ORIGINAL RESEARCH

Effect of Hurricane Sandy on Health Care Services Utilization Under Medicaid

Mark J. Sharp, PhD; Mingzeng Sun, PhD; Tatiana Ledneva, MS; Ursula Lauper, MA, MPH; Cristian Pantea, MS; Shao Lin, MD, PhD

ABSTRACT

Objective: This investigation assessed changes in utilization of inpatient, outpatient, emergency department, and pharmacy services in the aftermath of Hurricane Sandy in 8 counties in New York affected by the storm.

Methods: Medicaid data for enrollees residing in 8 counties in New York were used to obtain aggregated daily counts of claims for 4 service types over immediate, 3-month, and 1-year periods following the storm. Negative binomial regression was used to compare service utilization in the storm year with the 2 prior years, within areas differentially affected by the storm.

Results: Changes in service utilization within areas inside or outside the storm zone were most pronounced over the 1-year effect period. Differences in service utilization by year were the same by storm zone designation over the immediate effect period for all services.

Conclusions: Results are consistent with previous investigations demonstrating that some of the greatest effects of a disaster on health services utilization occur well beyond the initial event. One-year effects, combined with some 3-month effects, suggests that storm recovery, with its effect on health care services utilization, may have followed different paths in areas designated as inside or outside the storm zone. (*Disaster Med Public Health Preparedness*. 2016;10:472-484)

Key Words: Hurricane Sandy, Medicaid, health care services utilization

Hurricane Sandy was the largest storm ever to affect the northeastern United States, making landfall in the New York Metropolitan Area on October 29, 2012, causing widespread flooding, wind damage, power outages, and disruption in the transportation infrastructure. It was estimated that in New York, 305,000 homes were destroyed largely due to the storm surge, with the cost in damage to New York City (NYC) totaling $19 billion.[1] As many as 10% of people residing in flooded areas sustained injuries over the week following Sandy,[2] and the death toll has been estimated at 117, with 53 deaths in the NYC area alone.[3] Relatedly, Hurricane Sandy caused extensive damage to the health care infrastructure in the region, resulting in the evacuation and closure of major hospitals, with patients transported to other area hospitals and emergency department (ED) patients seeking treatment at alternative locations, creating a strain in those locations from absorbing the extra patients.[4,5] In light of this storm impact, the present investigation addressed changes in the utilization of health care services in 8 counties in southern New York, which include NYC, after Hurricane Sandy.

Changes in the utilization of health care services resulting from disasters such as Hurricane Sandy are an issue that has received considerable attention. Such changes have been suggested to occur through changes in the demand for services due to the effect on the health of affected persons, as well as in the supply, resulting from damage to the health care infrastructure. Furthermore, disaster exposure may have a more severe effect on certain population subgroups, such as greater increases in the prevalence of disability found among younger and middle-aged black women following Hurricane Katrina.[6] Disaster exposure can also affect demand for health care services through worsening of the health of individuals already compromised by preexisting chronic conditions. Conditions such as heart disease, cancer, stroke, diabetes, and chronic respiratory disorders may be exacerbated by disasters via lack of food and clean water, exposure to extreme heat or cold, physical and mental stress, injury, and exposure to infection.[7] Behavioral health may be affected as well, with one review noting that post-traumatic stress disorder (PTSD) and major depressive disorder can pose significant burden following a disaster, although the impact on substance abuse behavior is less clear.[8] The presence of chronic disease may differentially affect population subgroups with respect to health status following disasters, such as the elderly, people of low

socioeconomic status, and people with mental illness or disabilities, and pregnant women.[7]

Utilization of health services following a disaster such as Hurricane Sandy may be the result of a complex interaction among the pre-disaster health status of the affected population, post-disaster demand for health care services, and disruption of the availability of services following the disaster. Central to this conceptualization is the distinction between primary and secondary surge.[9] Primary surge refers to the demand for services immediately following a disaster resulting from acute injury and illness, including illness from inadequately treated preexisting chronic conditions, which causes a strain on the medical infrastructure of the affected area. This strain on the medical infrastructure leads to the inadequate treatment of acute disorders immediately following the disaster, resulting in many of these disorders becoming long-term conditions, which, in turn, produce a sudden increase in demand for health care long after the disaster event, referred to as a secondary surge. This surge in demand overloads the health care system, decreases the supply of services, and in turn may reduce health care services utilization for an extended period following the initial disaster event. Health disparities prior to a disaster, experienced by vulnerable population subgroups who may be less able to compete for available post-disaster services, may be exacerbated by reduced access to primary care following the disaster.[10]

Both short- and long-term changes in post-disaster health care services utilization have been demonstrated. One investigation documenting short-term effects found that a surge in transient dialysis patients during Hurricane Sandy began in the day before landfall, peaked in the 2 days following, and gradually decreased over the following week.[11] Investigations of post-hurricane ED utilization have found decreases in utilization during the main weather impact, followed by increases within days following the storms.[12,13] Regarding long-term changes in utilization, an increase in overall health care utilization was found over the 3 years following the 2004 Southeast Asian tsunami.[14] Similarly, in comparing primary care utilization before and after a catastrophic fire that occurred in the Netherlands on January 1, 2000, it was found that uninjured victims who witnessed the fire showed increases in the number of family practitioner contacts during the first year after the fire.[15]

