

ORIGINAL RESEARCH

Redistribution of Emergency Department Patients After Disaster-Related Closures of a Public Versus Private Hospital in New York City

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ABSTRACT

Sudden hospital closures displace patients from usual sources of care and force them to access facilities that lack their prior medical records. For patients with complex needs and for nearby hospitals already strained by high volume, disaster-related hospital closures induce a public health emergency. Our objective was to analyze responses of patients from public versus private emergency departments after closure of their usual hospital after Hurricane Sandy. Using a statewide database of emergency visits, we followed patients with an established pattern of accessing 1 of 2 hospitals that closed after Hurricane Sandy: Bellevue Hospital Center and NYU Langone Medical Center. We determined how these patients redistributed for emergency care after the storm. We found that proximity strongly predicted patient redistribution to nearby open hospitals. However, for patients from the closed public hospital, this redistribution was also influenced by hospital ownership, because patients redistributed to other public hospitals at rates higher than expected by proximity alone. This differential response to hospital closures demonstrates significant differences in how public and private patients respond to changes in health care access during disasters. Public health response must consider these differences to meet the needs of all patients affected by disasters and other public health emergencies. (*Disaster Med Public Health Preparedness*. 2015;9:256-264).

Key Words: hurricane, disaster medicine, public health, emergency medicine, surge capacity

Differences in health care access have increased over time because permanent hospital closures have been more frequent in neighborhoods of lower socioeconomic status and among hospitals with more publicly insured or uninsured patients.^{1,2} These hospital closures can represent public health emergencies for individuals with complex medical needs who lose access to their usual source of care.^{3,4} Hospital closures also induce systemic stress, which can reveal the underlying dynamics of health care delivery systems and the behaviors of patients who access them.⁵ When these hospital closures occur in the midst of a disaster, their effects are magnified, and they can compound the difficulties of ensuring access to health resources during the disaster response and recovery periods.

During Hurricane Sandy, a public hospital, Bellevue Hospital Center (Bellevue), and a private hospital, the main campus of New York University Langone Medical Center (NYULMC), closed just blocks away from each other on the East Side of Manhattan.⁶ These 2 hospitals serve very different patient populations that were both challenged by the loss of their usual source for hospital-based care.⁷ These closures added additional stress to the health management of

many individuals already affected by the disaster.⁸ Having survived the flood waters, nearby open hospitals were overwhelmed with emergency department (ED) volume from the facilities that closed.⁹

This scenario provided an unfortunate natural experiment to analyze the patterns of health care use by patients at public versus private hospitals after a disaster.¹⁰ To determine patient responses to hospital closures during Hurricane Sandy, we compared the redistribution of patients who historically accessed emergency care from Bellevue versus NYULMC. We then analyzed these patterns on the basis of the ownership of the surrounding hospitals and by the distance that patients traveled to access the facilities that remained open. Finally, we discuss the implications of our findings for disaster response when hospital closures complicate events like Hurricane Sandy.

METHODS

Study Design and Setting

Our study was a retrospective observational cohort study that analyzed ED use in New York City (NYC) before and after Hurricane Sandy. We used the

Statewide Planning and Research Cooperative System (SPARCS), an all-payer administrative claims database created by the New York State Department of Health (NYS DOH) that includes emergency visits at all NYS hospitals.¹¹ We excluded specialty hospitals with EDs that served specific patient populations (ie, cancer, orthopedic, psychiatric, veterans hospitals). In this database, we identified patients who had visited the ED at Bellevue or NYULMC prior to Hurricane Sandy and determined where they went for emergency care after the storm. Our study protocol was approved by the Data Protection Review Board at the NYS DOH and by the institutional review board at the University of Pennsylvania.

Selection of Participants

To track how the behavior of patients changed when these hospitals closed, we followed a group of patients with an established baseline pattern for accessing emergency care. We identified those ED users who had visited the ED at Bellevue or at NYULMC exclusively prior to the storm by using unique identifiers to identify visits among hospitals by the same patient. We designated a user of a specific ED as an individual who went to only one of these closed EDs and at least twice in the 5 years before Hurricane Sandy. We selected this narrowly defined cohort of ED users at Bellevue or NYULMC to ensure that our sample included patients with a demonstrated preference for a given ED.

