ORIGINAL RESEARCH

Vulnerability of Older Adults in Disasters: Emergency Department Utilization by Geriatric Patients After Hurricane Sandy

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ABSTRACT

Objective: Older adults are a potentially medically vulnerable population with increased mortality rates during and after disasters. To evaluate the impact of a natural disaster on this population, we performed a temporal and geospatial analysis of emergency department (ED) use by adults aged 65 years and older in New York City (NYC) following Hurricane Sandy's landfall.

Methods: We used an all-payer claims database to analyze demographics, insurance status, geographic distribution, and health conditions for post-disaster ED visits among older adults. We compared ED patterns of use in the weeks before and after Hurricane Sandy throughout NYC and the most afflicted evacuation zones.

Results: We found significant increases in ED utilization by older adults (and disproportionately higher in those aged ≥85 years) in the 3 weeks after Hurricane Sandy, especially in NYC evacuation zone one. Primary diagnoses with notable increases included dialysis, electrolyte disorders, and prescription refills. Secondary diagnoses highlighted homelessness and care access issues.

Conclusions: Older adults display heightened risk for worse health outcomes with increased ED visits after a disaster. Our findings suggest the need for dedicated resources and planning for older adults following a natural disaster by ensuring access to medical facilities, prescriptions, dialysis, and safe housing and by optimizing health care delivery needs to reduce the burden of chronic disease. (*Disaster Med Public Health Preparedness*. 2018;12:184-193)

Key Words: older adults, disaster management, emergency department, geographic information systems, vulnerable populations

The identification of vulnerable groups who face increased risk of medical morbidity during a natural disaster is a high priority.[1] While the US population aged 65 years and older will double from 43.1 million to 83.7 million from 2012 to 2050, those aged 85 years and older will triple from 5.8 million to 17.9 million.[2] In the face of anticipated increased natural and human-engineered disasters, disaster planners are challenged by this demographic shift, as many older adults have compromised ability to adequately prepare for and/or respond to emergency events.[3,4] Older adults experience persistent vulnerability after disasters owing to an absence of federal and local policies, guidance (disaster preparedness education), tracking systems, and warnings for individuals with sensory impairments (eg, vision, hearing, and proprioception), compromised ambulation, and chronic conditions.[5] Multiple chronic diseases, disabilities and mobility problems, dementia or cognitive impairments, and living in a long-term care facility are among the highest risks for vulnerable older adults.[6-10] This cluster of frailty contributors has led older adults to be disproportionately affected in diverse natural disasters such as Hurricanes Katrina and Rita, the 1995 Chicago heat wave, and the Great East Japan earthquake of 2011.[11-15] This vulnerability of older adults is manifested by increased mortality rates during diverse disaster scenarios and their aftermath.[11]

Despite improved warning times, the majority of geriatric populations are unable to comply with mandatory evacuations due to medical needs and lack of social support.[8,16] Compounding this problem, caregivers providing ongoing social support to geriatric patients are projected to decline from 7 caregivers for each older adult in 2010 to 4 by 2030 to less than 3 caregivers to 1 older adult by 2050.[17] Lack of emergency preparedness and response was cited as causal in three-quarters of deaths among adults aged 60 years and older during Hurricane Katrina.[10] In a

previous Hurricane Sandy analysis, there were a total of 117 deaths; 38 of these were indirectly and 79 were directly related to the storm's impact on power outages, which caused falls in the dark by older patients, medical equipment needs (ventilator dependence), and pneumonia and electrolyte disorders from hypothermia.[18,19] Nearly half (48% of 52) of New York City (NYC) Hurricane Sandy deaths occurred in individuals aged 65 years and older.[20]

Flooding and power outages coincided with Hurricane Sandy's landfall on October 29, 2012, posing complex public safety challenges to more than 1.5 million people and affecting approximately 30 nursing homes and adult facilities in Queens and Brooklyn.[21,22] A single-site analysis of emergency department (ED) visits and a preliminary analysis of citywide NYC hospitals after Hurricane Sandy suggested disproportionate increases in hospitalizations in very old patients (85 years and older) compared to older adult cohorts (65 years and older) due to hospital and outpatient clinic closures.[1,23] Single-site findings noted the significant indirect, downstream effects of power outages and flooding, which triggered ED visits among older adults relating to dialysis, respiratory devices, medication refills, and social requests (water, heat, food, and lack of evacuation transportation).[1,23] A previous study demonstrated that geospatial analysis is a viable strategy, as it presents high reliability over time and excellent granularity at a local level for chronic disease prevalence in ED visits.[24]

We aimed to utilize geospatial analyses to characterize primary and secondary medical needs in older adults (aged 65 years and older) following a natural disaster in NYC. We intended to correlate the most affected NYC geographic evacuation zones with ED utilization by using the New York State all-payer claims database. This geospatial analysis had the potential to highlight affected areas in early phases of a disaster on a census tract level, which would provide insight into communities where older adults need focused attention for specific medical and nonmedical needs after a storm.