The present investigation used New York State Medicaid claims and encounter data to address health care services utilization in the aftermath of Hurricane Sandy in 8 counties in downstate New York that were most affected by the storm. Medicaid enrollees constitute a large, socioeconomically disadvantaged population burdened by chronic conditions such as diabetes, mental illness, and substance abuse, and, as such, may be particularly susceptible to disruptions in the availability of health care resulting from a major disaster such as Hurricane Sandy. Changes resulting from Hurricane Sandy in the utilization of 4 service types were addressed: outpatient, ED, inpatient, and pharmacy. An advantage of using Medicaid claims data is the complete case ascertainment for these service types, given the rigorous verification processes used in New York to ensure data quality and completeness. For each, changes in utilization were assessed in the immediate period following landfall, as well as over periods of 3 months and 1 year after Hurricane Sandy, to examine how such changes may be influenced by temporal distance from the storm.

With the exception of ED services, it was hypothesized that service utilization will be reduced in the storm year compared to the previous 2 years among enrollees residing within the storm zone (ie, the geographic region most affected by the storm), than among those residing outside of the storm zone, given facility closures, disruption in the transportation system, and the vulnerability of the Medicaid population. Consistent with conceptual models describing primary and secondary surges in demand for services, it was expected that such reductions will be greater in the short-term and long-term time frames than in the intermediate time frame. It was expected that ED service utilization would increase in the same time frames, as enrollees may seek these services as alternatives to outpatient services, which would be in shorter supply and thus more difficult to obtain. For comparison to total outpatient, inpatient, and ED services, separate analyses were conducted for each service type among demographic subgroups, and for these services associated with primary diagnoses of diabetes, mental illness, and substance abuse. In the case of pharmacy services, total prescription fills were analyzed, along with those among demographic subgroups, as well those specifically for diabetes medications, and medications to treat mental illness.

METHODS

This project received review and approval by the New York State Department of Health Institutional Review Board with respect to its use of data on human subjects. All Medicaid enrollees, excluding those dually eligible for Medicare, in NYC (Bronx, Kings, New York, Richmond, and Queens), Suffolk, Nassau, and Westchester counties were identified from October 28, 2010, through October 28, 2013, for a total of 4,820,702 enrollees, 86.1% of whom were enrolled in Medicaid managed care. Figure 1 shows the number of enrollees by storm effect period, area (storm-affected or storm-unaffected), and comparison years (storm year vs the previous 2 years). Medicaid claims data for these enrollees were used to obtain aggregated daily counts of claims for outpatient and ED visits, inpatient admissions, and prescriptions filled. Outpatient services included visits for primary care, physician specialists, outpatient drug/alcohol treatment, or outpatient mental health treatment, and claim records were unduplicated by Medicaid ID, service date, provider ID, and primary diagnosis to avoid double-counting. ED services included only those claims not leading to an inpatient hospital admission.

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FIGURE 1

Number of Medicaid Enrollees, and Change From Prior Year, in Hurricane Sandy Study Population by Storm Effect Period, Area, and Storm Effect Comparison Years.

	2010 - 2011 Comparison Year												
	2010			2011									
Area	October	November	December	January	February	March	April	May	June	July	August	September	October
Unaffected	2,240,004												
Storm Affected	787,742												
Unaffected	2,338,946												
Storm Affected	821,291												
Unaffected	2,731,308												
Storm Affected	953,994												
	2011 - 2012 Comparison Year												
	2011			2012									
	October	November	December	January	February	March	April	May	June	July	August	September	October
Unaffected	2,298,978 (+2.63%)												
Storm Affected	799,319 (+1.47%)												
Unaffected	2,401,222 (+2.66%)												
Storm Affected	834,012 (+1.55%)												
Unaffected	2,812,052 (+2.96%)												
Storm Affected	970,401 (+1.72%)												
	Storm Year 2012-2013												
	2012			2013									
	October	November	December	January	February	March	April	May	June	July	August	September	October
Unaffected	2,404,482 (+4.59%)												
Storm Affected	826,209 (+3.36%)												
Unaffected	2,505,341 (+4.34%)												
Storm Affected	859,901 (+3.09%)												
Unaffected	2,894,868 (+2.95%)												
Affected	989,029 (+1.92%)												
	Immediate Storm Effect Period (October 28 - November 9)												
	3-Month Storm Effect Period (October 28 - Jan. 28 of the following year)												
	1 Year Storm Effect Period (October 28 - Oct. 27 of following year)												

ED records with service dates matching an inpatient admission, service, or discharge date or with a service date falling between an inpatient admission and a discharge date were excluded and were unduplicated by Medicaid ID and service date. Claim records for outpatient, ED, and pharmacy prescription fills (excluding durable medical equipment) were identified by using a coding system developed by the New York State Department of Health that employs a logic combining provider specialty codes, UB-04 revenue codes,[16] Common Procedural Terminology (CPT)[17] and Healthcare Common Procedure Coding System (HCPCS)[18] procedure codes, and International Classification of Diseases, 9th revision, Clinical Modification (ICD-9-CM) diagnosis codes. Inpatient services, the claims for which were identified by using codes derived from claim type and provider category of service, include all hospital admissions. Inpatient records were unduplicated by Medicaid ID, admission and discharge dates, patient status, and provider ID, with earliest admission date, latest discharge date, and most recent diagnosis retained for claims with overlapping admission and discharge dates.