Primary Outcome

The primary outcome of our study was the redistribution of these 2 patient cohorts to the nearby hospitals that remained open. We identified whether a patient, who historically had visited NYULMC or Bellevue before Hurricane Sandy, went elsewhere for emergency care after the storm. We calculated the proportion of these redistributed patients that the other NYC EDs received after Hurricane Sandy on October 30th, 2012, and prior to the reopening of a 911-receiving, free-standing ED at Bellevue on December 24th, 2012.⁷

Other Measures

Patient Characteristics

To determine the demographic and socioeconomic characteristics of the patients in our cohorts, we analyzed the patient characteristics available in our dataset. These included patient age, gender, race/ethnicity, and type of health insurance. We compared these characteristics between NYULMC and Bellevue to identify significant differences.

Distances Between Patients and Hospitals

To determine the distances between individual patients and the hospitals they visited, we geocoded patient and hospital addresses by using ArcGIS Desktop Version 10.1 (Environmental Systems Resource Institute, Redlands, CA). We calculated the distance between patients and hospital locations by using Manhattan distance, which assumes a grid

layout of city streets. This distance calculation is a reasonable estimate in NYC but would not be exactly equivalent to travel distance in areas that deviated significantly from a grid-like pattern.

Incremental Distance Traveled

To determine whether ED patients affected by closures traveled further for care after Hurricane Sandy, we calculated the incremental distance between patients and the hospitals they visited. To do this, we subtracted the distance between the patient's address and the ED visited after the storm from the distance between the patient's address and the ED at NYULMC or Bellevue. A positive incremental distance meant that the patient had to travel further for ED care; a negative distance meant that the patient lived closer to the ED they visited after the storm.

Distances Between Closed and Open Hospitals

We analyzed how the distance between closed and open hospitals correlated with the proportion of patients who redistributed to nearby EDs after the storm. We calculated distances between hospitals again by using Manhattan distance and then analyzed how proximity predicted the proportion of ED patients received by these nearby hospitals.

Size of Hospital Catchments

We mapped the hospital catchments for the EDs at Bellevue and NYULMC before the storm. To do this, we used patient addresses to locate all ED visits by NYC residents to Census tracts. Then, we calculated the share of ED visits by Census tract that went to each of the EDs at Bellevue and NYULMC in the 5 years before the storm to identify the geographic neighborhoods that these EDs had generally served. These hospital catchments provided context for the locations of the hospitals that received the highest proportion of redistributed ED patients.

Statistical Analysis

To compare the cohorts of ED users who were redistributed from the EDs that closed at Bellevue and NYULMC, *t*-tests were used for continuous variables (age), and Fisher's exact test was used for categorical variables (gender, race, and insurance status) to identify significant differences in the patient characteristics from the 2 hospitals. A *p*-value of <0.0125 was considered significant to adjust for multiple comparisons.

To determine whether our patient cohorts had to travel further for ED care after the storm, we calculated median incremental distances for the overall cohort and the hospitals that received the most redistributed patients. We used a nonparametric, binomial exact method to determine 95% confidence intervals for these medians and also calculated the proportion of ED patients who had to travel farther for care after the storm.

We also compared the redistribution of ED patients by hospital to the proximity of these open hospitals to Bellevue and

NYULMC. As hypothesized in prior studies, we believed that this relationship between distance and proportion of redistributed patients would be nonlinear.¹² Thus, we performed a locally weighted regression by using a bandwidth of 80% to determine how the proximity of nearby hospitals predicted the proportion of redistributed ED patients that they had received. Finally, we evaluated whether the hospital ownership (public or private) affected whether these hospitals received more or fewer redistributed ED patients on the basis of the predictions of the locally weighted regression.

Sensitivity Analysis

To test our method for identifying ED patients with an established preference for care at Bellevue or NYULMC, we performed a sensitivity analysis on the number of times that a patient had to have only visited Bellevue or NYU in the 5-year period prior to the storm. We analyzed changing the cutoff to 1 or 3 prior visits to determine whether this frequency had an impact on the study results. We assessed this factor because an individual who visited Bellevue or NYULMC only 2 times in the 5 years prior might not have considered that institution their primary source of hospital-based emergency care.

Statistical analyses were performed in Stata 12.1 (StataCorp, College Station, TX).