METHODS

Study Design

We analyzed the demographic characteristics, insurance status, geographic distribution by patient residence, and acute and chronic health conditions of older ED patients before and after landfall of Hurricane Sandy. The primary age subgroups for our study were 65 to 74 years, 75 to 84 years, and 85 years and older. We used an all-payer claims database of ED visits, which captured discharge diagnoses of patients in NYC during 2012. To evaluate post-disaster ED utilization for older adults in each subgroup that occurred in geographically vulnerable evacuation zones, we evaluated 2012 ED visits with specific attention to the differences between ED visits antecedent to landfall with those visits occurring subsequently. We analyzed primary and secondary diagnoses for those weeks with significant difference after the Hurricane Sandy landfall.

Data Source

For decades the New York State Department of Health has compiled claims data on ED visits and inpatient hospitalizations into the Statewide Planning and Research Cooperative System (SPARCS).[25] SPARCS is the most comprehensive resource for ED utilization in New York State. SPARCS includes privately insured, Medicare, Medicaid, and uninsured (self-pay) patients. The SPARCS dataset contains diagnosis codes to identify health conditions and patient addresses.

Study Population

Our current study included all adults aged 65 years and older who visited a NYC ED in 2012 and had a home address within NYC. On the basis of prior age analyses used in disasters and surveillance, we stratified this geriatric cohort into the predefined age subgroups of 65 to 74 years, 75 to 84 years, and 85 years and older.[2,26-30] Our study evaluated the geographic differences between each older adult age subgroup (65 to 74 years, 75 to 84 years, and 85 years and older) for consecutive weeks before the storm through the end of the year after the storm. We analyzed primary and secondary diagnoses for the weeks before and after Hurricane Sandy for all evacuation zones, with specific attention to the highest-level evacuation zone (zone one). We included noninstitutionalized NYC older adults who visited a 911-receiving ED based at a general, acute care hospital in NYC, because institutionalized patients are not included in SPARCS. We therefore excluded incarcerated patients (those presenting from correctional facilities), nursing home patients, and patients who visited an ED associated with a specialty hospital (ie, surgical subspecialty, oncological, or Veterans Administration facilities).

Evacuation Zones

In response to Hurricane Sandy's impact, NYC's Office of Emergency Management revised and expanded evacuation zone classifications (from 3 to 7) to delineate the zones in the city with the highest potential for adverse storm sequelae. Hence, evacuation zone one represented an area at highest risk for older adults (see the interactive display at https://maps.nyc.gov/hurricane/). A previous study identified that evacuation zone one experienced a significant increase in ED utilization after storm, in contrast to other zones.[1] Additionally, the NYC Mayor's Office identified evacuation zone one as the area most affected by the storm and requiring the most resource allocation.[21] To identify and locate older adult patients for this study, we geocoded patient addresses in NYC and specifically analyzed the sample of patients whose addresses were located in evacuation zone one on the basis of the publicly available NYC Department of City Planning GIS shapefile "Atomic Polygons" (Release 15B, April 2015).[31]

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ICD-9 Diagnosis Code Categories

To categorize health conditions associated with ED visits of older adult patients, we analyzed primary *International Classification of Diseases, Ninth Revision* (ICD-9) diagnostic codes.[32] We used the first 3-digit and letter prefix to group closely related ICD-9 codes.[24] To explore comorbidities and chronic conditions that may have contributed to or influenced geriatric patterns of ED utilization, we analyzed additional secondary ICD-9 diagnostic codes. Previous studies have validated that ED data have high accuracy for identifying specific disease conditions.[1,23,33,34]

Statistical Analysis

We analyzed visit frequency and timing, demographic characteristics, and insurance status of adult ED patients aged 65 years and older in the weeks following the hurricane, compared to the antecedent 2012 baseline, with specific attention to evacuation zone one. We evaluated the average weekly proportion of older adults by age subgroups (65 to 74 years, 75 to 84 years, and 85 years and older), gender, race/ethnicity, and insurance status. We stratified age by the above-mentioned subgroups from the base set by prior age standards used in disasters and surveillance found in the literature for older adults.[2,26-30]

Following an analysis of ED visits and establishing which weeks had significant volume alterations (ie, first 3 weeks after the storm), we evaluated ICD-9 codes from these ED visits to determine those with the greatest change in diagnosis frequency. We compared diagnoses in these post-landfall weeks to the weeks before Hurricane Sandy (2012 baseline) both in aggregate and individually. We evaluated primary and secondary diagnoses separately for each subgroup, anticipating that each might have differing medical needs during a disaster. From the prior weeks, we computed an average and standard deviation and then calculated z-scores for patient characteristics the week after the storm to determine statistically significant changes by using P values less than 0.05. 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 landfall had to be 1.96, correlating to a P value of at least 0.05.