Within each service category, total daily counts of service claims were determined, as well as separate counts for services associated with a primary diagnosis of diabetes, mental illness, or substance abuse, as documented on the claim. Counts of prescription fills were also determined in total and separately

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for medications to treat diabetes and mental illness. Given the more limited pharmaceutical treatments specifically for substance abuse, prescription fills associated with this condition were not counted separately. Medications to treat mental illness included all medications documented in the Medicaid pharmacy database classified as typical or atypical antipsychotics, miscellaneous antipsychotics, monoamine oxidase inhibitor antidepressants, selective serotonin reuptake inhibitors, serotonin-norepinephrine reuptake inhibitors, benzodiazepine anxiolytics, tricyclic antidepressants, or antidepressants not otherwise classified. Additional medications included those identified by the National Institute of Mental Health to treat anxiety disorders, bipolar/mood disorders, and attention deficit hyperactivity disorder.[19] Drugs to treat diabetes were identified through use of a drug directory specifying medications used to treat diabetes.

Immediate, 3-month, and 1-year storm effect periods were defined on the basis of a storm date of October 28, 2012. For the storm year, the immediate effect period was defined as October 28, 2012, to November 9, 2012; the 3-month effect period as October 28, 2012, to January 28, 2013; and the 1-year effect period as October 28, 2012, to October 27, 2013. To serve as controls, these time periods were defined for the 2 years before the storm year, anchored by the dates of October 28, 2010, and October 28, 2011. Analyses of daily service counts were conducted separately for each effect period by using the service date documented on the claims to determine effect period and storm year/control.

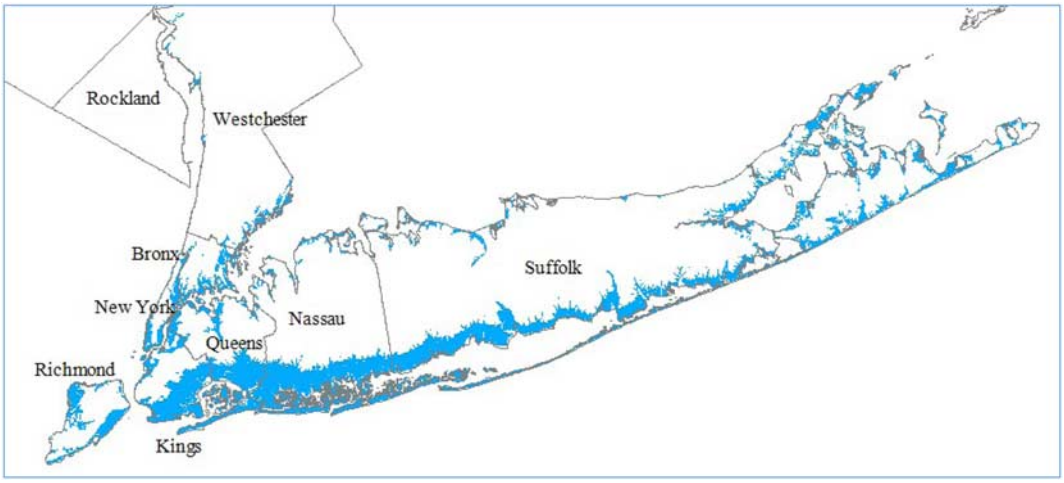
Storm zone, the area most affected by the storm surge, was determined on the basis of National Oceanic and Atmospheric Administration (NOAA) Sea, Lake and Overland Surge from Hurricanes (SLOSH)[20] model projections of vertical surge heights associated with the Saffir-Simpson scale of category 1 to 4 storms. Surge heights are associated with terrain elevation to delineate inundation zones for hurricane category 1 to 4 storms. Multiple storm landfall locations have been factored to produce a worst case flooding for any given area. Northwest direction storms with landfall at high tide are used as these storms produce the highest surge in this region. Figure 2 shows a map of the region, with the shaded areas designated as the storm zone.

For each effect period, service counts were compared on the basis of recipient residence inside or outside the storm zone, using geocoded addresses contained in the Medicaid enrollment data. Given that recipient addresses are subject to change, this determination was based on the address at which a recipient was living on the date the service was received.

Negative binomial regression, with generalized estimating equations (GEEs) to accommodate potentially correlated daily count data, was used as the analytic approach using the GENMOD procedure in SAS, version 9.4 (SAS Institute Inc., Cary, NC). This analysis was chosen given the use of service counts as dependent variables, combined with its ability to account for overdispersion, in contrast to Poisson regression.[21] Poisson regression was, however, used in the analysis of 2 models where negative binomial analysis failed to converge on a solution. County was specified as the cluster variable given the anticipated lack of independence of daily Medicaid service utilization within counties. The exchange covariance structure was specified in the analysis on the assumption that the service counts between days within a county will be evenly correlated regardless of temporal distance. With daily counts as the outcome variable, and total number of eligible Medicaid enrollees as the offset variable,

FIGURE 2

Map of 8 Counties in Downstate New York Affected by Hurricane Sandy*.



*Shaded areas correspond to the storm zone.

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the key predictor variables in the models were geographic storm zone designation (inside or outside of the storm zone) and year (storm year vs the aggregated previous 2 years), along with a storm zone by year interaction term, the term of particular interest and predicted to be significant in all models. Analysis controlled for day of the week and temporal trend, represented as years 2010, 2011, or 2012, over the 3 years of the study period.