RESULTS

Characteristics of the Study Subjects

We identified 51,019 unique ED patients who had exclusively visited the ED at NYULMC with at least 2 ED visits in the 5-year pre-hurricane period. The overwhelming majority of these patients lived in Manhattan. Of these patients, we identified 469

who redistributed to nearby EDs in the 2-month period after the storm closed NYULMC. We identified 127,624 unique ED patients who had exclusively visited the ED at Bellevue with at least 2 ED visits in the pre-hurricane period. We found that a significant proportion of these patients lived in areas outside of Manhattan. Of these patients, we identified 1143 who redistributed to nearby EDs after the storm closed Bellevue.

Comparing patients redistributed from NYULMC and Bellevue after Hurricane Sandy, we found that patients at NYULMC, the private hospital, were more likely to be older, white, and privately insured or to have Medicare compared with patients at Bellevue, the public hospital, who were more likely to be younger, minority, and insured by Medicaid or uninsured (Table 1).

Redistribution of ED Users

We mapped the redistribution of ED patients from NYULMC and Bellevue relative to their hospital catchments prior to the storm to explore where our cohort of patients went for ED care after the storm. Figure 1A depicts hospitals that received the highest proportions of the cohort of ED patients redistributed from NYULMC. The ED catchment for NYULMC was primarily focused in Manhattan, with only small pockets of patients living in other parts of NYC. Beth Israel Medical Center (Beth Israel), the nearest hospital, saw the highest proportion of these redistributed NYULMC ED patients at 32%. Most of the other NYULMC ED patients were distributed to other nearby hospitals in Manhattan.

In comparison, the overall hospital catchment for Bellevue’s ED was more widely distributed, with many patients living outside of Manhattan in other parts of NYC including

TABLE 1

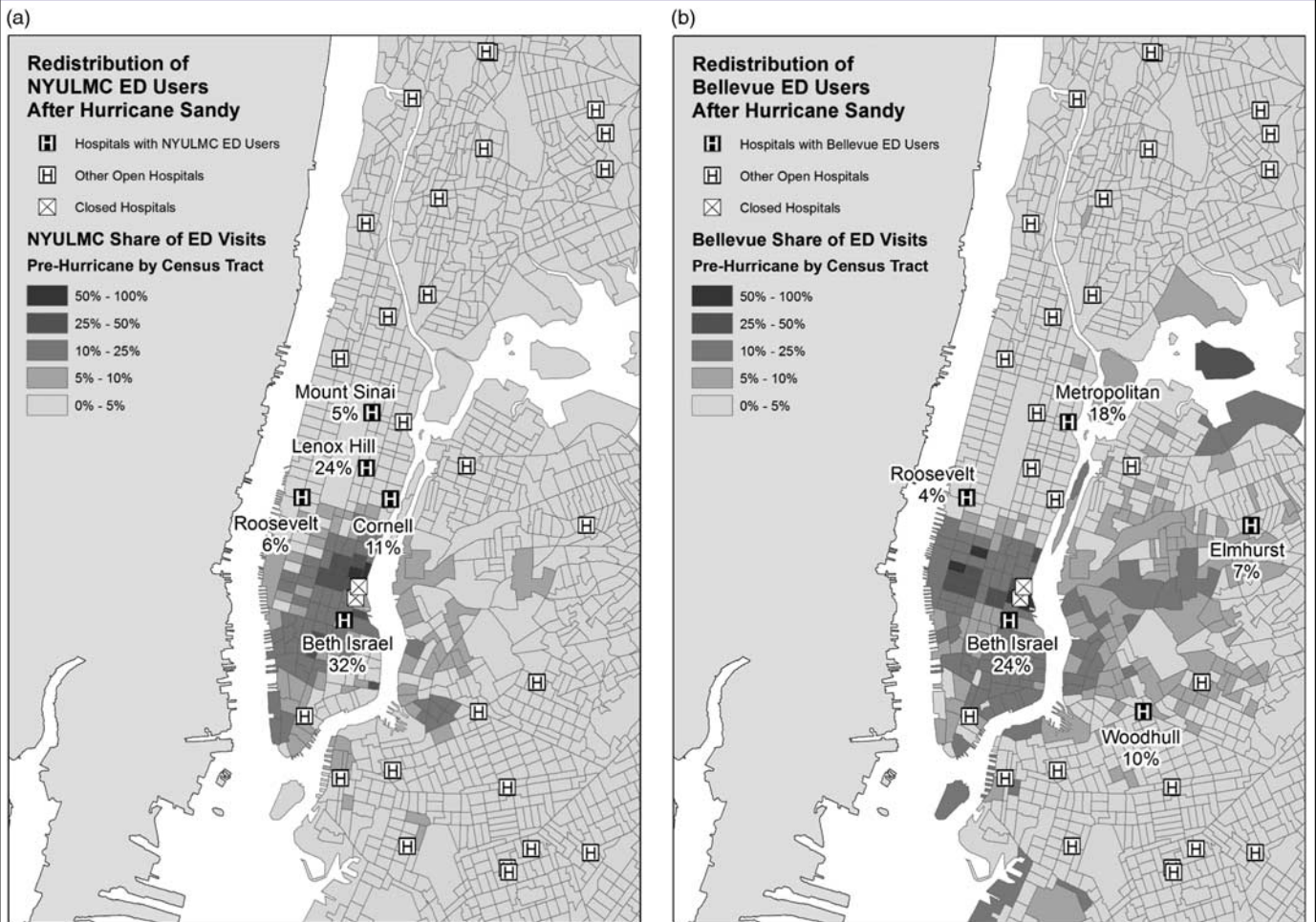
Characteristics of ED Patients at NYULMC Versus Bellevue^a