We evaluated the geospatial distribution of ED patients from NYC who were 65 years and older by comparing the number of ED visits for the weeks after the storm to 2012 weekly baseline ED use prior to Hurricane Sandy landfall. Geospatial analysis has been identified as a viable strategy to potentially identify communities at risk to help them prepare and facilitate resources allocation during such a disaster.[24] This geographic distribution was explored to identify significant changes in the ED utilization rate. We studied the frequency change in volume of ED visits at a more granular level by census tract and identified the change in number of ED visits for older adults. Additionally, we analyzed z-scores for changes in volumes to identify statistically significant changes with z-scores of 1.96 and 2.545. These correspond to a 95% and 99% confidence of an increase or decrease in post-disaster ED use.

Stata 12.1 (StataCorp, College Station, TX) was used to perform the statistical analyses. Geographic analysis utilized ArcGIS Desktop 10.2 (ESRI, Redlands, CA).

Ethics

This study was approved by the Institutional Review Board of the NYU School of Medicine, Office of Science and Research, and the SPARCS Data Protection Review Board at the New York State Department of Health.

RESULTS

Study Population Characteristics

Older adults' overall weekly ED visits for all NYC evacuation zones averaged 9852 visits in the weeks prior to Hurricane Sandy's landfall and increased in the first week after to 10,073. There was a markedly significant increase in visits for older adult ED visits in evacuation zone one from 552 to 1111 ($P < 0.01$; Table 1). This was significant across all older age subgroups in the first week, tapered by the second week, and normalized by the fourth week (Figure 1). The ED visits of every older age subgroup increased in evacuation zone one; however, these increases were not proportionally distributed throughout the older adult age cohorts (Table 1 and Figure 1). For the subgroup aged 65 to 74 years, there was a statistically significant decrease in proportions for all NYC evacuation zones (45% to 44%, $P = 0.01$) and especially in NYC evacuation zone one (42% to 36%, $P = 0.01$). No significant change was found in the subgroup aged 75 to 84 years for all NYC evacuation zones and evacuation zone one. In the subgroup aged 85 years and older, there was a statistically significant increase in percentage (from 21% to 23%, $P < 0.01$) for all evacuation zones in NYC and particularly in evacuation zone one (23% to 28%, $P < 0.01$) (Table 1).

Gender analysis indicated a statistically significant increase in the proportion of males (from 40% to 43%, $P < 0.01$), and a corresponding decrease in female proportion in all NYC evacuation zones; evacuation zone one showed similar trends, although these results were not statistically significant. We did find a statistically significant change in racial/ethnic proportions in both black (from 26% to 24%, $P < 0.01$) and Hispanic (from 22% to 20%, $P < 0.01$) patients seen in the ED for all evacuation zones in NYC. This finding persisted in evacuation zone one, but did not achieve statistical significance (these groups were less represented in zone one). There was a statistically significant decrease in the proportion of private (from 7% to 6%, $P < 0.01$) and Medicaid (from 6% to 5%, $P = 0.01$) insurance, and a slight increase of proportion in Medicare (from 83% to 84%, $P = 0.04$) status. For evacuation zone one there was a similar statistically

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TABLE 1

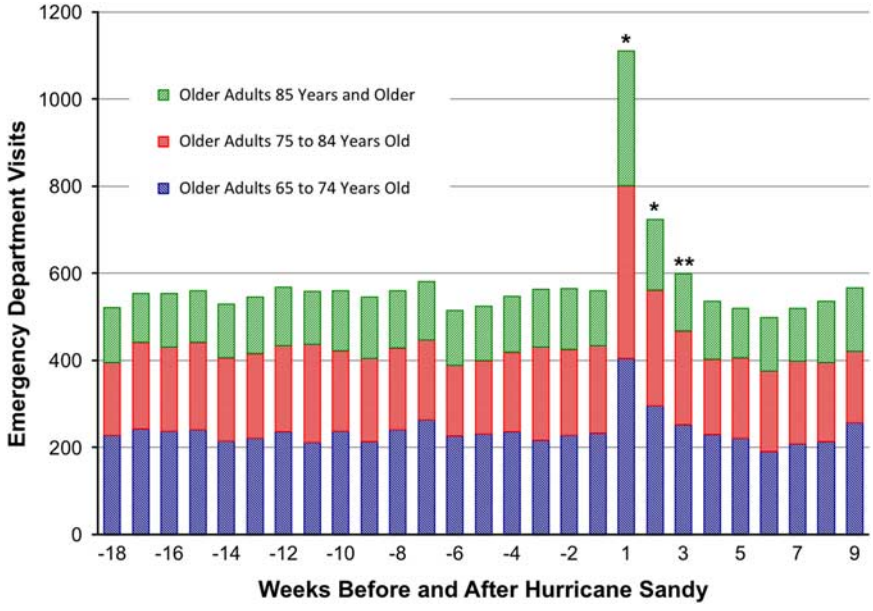
Emergency Department Use by Older Adults Before and 1 Week After Hurricane Sandy in 2012[a]