Models were analyzed separately for counts of all services of each type and for each effect period (immediate, 3-month, and 1-year). Separate models for each service type within each effect period were also analyzed for counts of services among Medicaid enrollees with primary diagnoses of diabetes and mental illness. Additionally, overall daily service counts for inpatient, outpatient, ED, and pharmacy prescription fills were conducted separately for demographic subgroups by age group (<19, 19-44, 45-64, and ≥65 years), sex, and race (non-Hispanic white, non-Hispanic black, Hispanic, other race/ethnicity), again, within each effect period. In total, 165 models were analyzed. To control the increased likelihood of Type I error that results from testing multiple hypotheses, the *P* values associated with the storm zone by year interaction terms were evaluated for significance at a false discovery rate of 0.05 using the Benjamini and Hochberg procedure,[22,23] ensuring that no more than 5% of those determined to be significant were actually false positives. In models where the GEE parameter estimate for the storm zone by year interaction term was significant after applying this adjustment, analysis of simple effects was conducted to interpret the interactions by comparing differences in service utilization in the storm year to that in control years, within areas designated as inside and outside the storm zone. In light of the fact that interaction terms are subject to misinterpretation in nonlinear models, examination of this differential change by storm zone designation enables a clearer assessment of the effect of the storm on services utilization.[24]

RESULTS

The number of Medicaid enrollees residing inside the storm zone over the immediate storm effect period in 2012, the storm year, was 826,209. Of these, 54.8% were female. With respect to age, 40.6% were 18 years of age or younger, 57.6% were between 19 and 64, and 1.8% were 65 years of age or older. Non-Hispanic whites accounted for 18.2% of this cohort, Non-Hispanic blacks 26.3%, and Hispanics 27.8%, with the remaining 27.7% of some other race/ethnicity. This demographic profile was relatively stable over time, as well as by residence inside or outside the storm zone.

To show service utilization levels, mean daily rates of services received, overall and for services associated with primary diagnoses of diabetes, substance abuse, and all mental illness, by year and storm zone designation, are presented in Table 1. As would be expected, outpatient and pharmacy showed the highest levels of utilization, and ED services the lowest, with generally more variation by year than by storm-affected or unaffected area.

From the negative binomial regression analyses, the analyses of simple effects associated with significant GEE parameter estimates for model interaction terms were of central importance to assess differences in service utilization by year (storm year vs previous 2 years) within areas designated as inside or outside the storm zone. The hypothesis was that service utilization levels would be lower in the storm year inside the storm zone but would not differ significantly by year outside the storm zone. While differential change in utilization by storm zone designation was observed for some models for the 3-month and 1-year effect periods, this was not observed for any service types, neither in total nor for demographic and diagnostic subgroups, for the immediate effect period. In other words, any observed differences in service utilization by year were the same inside and outside the storm zone over the latter period. Tables 2 through 4 show the GEE parameter estimates for models with significant interaction terms, along with the risk ratios (exponentiated least squares mean differences) and associated confidence limits resulting from analysis of simple effects, for inpatient, outpatient and ED, and pharmacy utilization, respectively. Parameter estimates for all other models are shown in the online data supplement.

With respect to inpatient utilization (Table 2), changes in the storm year compared to the previous 2 years show differences by storm zone designation for over the 1-year effect period for all inpatient services, for males, females, those aged 45-64 years, those with diagnoses of substance abuse, and for Medicaid enrollees of Hispanic ethnicity. In each instance, risk ratios reflect significant reduction of inpatient utilization outside the storm zone, but no change inside the storm zone, except for lesser but significant reductions among males and those with substance abuse residing inside the storm zone. Changes in inpatient utilization over the 3-month effect period within storm zone designation were found among Medicaid enrollees aged 45-64 years, with analysis of simple effects showing an increase in inpatient utilization for this group during the storm year inside the storm zone and a reduction during the storm year outside the storm zone.

As shown in Table 3, differential changes in outpatient utilization by time within storm zone designation were found over the 1-year effect period among Medicaid enrollees with mental illness, females, males, and those aged 45-64 years. Among those with mental illness, aged 45-64 years, and males, reductions in inpatient utilization were observed during the storm year both inside and outside the storm zone, but to a greater extent inside the storm zone. Among females, a greater reduction outside the storm zone was observed. Over the 3-month effect period for those with mental illness and diabetes, outpatient services utilization was reduced during

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TABLE 1

Mean Daily Events Per 100,000 Medicaid Recipients of Inpatient, Outpatient, Emergency Department, and Pharmacy Services by Type of Service, Diabetes, Substance Abuse, or Mental Health Primary Diagnosis, Storm Zone, and Year[a]