Patient Characteristics	NYU Langone Medical Center	Bellevue Hospital Center	P Value for Significant Difference
Number of Patients Redistributed From Closed ED after Hurricane Sandy	469	1143	
Age, y	63.9	38.0	<i>p</i> < 0.001
Gender, %			
Male	45.0	47.8	<i>p</i> = 0.42
Female	55.0	52.2	
Race/Ethnicity, %			
White	71.2	16.8	<i>p</i> < 0.001
Black	9.5	25.7	
Hispanic	9.2	43.2	
Other	10.1	14.3	
Insurance Type, %			
Private	45.8	7.4	<i>p</i> < 0.001
Medicare	49.4	12.7	
Medicaid	2.0	42.6	
Self-pay	2.8	37.2	

^aAbbreviations: ED, emergency department; NYULMC, New York University Langone Medical Center.

FIGURE 1

Redistribution of (A) NYULMC ED and (B) Bellevue ED Users after Hurricane Sandy.



Abbreviations: Beth Israel, Beth Israel Medical Center; Cornell, Weill-Cornell Medical Center; ED, emergency department; Elmhurst, Elmhurst Hospital Center; Lenox Hill, Lenox Hill Hospital; Metropolitan, Metropolitan Hospital Center; Mount Sinai, Mount Sinai Medical Center; NYULMC, New York University Langone Medical Center; Roosevelt, Roosevelt Hospital; Woodhull, Woodhull Medical Center.

Queens and Brooklyn (Figure 1B). Beth Israel, a private hospital, again saw the highest proportion of redistributed ED patients from Bellevue at 24%. But this proportion was much lower than the percentage of patients who had redistributed from NYULMC to Beth Israel. The rest of the Bellevue ED patients often went to other public hospitals (ie, Metropolitan Hospital Center, Elmhurst Hospital Center, and Woodhull Medical Center), rather than to other private hospitals that were nearer to Bellevue.

Incremental Distance Traveled

We also compared the incremental distance traveled by our cohort of redistributed ED patients to determine if they had to travel farther for emergency care after the storm (Table 2). For patients at NYULMC, we found that for the entire cohort of patients going to other NYC hospitals, the median

incremental distance traveled was not significantly changed. When evaluating the closest hospital option, we found that redistributed patients at Beth Israel did not have to travel farther for care. However, for patients who went to some hospitals located farther away (ie, Lenox Hill Hospital and Weill-Cornell Medical Center), a higher proportion had to travel significantly longer distances to access emergency care.

In comparison, when we analyzed patients who redistributed from Bellevue, we found that a majority of patients (70%) actually lived closer to the ED where they accessed emergency care after the storm. For hospitals located farther away from Bellevue outside of Manhattan in other parts of NYC, patients lived significantly closer to the ED where they went for care after the storm. The only hospital that received more patients who had to travel significantly farther for care was Metropolitan Hospital (64%), the nearest public hospital in Manhattan.