	All Evacuation Zones in New York City			Evacuation Zone One		
Patient Characteristics	**Weekly Average Before Sandy in 2012[b]**	**1 Week After Sandy**	***P* value**	**Weekly Average Before Sandy in 2012[b]**	**1 Week After Sandy**	***P* value**
Weekly ED patients, No.	9852	10,073	0.38	552	1111	<0.01
Age subgroup						
65 to 74 years	45%	44%↓	0.01	42%	36%↓	0.01
75 to 84 years	34%	34%	0.84	34%	36%↑	0.52
85 years and older	21%	23%↑	<0.01	23%	28%↑	<0.01
Sex						
Male	40%	43%↑	<0.01	42%	43%	0.51
Female	60%	57%↓		58%	57%	
Race/ethnicity						
Black	26%	24%↓	<0.01	18%	17%	0.46
Hispanic	22%	20%↓	<0.01	13%	12%	0.34
Health insurance						
Private	7%	6%↓	<0.01	6%	4%↓	0.02
Medicare	83%	84%↑	0.04	86%	89%↑	0.09
Medicaid	6%	5%↓	0.01	4%	3%	0.12
Self-pay	4%	4%	0.09	3%	4%	0.24

[a]Abbreviation: ED, emergency department.
[b]Baseline weekly average in the 43 weeks in 2012 before Hurricane Sandy's landfall.

FIGURE 1

Snapshot of Weeks With Increase in Emergency Department Use by Older Adults in Evacuation Zone One Stratified by Age Subgroup in 2012.



***$P < 0.001$; **$P = 0.016$. For visualization purposes, only the 18 weeks before Hurricane Sandy landfall are shown.**

significant decrease in proportion for private insurance (from 6% to 4%, $P = 0.02$) and a nonsignificant increase in the proportion of Medicare patients (Table 1). Figure 1 displays ED visits in the older age subgroups in the weeks before and after Hurricane Sandy in evacuation zone one.

Primary and Secondary Diagnoses

Previous work demonstrated temporal "waves" of diagnostic conditions following Hurricane Sandy landfall.[1] After finding that ED visits increased significantly in the 3 weeks after the storm, we evaluated the increases in specific primary

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TABLE 2

Increases in Emergency Department Primary Diagnoses in Evacuation Zone One for Older Adults 1 Week After Hurricane Sandy, Stratified by Age Subgroups

Older Adults, 65 to 74 Years (n = 405)	Older Adults, 75 to 84 Years (n = 396)	Older Adults, 85 Years and Older (n = 310)
Prescription Refills (+3.5%)	Dialysis (+2.7%)	Homelessness (+2.2%)
Dialysis (+1.9%)	Electrolyte Disorders (+1.9%)	Dementia (+1.7%)
Chronic Kidney Disease (+1.9%)	Hypertensive Kidney Disease (+1.9%)	General Symptoms (+1.7%)
Drug Dependence (+1.6%)	Chronic Bronchitis (+1.8%)	Nutritional Deficiency (+1.3%)
Anxiety Disorders (+1.3%)	Chronic Kidney Disease (+1.7%)	Dialysis (+1.3%)
Cardiopulmonary Symptoms (+1.2%)	Chronic Airway Obstruction (+1.4%)	Prescription Refills (+1.3%)
Homelessness (+1.2%)	General Medical Examination (+1.2%)	Observation and Evaluation (+1.2%)
Hypertensive Kidney Disease (+1.2%)	Observation and Evaluation (+1.1%)	General Medical Examination (+1.2%)
Chronic Airway Obstruction (+1.1%)	Hypertension (+1.0%)	Alzheimer's Disease (+1.0%)
Seizures (+1.0%)	Hypothermia (+1.0%)	Chronic Airway Obstruction (+0.9%)

TABLE 3

Increases in Emergency Department Secondary Diagnoses in Evacuation Zone One for Older Adults 1 Week After Hurricane Sandy, Stratified by Age Subgroups