	Immediate Storm Effect: Oct. 28 – Nov. 9														
Area and Year	All Diagnoses				Diabetes				Substance Abuse			Mental Health			
Non-Storm Zone	INPT	OUTPT	ED	PHARM	INPT	OUTPT	ED	PHARM	INPT	OUTPT	ED	INPT	OUTPT	ED	PHARM
2010	55.9	5512.0	140.6	3877.4	0.8	123.7	0.7	105.3	7.8	383.2	6.0	4.3	376.6	4.2	339.2
2011	53.6	5559.7	142.1	3989.7	0.8	125.4	0.6	114.2	7.4	525.2	6.0	4.2	375.8	3.7	349.9
2012	48.3	4296.9	126.6	3748.7	0.7	95.6	0.8	129.0	5.7	435.4	6.5	3.5	243.4	3.6	327.4
Storm Zone															
2010	57.0	5876.7	141.9	4033.5	0.9	147.7	0.9	115.3	8.1	423.8	6.7	5.0	451.0	4.5	386.7
2011	53.1	5944.7	144.1	4122.3	1.0	146.8	0.9	127.1	7.8	595.9	6.7	4.7	454.5	4.1	387.8
2012	49.3	4085.0	129.5	3588.9	0.9	94.1	1.1	133.0	6.2	468.2	7.0	4.5	258.7	4.1	348.7
	3-Month Storm Effect: Oct. 28 - Jan. 28														
	All Services				Diabetes				Substance Abuse			Mental Health			
Non- Storm Zone	INPT	OUTPT	ED	PHARM	INPT	OUTPT	ED	PHARM	INPT	OUTPT	ED	INPT	OUTPT	ED	PHARM
2010	55.0	5223.2	154.1	3909.6	0.8	114.8	0.7	105.5	7.3	389.2	6.1	3.9	346.4	3.8	340.2
2011	53.3	5429.7	152.4	4037.1	0.8	121.1	0.7	118.2	6.9	529.4	6.1	4.0	357.3	3.8	352.9
2012	48.9	5235.7	155.3	4152.8	0.8	115.4	0.7	130.9	5.7	524.3	6.2	3.5	292.8	3.8	346.0
Storm Zone															
2010	54.2	5571.5	151.7	4064.8	0.8	137.8	0.9	117.1	7.4	438.5	6.7	4.3	414.8	4.1	387.6
2011	53.0	5779.5	152.6	4170.8	0.9	141.7	1.0	130.4	7.6	598.7	7.0	4.7	432.1	4.2	397.6
2012	49.5	5363.0	154.7	4175.9	0.9	122.8	0.9	138.2	6.4	594.0	6.5	4.1	333.2	4.2	381.7
	1-Year Storm Effect: Oct. 28 - Oct. 27														
	All Services				Diabetes				Substance Abuse			Mental Health			
Non- Storm Zone	INPT	OUTPT	ED	PHARM	INPT	OUTPT	ED	PHARM	INPT	OUTPT	ED	INPT	OUTPT	ED	PHARM
2010	54.1	5496.5	152.5	3937.0	0.8	123.7	0.8	107.5	7.4	461.6	6.4	4.0	366.3	4.2	348.9
2011	53.2	5688.1	152.9	4137.4	0.8	127.0	0.8	125.9	6.9	570.3	6.5	4.1	361.8	3.9	358.4
2012	49.4	5583.7	151.5	4203.5	0.8	123.1	0.7	134.5	6.0	576.8	6.6	3.8	316.3	3.9	356.8
Storm Zone															
2010	53.9	5840.2	152.0	4101.5	0.9	146.7	1.0	120.4	7.9	523.6	7.2	4.6	439.0	4.3	397.0
2011	53.5	5979.2	154.6	4253.0	0.9	143.2	1.0	136.8	7.8	641.1	7.0	4.7	426.2	4.3	402.1
2012	50.6	5807.5	153.2	4266.2	0.9	133.6	1.0	143.3	6.9	663.6	7.1	4.4	364.8	4.5	397.5

[a]Abbreviations: INPT, inpatients; OUTPT, outpatients; ED, emergency department; PHARM, pharmacy.

the storm year both inside and outside the storm zone, but with a greater reduction among those inside the storm zone.

Also shown in Table 3, changes in ED utilization were observed between storm year and the previous 2 years within storm zone designation over the 1-year effect period among enrollees with mental illness and for those of other race/ethnicity. Among those with mental illness, ED utilization increased overall during the storm year but to a greater degree among those residing inside the storm zone. Among those of other race/ethnicity, change in utilization by year was not significant within the storm zone but was reduced outside the storm zone. Although the storm zone by year interaction term reached statistical significance among those with substance abuse with respect to ED utilization, analysis of simple effects showed a slight and nonsignificant increase outside the storm zone.

Overall pharmacy utilization (Table 4) was reduced during the storm year over the 1-year effect period, with a greater reduction inside the storm zone. This pattern of change in pharmacy utilization was also observed among both male and female Medicaid enrollees, those with diabetes and with mental illness, those aged 45-64 years, those aged 65 years and older, and those of other race/ethnicity. This pattern was also found for Medicaid enrollees aged 45-64 years over the 3-month effect period.