TABLE 2

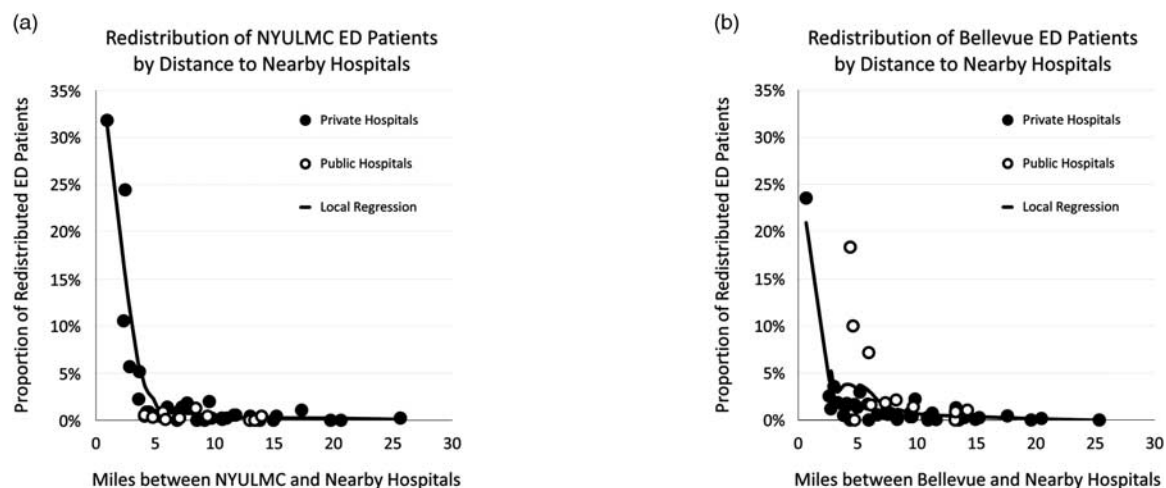
Incremental Distance Traveled by Patients Redistributed from Closed Hospitals for ED Care^a

Hospitals Visited by Redistributed ED Patients (miles from closed hospital)	Hospital Ownership	Percentage of Redistributed ED Users, %	Median Incremental Distance to ED, miles	95% Confidence Interval for the Median, miles	Percentage of ED Users Farther from ED, %
Redistribution from NYU Langone Medical Center					
All New York City Hospitals	Varies	100	-0.2	-0.4 to +0.2	46
Beth Israel Medical Center (0.9 miles)	Private	32	-0.4	-0.4 to -0.2	35
Lenox Hill Hospital (2.5 miles)	Private	24	+2.2	+1.6 to +2.2	73
Weill-Cornell Medical Center (2.3 miles)	Private	11	+1.1	+0.5 to +1.7	69
Roosevelt Hospital (2.9 miles)	Private	6	+0.6	-1.1 to +1.4	54
Mount Sinai Medical Center (3.7 miles)	Private	5	+2.9	-3.1 to 3.7	58
All Other Hospitals	Varies	Each ≤ 3 (Total of 22)	-4.6	-6.0 to -3.6	21
Redistribution from Bellevue Hospital Center					
All New York City Hospitals	Varies	100	-1.0	-1.4 to -0.7	30
Beth Israel Medical Center (0.7 miles)	Private	24	-0.2	-0.2 to -0.2	28
Metropolitan Hospital Center (4.4 miles)	Public	18	+2.5	+1.9 to +2.5	64
Woodhull Medical Center (4.6 miles)	Public	10	-3.7	-3.8 to -3.2	11
Elmhurst Hospital Center (5.9 miles)	Public	7	-4.4	-5.1 to -3.6	5
Roosevelt Hospital (3.0 miles)	Private	4	+0.6	-0.9 to +0.9	57
All Other Hospitals	Varies	Each ≤ 3 (Total of 37)	-4.5	-4.9 to -4.1	21

^aAbbreviations: ED, emergency department; NYULMC, New York University Langone Medical Center.

FIGURE 2

Locally Weighted Regression Between Distance to Nearby Hospitals and the Proportion of Redistributed ED Patients From NYULMC Versus Bellevue.



Abbreviations: ED, emergency department; NYULMC, New York University Langone Medical Center.

Redistribution by Hospital Proximity

Using locally weighted regression, we identified the correlation between the proportion of patients who redistributed from closed to open EDs and the proximity of these open hospitals to NYULMC and Bellevue (Figure 2). In both of these distributions, we found that there was an exponential decay in the proportion of redistributed ED patients and the

proximity of the hospitals that remained open. However, for Bellevue, there were 3 significant outliers to the locally weighted regression, which were all public hospitals that received more patients than expected by the regression. In comparison, the redistribution of ED patients from NYULMC more closely followed the locally weighted regression, and proximity predicted the proportion of patients who

redistributed from NYULMC to the nearby hospitals that remained open.