Older Adults, 65 to 74 Years (n = 405)	Older Adults, 75 to 84 Years (n = 396)	Older Adults, 85 Years and Older (n = 310)
Homelessness (+3.2%)	Homelessness (+7.6%)	Homelessness (+10.1%)
Medical Facility Unavailable (+3.0%)	Ventilator Dependence (+4.3%)	Diabetes (+2.5%)
Prostatic Hypertrophy (+2.0%)	Other Health Conditions (+3.1%)	Medical Facility Unavailable (+2.4%)
General Symptoms (+1.9%)	Cardiopulmonary Symptoms (+2.7%)	Ventilator Dependence (+2.1%)
Ventilator Dependence (+1.8%)	Dementia (+2.0%)	Chronic Kidney Disease (+2.0%)
Dialysis (+1.4%)	Medical Facility Unavailable (+2.0%)	Isolation Requirement (+1.7%)
Isolation Requirement (+1.3%)	Post-Procedure Aftercare (+1.7%)	Other Hemorrhagic Conditions (+1.6%)
Post-Procedural State (+1.3%)	Chronic Kidney Disease (+1.6%)	Obesity (+1.2%)
Specific Procedure Required (+1.3%)	Other Lung Diseases (+1.6%)	Sepsis (+1.2%)
Other Disease History (+1.3%)	Urinary Symptoms (+1.2%)	Dementia (+1.2%)

diagnoses among older adult ED patients for week one after Hurricane Sandy (Table 2) and for weeks two and three (Supplements 1 and 3 in the online data supplement), stratified by the predetermined older adult age subgroups. The subgroup aged 65 to 74 years had increased visits particularly notable for prescription refills, hemodialysis, and kidney disease. For the age subgroup aged 75 to 84 years, increases were clustered around kidney dysfunction (dialysis, electrolyte disorders, hypertensive kidney disease, and chronic kidney disease) and pulmonary dysfunction (chronic bronchitis and chronic airway obstruction). For those over 85 years, primary diagnoses were notable for homelessness, dementia, general nonspecific symptoms, and malnutrition. Later weeks (second and third) highlighted the need for prescription refills in the age subgroups of 65 to 74 years and 75 to 84 years. Pneumonia and acute renal failure figured prominently in the oldest age subgroup.

Similar to primary diagnoses, with stratification by age subgroups, we evaluated increases in secondary diagnoses among older adult ED patients for the first week after Hurricane Sandy (Table 3) and subsequent weeks (Supplements 2 and 4 in the online data supplement). The most striking finding was a statistically significant increase in visits for homelessness and lack of access to care ("medical facility unavailable") among all age subgroups in our study during the first week after landfall. Later weeks (second and third) emphasized a wide range of secondary diagnoses such as dementia, prescription refills, asthma, electrolyte disorder, and post-procedural aftercare (such as dressing, sutures, drains, and others) (Supplements 2 and 4 in the online data supplement).

Geographic Distribution

Distinct geospatial pockets of increases or decreases in ED visits were evident. Following Hurricane Sandy landfall, there were definite increases by percentage over baseline (Figure 2A; Supplements 5A and 6A in the online data supplement) and by statistical significance (Figure 2B; Supplements 5B and 6B in the online data supplement). As mentioned above, the greatest increase in ED use by older adults was found in locales situated in the post-storm evacuation zone one. In the first week, we identified