DISCUSSION

Based on a conceptual model describing the potential of reduced service utilization in the short- and long-terms after a disaster, exacerbated by the prevalence of chronic conditions that may characterize vulnerable, socioeconomically

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TABLE 2

GEE Parameter Estimates and Analysis of Simple Effects for Inpatient Models with Significant Storm Zone by Year Interactions

	1-Year Effect Period												3-Month Effect Period	
	All		Females		Males		Age 45-64 Years		Substance Abuse		Hispanic Ethnicity		Age 45-64 Years	
Covariate	**Estimate**	***P***	**Estimate**	***P***	**Estimate**	***P***	**Estimate**	***P***	**Estimate**	***P***	**Estimate**	***P***	**Estimate**	***P***
Intercept	74.1506	<0.0001	72.0185	<0.0001	41.6372	<0.0001	62.4737	<0.0001	106.4234	<0.0001	76.085	<0.0001	122.6801	<0.0001
Storm Zone Designation	–0.0076	0.1464	–0.0207	0.0004	0.0336	<0.0001	0.0851	<0.0001	0.0552	<0.0001	–0.0165	0.017	0.0542	0.0002
Years: Storm Year vs. Previous 2 Years	–0.0518	<0.0001	–0.0486	<0.0001	–0.0659	<0.0001	–0.0586	<0.0001	–0.0928	<0.0001	–0.0579	<0.0001	–0.0552	0.0140
Storm Zone by Years	0.0309	<0.0001	0.0408	<0.0001	0.0246	0.0030	0.0579	<0.0001	0.0446	0.0053	0.0399	0.0001	0.0782	0.0003
Day														
Monday	0.0725	<0.0001	0.0825	<0.0001	0.0648	<0.0001	0.0941	<0.0001	0.0528	<0.0001	0.0723	<0.0001	0.1077	<0.0001
Tuesday	0.0470	<0.0001	0.0495	<0.0001	0.0455	<0.0001	0.0463	<0.0001	–0.0017	0.8969	0.0457	<0.0001	0.0640	0.0004
Wednesday	0.0228	0.0003	0.0372	<0.0001	0.0062	0.3677	0.0225	0.0027	–0.0225	0.0792	0.0245	0.0024	0.0370	0.0406
Friday	–0.3541	<0.0001	–0.3633	<0.0001	–0.3285	<0.0001	–0.3871	<0.0001	–0.5522	<0.0001	–0.3353	<0.0001	–0.3742	<0.0001
Saturday	–0.4007	<0.0001	–0.3944	<0.0001	–0.3992	<0.0001	–0.4774	<0.0001	–0.7016	<0.0001	–0.3732	<0.0001	–0.4594	<0.0001
Sunday	0.0568	<0.0001	0.0614	<0.0001	0.0465	<0.0001	0.0755	<0.0001	0.0809	<0.0001	0.0573	<0.0001	0.0853	<0.0001
Year Trend	–0.0405	<0.0001	–0.0395	<0.0001	–0.0244	<0.0001	–0.0345	<0.0001	–0.0577	<0.0001	–0.0415	<0.0001	–0.0645	<0.0001

Analysis of Simple Effects for Interaction Terms in Models Above:

	Storm Zone			Non-Storm Zone		
Model	**Risk[a]**	**95% Confidence Limit**		**Risk[a]**	**95% Confidence Limit**	
Inpatient – 1-Year Effect Period						
All Inpatient Admissions	0.9793	0.9541	1.0053	0.9495	0.9238	0.9759
Females	0.9922	0.965	1.0202	0.9525	0.9396	0.9657
Males	0.9596	0.9343	0.9855	0.9363	0.9066	0.9669
Age 45-64 years	0.9992	0.9785	1.0204	0.9431	0.9258	0.9606
Substance abuse	0.9530	0.9179	0.9895	0.9114	0.8671	0.9580
Hispanic ethnicity	0.9822	0.9443	1.0217	0.9438	0.9166	0.9717
Inpatient – 3-Month Effect Period						
Age 45-64 years	1.0233	1.0019	1.0451	0.9463	0.9064	0.988

[a]Exponentiated least-squared mean differences between storm year and previous 2 years.

disadvantaged populations,[10] it was hypothesized that utilization of outpatient, inpatient, and pharmacy services would be lower, and that ED utilization would be higher during the storm year, as compared to the 2 prior years. Furthermore, these changes would be most pronounced over the immediate and 1-year effect periods (reflecting primary and secondary surges) and among Medicaid enrollees residing inside the storm zone, where the barriers to receiving services would be most severe. These hypotheses were supported in part.

Hurricane Sandy resulted in widespread health care facility closures in the NYC area, including the closure of 40 of the 100 area dialysis centers, some sustaining damage that caused the closure to last for months. The disruption in the public transportation created difficulty for patients to receive care and in some cases created a reliance on health care facilities for the provision of transportation for their patients.[4,5,25] At the same time, demand for health care can be affected by injury and other negative health outcomes resulting directly from disaster exposure, eg, drowning, electrocution, physical trauma, and exposure to secondary hazards such as contaminated drinking water and contact with contaminated floodwater, population displacement and disruption of services, including spread of infections in temporary shelters, mental illness (exacerbation of existing conditions, or new ones, such as PTSD, that arise), and work hazards associated with recovery efforts, such as wounds or sprains, and exposure to indoor dust and mold.[26] The reductions in service utilization during the storm year observed in this investigation, largely over the 1-year effect period, are consistent with secondary surge, resulting from a diminished supply of health care services due to such infrastructure damage and negative health outcomes.