Sensitivity Analysis

In our sensitivity analysis, we used more strict and more relaxed inclusion criteria for the number of prior ED visits that patients had to have at each of the facilities prior to the storm. We did not find that changing the number of prior visits to 1 or 3 had a material effect on our study results. These changes had minor effects on the number of patients identified in the patient cohorts, and we found small differences in the absolute proportion of patients who redistributed to nearby hospitals. However, the overall trends we found were unchanged.

DISCUSSION

Public health response to disasters must be shaped in a way that considers the differential access to care that exists in the United States.¹³ Broad generalizations about how to respond to medical needs during a disaster may not be appropriate for all types of patients, and specific interventions may be required to target particularly vulnerable populations.¹⁴ We demonstrate that patient responses to hospital closures during disasters are significantly influenced by socioeconomic factors, especially insurance status.¹⁵ These findings suggest that public health responses to events such as Hurricane Sandy must be tailored for the populations most at risk.¹⁶

In the past, more permanent hospital closures were typically small hospitals or in regions where there was an oversupply of hospital beds.^{17,18} However, more recent hospital closures have increasingly included large hospitals with high occupancy rates.^{19,20} Continuation of these trends risks a health care system with little excess capacity or reserve to handle surges in hospital utilization associated with novel infections or disasters.^{21,22} Hospitals with high proportions of Medicaid and uninsured patients experience hospital closures more frequently.¹ Thus, populations with lower socioeconomic status are especially prone to worsening of their already decreased access to care and poor outcomes.^{23,24}

When disasters strike, there are similarly subpopulations with different risk profiles for losing access to their medical care.²⁵ As Hurricane Katrina demonstrated, populations with the worst access to care at baseline were particularly afflicted.¹⁵ When disasters disrupt the existing infrastructure of the health care system, the underlying vulnerabilities of the system are revealed.^{26,27} During a disaster, even temporary hospital closures add significant additional strain to the system. Thus, methods by which to identify those patients who will have difficulty in meeting their medical needs after an event such as Hurricane Sandy are critical.²⁸

Our study showed how patients with an established baseline of seeking emergency care at a public versus a private hospital redistributed to nearby hospitals that remained open after

their usual place of care was temporarily closed. We found that proximity of nearby open hospitals was a very strong predictor for this redistribution of patients, and we demonstrated the shape of this relationship through our regression analysis. However, we also found that ED patients from the public hospital also preferentially accessed nearby open public hospitals even if they were located farther away than other private hospitals that remained open.

We investigated these findings by analyzing the incremental distance traveled by patients after a hospital closure and found that most patients traveling to the nearest hospital actually did not have to travel further for care. However, from prior studies, we found that the closest ED to the hospitals that closed (Beth Israel) was limited in its capacity to serve the overwhelming needs of displaced patients, and some of those patients who were not able to receive care at the nearest facility were forced to travel further for care.^{7,29}

Patients with private insurance went to nearby EDs in proportions predicted by the proximity of the open EDs to their address of residence. However, a significant number of public patients who did not go to the closest ED preferentially accessed other public hospitals, thus bypassing closer private hospitals. On the basis of a subgroup analysis, we found that there were 2 different types of patients who went to Bellevue for emergency care: those who lived near the public hospital in the first place and those who even before the storm traveled from outside of Manhattan to access care at Bellevue, the public hospital.

Why this second group of patients traveled further for care before the storm is unclear. However, it may have been for convenience (ie, located closer to work or where they developed their injury or illness) or personal preference, or they may have traveled further for the care at Bellevue for specialty surgical, medical, or psychiatric services not offered at other public facilities in NYC.²⁸

Upon the closure of the public hospital, proximity to nearby hospitals was still a strong predictor of how patients redistributed, but a significant proportion of the patients of the public hospital went to their closest public hospital instead of closer private hospitals. For those living far from Bellevue initially and outside of Manhattan, this pattern surprisingly meant shorter distances traveling to the nearest available public hospital.