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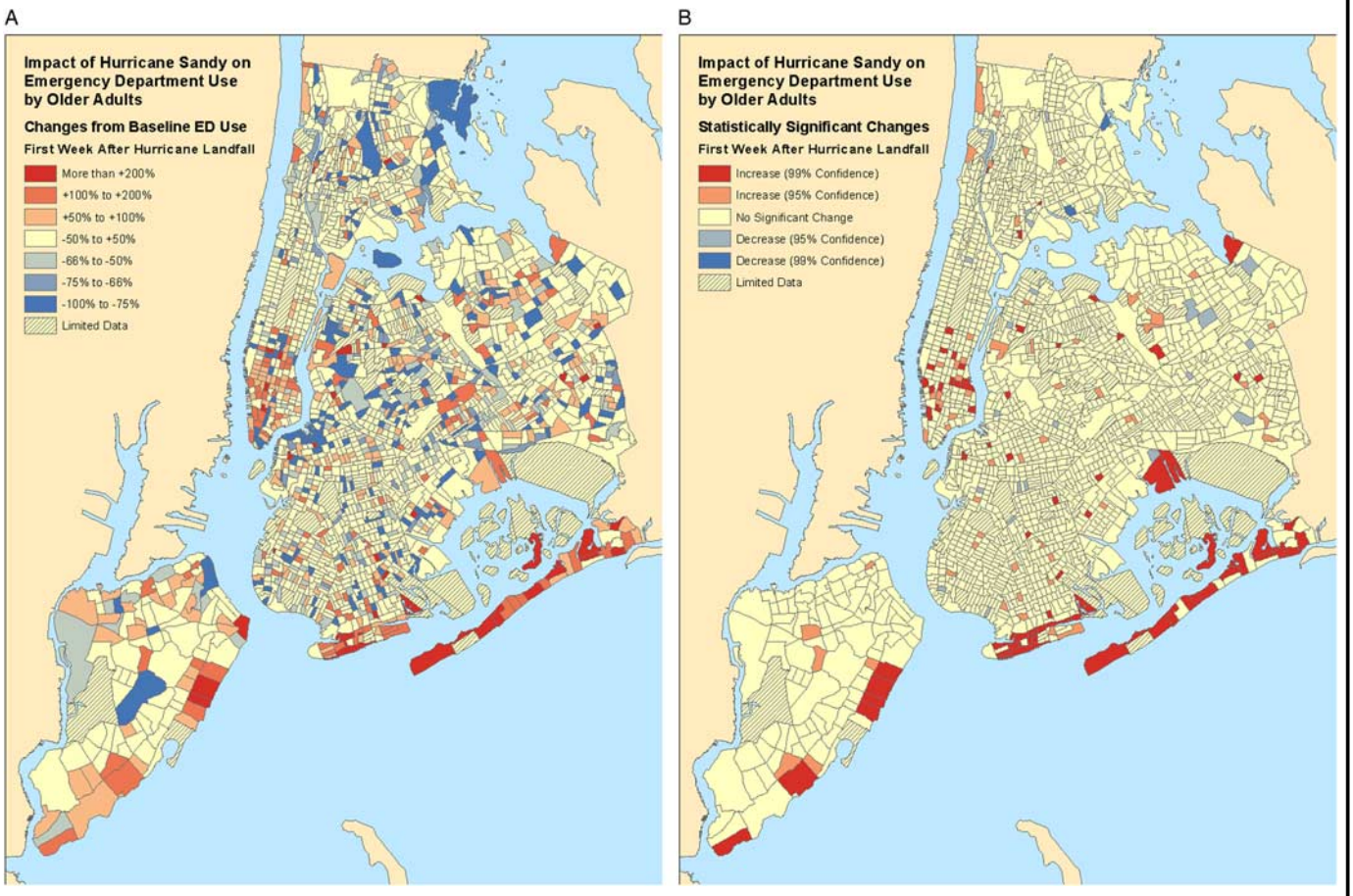
FIGURE 2

Significant Changes in Emergency Department (ED) Use by Older Adults After Hurricane Sandy Compared to Baseline ED Use in 2012 for First Week After Hurricane Landfall. (A) By Census Tract Level Based on Percentage Change. (B) By Census Tract Level Based on Z-score.



neighborhoods with increases in ED visits in Queens (Rockaway, Breezy Point, and Howard Beach), Brooklyn (Coney Island, Brighton Beach, and Homecrest), Eastern Staten Island, and Manhattan (lower Manhattan, Stuyvesant Park, Kips Bay, and Upper West Side) (Figure 2A). Similarly, we identified neighborhoods with increases in ED visits in the second week (Supplement 5A in the online data supplement) and third week (Supplement 6A in the online data supplement) at the census tract level. Areas with the highest statistically significant changes in ED utilization for geriatric patients in the 3 weeks after the storm by census tract level z-scores are provided in Figure 2B and Supplements 5B and 6B in the online data supplement.

DISCUSSION

We detected significant increases in ED utilization by older adults in specific communities in the first 3 weeks after Hurricane Sandy's landfall. This corresponded to evacuation zone one, the area most afflicted by the storm. A single-site study found similar disproportionate increases in ED visits among the age subgroups of older adults.[23] Our analyses extend the single-site findings citywide. The limitations of the SPARCS dataset led us to exclude older adults cared for at NYC nursing homes during Hurricane Sandy, as well as those who presented to the ED due to closure of nursing homes, adult residential houses, and prison facilities.[21] Therefore, our results likely underestimate acute care burdens for the elderly in disaster. Our findings apply to those nominally independent older adults. While older adults' residential status does not necessarily equate to functional independence, their noninstitutionalized status does suggest older adults who are potentially at risk. While individual housing status may be fluid, the community-level findings of our methodology have been demonstrated to be robust and imply underlying preparedness needs.[24,34]

While older adults were clearly affected in zone one compared to other zones, the very old (those 85 years and older) were

