, electrical outages and
damage to infrastructure led to the loss of the ability to
use durable equipment at home and the closure of dialy-
sis centers.37–39

In addition, the closure of outpatient clinics and hos-
pitals with their associated medical care centers might
further limit the access to regular medical care.40 An
intervention to address the need for unfilled prescriptions
may come in the form of mobile pharmacies that
can deliver diabetic medications to patients in need.41
An important window of opportunity may exist as
patients with a primary diagnosis of diabetes presented
somewhat delayed on days 4 and 5 following Hurricane
Sandy’s landfall compared to other patients, for
example, ventilator-dependent or dialysis-dependent
individuals, who came to the ED for care immediately
after the storm.9,42

Prior disaster literature has documented the increased
incidence of acute myocardial infarction in the general
population after disasters such as Hurricane Katrina,
and the Hanshin-Awaji and Niigata-Chuetsu earth-
quakes.43–45 The proposed mechanism of this increase
in acute myocardial infarction is thought to be related to
the mental stress and physical activity induced by
disaster-related damage to property, delays in recovery
and reconstruction, loss of livelihood, all coupled with
interrupted access to healthcare and medications leading
to an increased emotional distress, blood pressure, and
catecholamine release.44–46 Our data, although based on
small numbers of events in the level 1 evacuation zone,
demonstrate three times the number of cases of myocar-
dial infarction among diabetic adults, which suggests the
need to optimize cardiovascular health and to provide
social support for diabetic patients highly affected by a
disaster like Hurricane Sandy.47

Finally, in our geographic analysis of patients from all
of New York City, we found that statistically significant
increases in ED use primarily were concentrated in
flood-prone areas. These hot spots may be areas in
which interventions can be focused and geographically
targeted.48 Furthermore, finding statistically significant
clusters of diabetic patients in disaster-prone regions
using geospatial analysis may help in preplanning to
identify areas in which interventions may be targeted to
provide home care services for patients with diabetes
who had recent surgical or medical interventions, or
mobile pharmacies to deliver diabetic medications, or
other interventions to optimize cardiovascular health of
diabetic patients at higher risk for myocardial infarc-
tion.49 In fact, our prior studies demonstrate that geo-
graphic analysis of patients with chronic disease and ED
use can help enhance disaster planning and response to
optimize care for particularly vulnerable populations of
patients.

Limitations

Our study is a geographic analysis of ED administrative
claims data, which means that it is subject to coding
errors that can occur in data collection. In addition, we
used municipal administrative evacuation zones devel-
oped post hoc based on the damage incurred by
Hurricane Sandy. These areas may not precisely repre-
sent the true underlying geographic impact of
Hurricane Sandy, particularly for electrical failures.
Given the number of ICD-9 diagnosis code categories
that we examined, we made adjustments to the level of
statistical significance required to identify a category
with increased ED utilization. Important categories of
ED utilization may have been missed by using this strin-
gent requirement for statistical significance. Finally, our
study is limited to Hurricane Sandy and New York City, a
unique and densely populated urban environment.
Findings of our study may not be generalizable to other
regions of the country or other types of disasters in
which different changes in ED utilization may occur.

Conclusions

Our findings suggest that there is need to support dia-
abetic adults during disasters by ensuring access to medi-
cations, aftercare for patients following a recent
procedure, and optimize their cardiovascular health to
reduce the risk of heart attacks. This study fills the void
on a number of questions: specifically what conditions
cause diabetic patients to present for emergency care
after a disaster, and which patient characteristics among
diabetic adults contribute to a higher risk of requiring
acute medical needs after a disaster. In addition, this
study demonstrates that geographic analysis can help
identify diabetic patients who are most vulnerable after a
disaster, which may help targeting interventions to
improve disaster preparedness or response. The implica-
tions of these results will help shape future disaster man-
agement and policies, especially for diabetic patients,
who we find are particularly at risk during events such as
Hurricane Sandy.

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David C Lee, Vibha K Gupta, Brendan G Carr, Sidrah Malik, Brandy Ferguson, Stephen P Wall, Silas W Smith and Lewis R Goldfrank

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