For the majority of public hospital patients who lived in Manhattan and close to Bellevue initially (Table 3), the closure of Bellevue meant either going to the closest hospital at Beth Israel (48%) or the nearest public hospital in Manhattan (19%). Although the public transportation network had been temporarily compromised after the storm, some publicly insured patients in Manhattan still traveled further

TABLE 3

Incremental Distance Traveled by Manhattan Bellevue Patients for ED Care^a

Hospitals Visited by Redistributed ED Patients (miles from Bellevue)	Hospital Ownership	Redistribution from Bellevue Hospital Center for Manhattan Residents Only			
		Percentage of Redistributed ED Patients, %	Median Incremental Distance to ED, miles	95% Confidence Interval for the Median, miles	Percentage of ED Users Farther from ED, %
All New York City Hospitals	Varies	100	-0.2	-0.2 to -0.0	45
Beth Israel Medical Center (0.7 miles)	Private	48	-0.2	-0.2 to -0.2	32
Metropolitan Hospital Center (4.4 miles)	Public	19	+3.7	+1.6 to +4.0	66
Roosevelt Hospital (3.0 miles)	Private	7	+0.3	-1.1 to +0.9	52
Weill-Cornell Medical Center (2.6 miles)	Private	4	+2.3	+1.2 to +2.5	83
New York Downtown Hospital (3.3 miles)	Private	3	-1.0	-1.9 to +0.3	28
All Other Hospitals	Varies	Each ≤3 (Total of 19)	-0.8	-2.8 to +2.6	47

^aAbbreviation: ED, emergency department.

to access care at public facilities despite the presence of private hospitals that were closer. For patients in NYC, the number of available public hospitals at least meant that there were still options for care at public facilities even after Bellevue closed. In regions where public hospitals are few, the closure of a public hospital may have more significant consequences for those who regularly access care at public facilities.

Policy Implications

To bolster public health response to disasters complicated by hospital closures, our study has several implications.^{30,31} First, we demonstrate that the redistribution of patients from closed hospitals, at least acutely, follows a predictable pattern based on the proximity of nearby hospitals.^{32,33} These findings can give critical insight as to where surges in patient volume will occur and can guide state and federal agencies in augmenting surge capacity after hospital closures or disasters.³⁴

Additionally, we demonstrate that patient redistribution secondarily depends on the types of hospitals and patients involved.³⁵ This finding should inform the creation of hospital networks and health care coalitions that can share data before and after a storm,³⁶ because continuity of care depends on reliable access to medical records especially after a disaster or hospital closure.^{37,38}

Finally, directing an appropriate response to the medical needs that arise during a public health emergency requires an advance understanding of the medical needs that exist within communities of different socioeconomic backgrounds in order to optimally match resources to the specific needs of populations affected by disasters.³⁹ Our study demonstrates how hospital catchments can help to predict how and where patients will redistribute for emergency care after events that result in the loss of their usual source for hospital-based care.

Limitations

Our study was a retrospective observational cohort study, and these associations do not imply causation. Additionally, our study only analyzed those patients who were able to access emergency care after the storm; however, some individuals may have been unable to access emergency care during the disaster. Although our study analyzed the impact of the closure of 2 geographically proximate public and private hospitals, the study's uniqueness limits generalizability of the study findings, because some regions of the country do not have public hospital systems. Also, our study was located in NYC, which is a unique and dense urban environment, and the characteristics of ED use in NYC may not be generalizable to hospital closures in other regions.

Our study used patient-level addresses to locate patients by using geographic information systems. Thus, our study was limited, because patient home addresses may not be the same location as where a patient decided to go the ED or activate 911; ie, injury or illness may have developed away from the home. For example, Manhattan's commuters substantially increase its population during the workday. However, prior studies of ED utilization have shown that the home address can be used to create a reasonable estimate of distance traveled to the hospital.⁴⁰ In aggregate, we believe our analysis at least provides the general direction of trends, even if the exact magnitude of the distance may not be correct for any given patient in our study.

CONCLUSIONS

In our study of a public versus private disaster-related hospital closure, we found that proximity predicted the redistribution of patients to nearby open hospitals and that hospital catchments can be used to inform how patients will respond to changes in health care access during disasters. These findings have important policy implications in helping to predict where surges in patient volume will occur and to identify patient populations at risk when disaster-related hospital closures occur.

However, we also found that this redistribution of patients was also strongly influenced by hospital ownership, because Bellevue's patients redistributed to other public hospitals at rates higher than expected by proximity alone. This differential response to hospital closures demonstrates significant differences in how public and private patients respond to changes in health care access. Thus, public health response to disasters must consider these sharp divisions in how different populations access health care in order to effectively meet the needs of all types of patients affected by disasters and other public health emergencies.

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