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particularly afflicted. Several reasons may explain the increase in older adult patient visits to EDs in the weeks after Hurricane Sandy. Older adults who became newly homeless as the result of damage to their homes from Hurricane Sandy might have sought help in an ED. Older adults, already considered a medically vulnerable population prior to the storm, may have experienced acute exacerbations of underlying conditions, may have required ongoing care for chronic illnesses that were interrupted (such as inability to receive dialysis), or may have faced environmental exposures contributing to diagnoses such as pneumonia or electrolyte disorders that forced them to utilize the ED after Hurricane Sandy. Prior studies have also highlighted the fact that lack of emergency preparedness and inadequate social support can act as a trigger for older adults to seek care in an ED due to its easy accessibility during a natural disaster.[8,10,16] Indeed, the NYC Hurricane Sandy Assessment Report recommended "developing a homebound door-to-door service task force and action plan to reach these populations; ensure critical access to healthcare services, medicines, and medical supplies; and increase and refine pre-storm communication and education."[21]

Older adults (aged 85 years and older) in all NYC evacuation zones sought care at EDs after the storm. This study and prior investigations highlighted newly homeless older adults' increased ED utilization rates in the early weeks after Hurricane Sandy both for all NYC evacuation zones and for evacuation zone one.[35] We found that older adults with Medicare were proportionately at risk for ED visits, which may provide a useful marker for lack of emergency preparedness. For example, we noted a burden of ED visits for prescription refills, which can be anticipated and prevented with adequate pre-emergency preparedness steps. Legal, regulatory, or administrative guidelines could be relaxed to permit an "early medication refill" strategy in patients with established chronic conditions before the storm. Similarly, a clinical pre-storm "early dialysis" strategy could extend post-storm stability in these patients. In response to past hurricanes, there has been a recognized need for a federal tracking system for frail older adults, especially those with chronic conditions, that can be employed at state and local levels during disasters for a coordinated evacuation of these elders to NYC's special needs shelters.[5,6,36-38] Extant Medicare status present in >80% of those visiting the ED in our study may provide the meaning to facilitate their identification. The Americans with Disabilities Act (ADA) provisions may be waived, provided that a shelter has a sufficient number of adequately trained medical staff and volunteers along with effective communication for people with disabilities or response conditions.[39] This could provide increased elderly response capacity. Older adults with burdens of compromised ambulation, frailty, or sensory impairment would benefit from coordinated training and education programs for disaster planning, tailored by gerontologists and local officials to improve disaster resilience.[5,36-38]

We found that certain existing medical conditions (dialysis, electrolyte disorders, and diabetes) and environmental conditions (unavailability of medical facility) placed geriatric patients at higher risk of requiring immediate care in the first 3 weeks after Hurricane Sandy. In addition to their need for greater preparation, older adults are often disproportionately challenged by disasters due to several factors, including complex chronic conditions, the need for assistance with activities of daily living, limitations of physiological disabilities (eg, mobility, cognitive, and sensory), lack of social support, and inadequate financial means.[7,33] A recent survey by the Centers for Disease Control and Prevention found that nearly 52% of adults aged 65 or older have hypertension, 36% have arthritis, 20% have coronary heart disease, 20% have cancer, 25% have diabetes, and 9% have had a stroke.[9] Our findings of significantly increased visits for dementia and malnutrition in the oldest age subgroup suggest a population with serious underlying care needs with little tolerance for environmental or infrastructure stressors.

Earlier studies have identified gender as a critical variable that can impact vulnerability after an adverse event.[40,41] Women tended to fare better than men in the Chicago heat wave, presumably because they were less prone to isolation and demonstrated stronger ties to family and friends.[13] Increased pre-disaster social support has been correlated with less psychological distress and stress related to hurricanes.[40] We found higher rates of older adult male ED visits, which we can speculate emerged from a similar disproportionate social connectivity. Prior studies identified that older adult males utilized more instrumental (tangible) and informational support compared to females, who rely on emotional support.[40,41] An earlier study reported the Health-Related Quality of Life (HRQoL) among married elderly after the flood disaster in Sichuan, China; married couples had significantly higher HRQoL than did singles because of shared emotional and physical support among couples.[42] Additionally, males experienced higher HRQoL with both types of support (emotional and physical) relative to females, who benefited more from emotional support alone.[42] Targeted supports for each gender could help these potentially medically vulnerable populations prepare for natural disasters. In addition to gender, previous studies have found that minority racial or ethnic groups experience worse health outcomes due to socioeconomic factors during natural disasters.[43,44] This study found a proportionate decrease in ED visits for black and Hispanic patients, although socioeconomic factors could have hindered seeking ED care in the early weeks after Hurricane Sandy's landfall.