The majority of models, 140 of a total of 165 analyzed, resulted in no significant storm zone by year interaction. In other words, contrary to hypothesis, any differences in services utilization in the storm year as compared to the prior 2 years were the same regardless of whether Medicaid enrollees lived inside or outside of the storm zone. This suggests that, consistent with other studies,[27] storm effects extended well beyond the geographic areas defined as the storm zone. It might also illustrate the effects of the federal, state, and city responses to Hurricane Sandy. At the federal level, a public health emergency was declared on October 31, 2012, with the implementation of a waiver under Section 1135 of the Social Security Act. Under this waiver, Medicaid eligibility was extended among enrollees for whom it was set to expire, and provider requirements regarding in-state licensure and the provision of services were eased. Along with the federal response, emergency measures were taken by New York State and NYC to mitigate the effects of the storm.[28,29] One such effort was the opening of 8 emergency shelters in NYC for individuals with special health needs (eg, special dietary needs, electricity-dependent care, prescription medication), serving 2236 evacuees from October 28 to November 19, 2012. Additionally, mobile primary care units were deployed to affected areas, providing basic primary care and prescription services, serving more than 4000 people, and NYC assisted the reopening of pharmacies and provided mobile pharmacy services, with copayments being waived. It is possible that such emergency measures, including the 1135 Waiver, averted greater decreases in health care services utilization inside the storm zone and thus mitigated the observed differences by area.

It is noteworthy that any changes in service utilization between the storm year and the previous 2 years were the same inside and outside the storm zone for all service types, and among all demographic and diagnostic subgroups, over the immediate effect period, ie, there were no significant storm zone designation by year interactions for any of the models analyzed for the immediate effect period. This may be, in part, attributable to the governmental responses described above. It has been suggested that similar storm response efforts in Houston, Texas, following Hurricane Katrina may have deflected an increase in ED services over the month following that storm,[30] and it is reasonable to consider that these efforts in NYC may have averted increases in ED services there following Hurricane Sandy, as well as large decreases in outpatient and pharmacy utilization that might otherwise have been observed inside the storm zone immediately following the storm.

Differential changes in service utilization by storm zone designation were found only in the longer term, ie, for the 3-month and 1-year effect periods, with the most such effects found in the latter. This is generally consistent with the concept of secondary surge, ie, the increased demand long after the disaster event resulting from inadequate care in the immediate aftermath of the disaster, reducing utilization due to the shortened supply of services.[10] At the same time, it is possible that recovery from the storm may have taken different trajectories inside and outside the storm zone, as emergency services provided immediately following the storm, largely inside the storm zone, were phased out over time. Each service type, however, shows somewhat different patterns of change in utilization where differential change in utilization by storm zone designation was observed.

Inpatient services overall showed a reduction over the study period, which may in part reflect Medicaid reform efforts in New York State targeting avoidable hospitalization. However, differential change by storm zone designation was observed largely over the 1-year effect period, with inpatient utilization generally unchanged within the storm zone, inconsistent with the general trend, but reduced outside the storm zone, which is consistent with the general pattern of reduced inpatient utilization. That this pattern of results was also found among some demographic subgroups (females, those aged 45-64 years, those with substance abuse, and those of Hispanic ethnicity) is thought to be of little substantive importance, as it is mirrors the pattern found for inpatient utilization overall. The general lack of reduction of inpatient utilization inside the storm zone over the 1-year effect period, along with an increase in the

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3-month period among those aged 45-64 years, suggests an increased need for such services among those residing inside the storm zone, with sufficient storm recovery over the longer term to at least partially meet that need.

Overall outpatient and ED services utilization showed no differential changes by storm zone designation over any of the effect periods. However, such change occurred among some subgroups. Most notably, Medicaid enrollees with mental illness showed reduced outpatient service utilization over both the 3-month and 1-year effect periods, with greater reductions inside the storm zone. At the same time, this group showed significant increases in ED utilization, and to a slightly greater degree inside the storm zone, supporting the idea that ED services may be sought as an alternative to less available outpatient services. The fact that this result was observed over the 1-year effect period is consistent with previous discussions of mental illness following disasters that suggest some mental health conditions, such as PTSD, may reach their peak within a year following a disaster, with the symptoms persisting for months and years.[8] The greater reduction among males in outpatient utilization within the storm zone, in contrast to the greater reduction outside the storm zone among females, may reflect sex differences with respect to health conditions and injuries. The greater reduction of outpatient services inside the storm zone among those with diabetes over the 3-month effect period may be due to an increased vulnerability to disasters such as Hurricane Sandy among this patient population.

Although the descriptive figures in Table 1 show an increase in pharmacy utilization, the analysis of simple effects for the interaction term, controlling for the other covariates in the model, shows a slight decrease in all prescription fills over the 1-year effect period, greater in magnitude inside the storm zone. This same pattern was found for both males and females, those with mental illness or diabetes, those aged 45-64 and 65 years and older, and those of other race/ethnicity and may largely account for the overall reduction. A similar reduction over the 3-month effect period among those aged 45-64, combined with the absence of any differential reduction in total prescription fills by storm zone designation over this period, suggests a vulnerability among Medicaid enrollees in this age group.

Significant storm zone designation by year interactions for demographic subgroups suggests differential vulnerability to effects of the storm and is consistent with previous investigations demonstrating increased vulnerability of some population subgroups and with conceptual models predicting exacerbated disaster effects for more vulnerable groups, such as those with preexisting chronic conditions or socioeconomic disadvantages.[6,26] For example, the greater reductions in outpatient services in the storm year among those with diabetes residing in the storm zone during the 3-month effect period would be anticipated. Medicaid enrollees aged 45-64 years appear to have been particularly affected by Hurricane Sandy (eg, increased inpatient utilization over the 3-month effect period inside the storm zone, decreased outpatient utilization over the 1-year effect period inside and outside the storm zone, although to a greater degree in the former, decreased pharmacy utilization over the 3-month and 1-year effect periods). Although there may be other reasons for this, supplemental analysis revealed that those with conditions such as mental illness and diabetes are disproportionately represented in this age group. This is important to note since those aged 65 and older, who are generally more prone to chronic illness, are underrepresented in this study population given the exclusion of Medicaid enrollees dually eligible for Medicare. Also, the general lack of consistency with respect to the storm impact on demographic subgroups may reflect the overall economic disadvantage that defines Medicaid eligibility, obscuring the influence of demographic categories to which enrollees may belong.