Combinations of factors increased the vulnerability of older adults further during natural disasters.[5,6] Power outages during Hurricane Sandy that lasted for days in some evacuation zones led to loss of the ability to use durable equipment (ventilators) at home, difficulty in ambulating, and closure of dialysis centers.[1,23] Older adults are often dependent on their caregivers for social support such as obtaining prescriptions,

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transportation to dialysis centers, ventilator dependence, or navigating dementia. With the complicated disruption from disasters, caregivers may be unable to assist older adults in managing their lives.[33] Only about one-third of older adults have emergency preparedness plans in place before a disaster.[33] Secondary diagnoses of dementia or psychiatric disorders may exacerbate a lack of disaster planning among the medically vulnerable geriatric population, given the notable frequency of dementia-related presentations to the ED in the oldest cohort.[1] Dementia should be recognized as a significant disability and frailty contributor before a natural disaster, and complex disasters may exacerbate care needs in a synergistic fashion.

Closure of hospitals and outpatient clinics increased the burden on surrounding hospitals, EDs, and clinics to provide the needed medical care.[45,46] On the other hand, ensuring access to primary care health providers serving vulnerable subgroups can represent resiliency and display adaptive capacity under adverse circumstances from natural disasters.[45-47] Given the influx of older adult visits to EDs after the storm, local hospitals should anticipate a range of needs typically provided by community-based services. These findings would be magnified by closure of local hospitals or outpatient clinics due to a storm, increasing the burden on emergency medical services workers, physicians, nurses, social workers, hospital administrators, disaster planners, and other medical professionals to meet older adults' disaster care needs. Forward-thinking solutions would benefit medically vulnerable older adults through outreach, such as providing door-to-door services for medication refills, power sources, and drinks to balance electrolytes.[21] These measures may be vital to maintaining the viability of this medically vulnerable population who represent the "disaster penumbra."

We discovered increased ED utilization in our study from the intertwined factors of chronic medical conditions and comorbidities for the first 3 weeks after Hurricane Sandy's landfall compared to the pre-Sandy weekly baseline in 2012 among older adults for the high-risk evacuation zone one in NYC.[1] For geriatric patients presenting to the ED, their common primary and secondary diagnoses were for different conditions compared to before Hurricane Sandy. Most common of these diagnoses were potentially directly related to the disaster, such as pulmonary conditions, electrolyte disorders, need for dialysis, and prescription refills. This suggests the importance of emergency preparedness for older adults before natural disasters.

Limitations

This was a geospatial analysis of ED administrative claims data in a single-state, all-payer claims dataset. It is subject to coding errors that can occur in the routine course of such data collection. The evacuation zones were determined by the municipality post hoc and may not precisely represent the underlying geographic zones at risk, particularly for utilities threats. Nevertheless, we were able to evaluate ED utilization changes at the census tract level to identify communities at risk regardless of administrative designation. Due to our geographic specificity, we were able to account for unanticipated co-factors in Hurricane Sandy such as electrical failure, which may not be reflected in the evacuation zones. We could highlight critical locales in the early post-disaster phase with an increased burden of medical and nonmedical needs. Although there were a number of ICD-9 code categories, we adjusted for statistical significance to identify the top 10 categories with increased ED utilization. The all-payer claims data are deidentified; hence, we were unable to determine the transportation modality of the patients who presented to the ED. Our study was limited to NYC, a unique and densely populated urban environment, and to Hurricane Sandy. 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. However, we believe similar uses of all-payer databases of ED visits can suggest areas at risk or the need for planning. The patient dataset did not include institutionalized facilities. Therefore, our findings likely underestimated older adult populations at risk in areas where these facilities reside.

CONCLUSION

We found that ED visits for older adults (65 years and older), and particularly for those of eldest age (85 years and older), increased significantly in the weeks following Hurricane Sandy. Our findings suggest a need exists to support older adults immediately after a natural disaster to reduce exacerbations of chronic diseases by ensuring access to medical facilities, prescription refills, and dialysis. Geospatial techniques can help to identify potentially vulnerable older communities at risk before a disaster to mitigate ED visits and stressors on the health care system.

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Author Contributions

Study conception and design: DCL, IP, LRG, and SWS; acquisition of the data: DCL; analysis and interpretation of data: SM, DCL, KMD, CRG, JW, IP, LRG, and SWS; drafting of the manuscript: SM, JW, SWS; critical revision of the manuscript for important intellectual content: DCL, KMD, CRG, IP, and LRG; obtaining funding: DCL, IP, LRG, SWS; administrative, technical, or material support: SM, KMD, CRG, IP, and SWS; supervision: LRG. SM, DCL, LRG, and SWS take responsibility for the work as a whole, including the study design, access to data, and the decision to submit and publish the manuscript.

Supplementary material

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