Limitations

Some limitations of this investigation should be noted. First, ongoing Medicaid reform efforts in New York, initiated in 2011, may confound the effect of Hurricane Sandy on health care service utilization. This may apply particularly to hospital-based services, as a major goal of these reforms is to reduce avoidable hospital use. However, Medicaid reform efforts would be expected to have the same effect on utilization both inside and outside the storm zone, and the finding of storm zone/non–storm zone differences with respect to inpatient utilization make Medicaid reform seem less likely as an explanation. Furthermore, some models showed predicted increases in ED services during the storm year despite these reforms that would reduce such utilization. Second, it is unlikely that Medicaid claims data capture service utilization among enrollees following the storm in its entirety given the availability of emergency health care services provided in response to the storm, at least some of which were not billed to Medicaid. Thus, some observed changes in utilization based on claims may not reflect care actually received, although perhaps to a lesser extent over the 1-year effect period as such emergency services are phased out. Third, the use of primary diagnosis may result in undercounting services associated with diabetes, mental illness, and substance abuse, because other related conditions may appear as the primary diagnosis on a claim, eg, a person with diabetes presenting for services for a related heart condition, with the latter documented as the primary diagnosis for the claim.

CONCLUSIONS

Contrary to our hypothesis, the results showed no differential impact of Hurricane Sandy on health care services utilization between storm zone and non–storm zone areas over the immediate effect period. One possible explanation for this is that Hurricane Sandy had disruptive effects on health care services utilization in its immediate aftermath beyond areas defined as the storm zone for this investigation, resulting in

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TABLE 3

GEE Parameter Estimates and Analysis of Simple Effects for Outpatient and Emergency Department Models with Significant Storm Zone by Year Interactions[a]

	Outpatient Services												Emergency Department Services					
	1-Year Effect Period								3-Month Effect Period				1-Year Effect Period					
	Mental Illness		Females		Males		Age 45-64 Years		Mental Illness		Diabetes		Mental Illness		Substance Abuse		Other Race/ Ethnicity	
Covariate	**Estimate**	***P***	**Estimate**	***P***	**Estimate**	***P***	**Estimate**	***P***	**Estimate**	***P***	**Estimate**	***P***	**Estimate**	***P***	**Estimate**	***P***	**Estimate**	***P***
Intercept	77.3068	<0.0001	−26.7577	<0.0001	30.2397	<0.0001	−33.0946	<0.0001	−153.897	<0.0001	−145.854	<0.0001	91.9567	<0.0001	−2.7341	0.8303	−33.9018	<0.0001
Storm Zone Designation	0.2599	<0.0001	0.0678	<0.0001	0.0828	<0.0001	0.0740	<0.0001	0.2787	<0.0001	0.1614	<0.0001	0.1487	<0.0001	0.1102	<0.0001	0.1498	<0.0001
Years: Storm Year vs. Previous 2 Years	−0.1250	<0.0001	−0.0568	<0.0001	−0.0275	<0.0001	−0.0587	<0.0001	−0.3257	<0.0001	−0.1424	<0.0001	0.0316	0.0175	0.0241	0.0364	−0.0359	<0.0001
Storm Zone by Years	−0.0357	0.0001	0.0118	0.0001	−0.0279	<0.0001	−0.0091	0.0063	−0.058	<0.0001	−0.0468	0.0025	0.0617	<0.0001	−0.0308	0.0074	0.0225	0.0010
Day																		
Monday	0.3712	<0.0001	0.1908	<0.0001	0.1858	<0.0001	0.1539	<0.0001	0.3903	<0.0001	0.1812	<0.0001	0.0597	<0.0001	−0.0216	0.0226	0.0655	<0.0001
Tuesday	0.3459	<0.0001	0.1626	<0.0001	0.1662	<0.0001	0.1300	<0.0001	0.3601	<0.0001	0.1295	<0.0001	0.0804	<0.0001	−0.0294	0.0019	0.0497	<0.0001
Wednesday	0.3321	<0.0001	0.1362	<0.0001	0.1344	<0.0001	0.1031	<0.0001	0.3323	<0.0001	0.0639	<0.0001	0.0464	<0.0001	−0.0345	0.0003	0.0207	0.0005
Friday	−1.0364	<0.0001	−0.9043	<0.0001	−0.8444	<0.0001	−0.8679	<0.0001	−0.9578	<0.0001	−0.7975	<0.0001	−0.2457	<0.0001	−0.0694	<0.0001	−0.0515	<0.0001
Saturday	−1.8475	<0.0001	−1.5498	<0.0001	−1.3443	<0.0001	−1.3913	<0.0001	−1.8102	<0.0001	−1.5286	<0.0001	−0.2790	<0.0001	−0.1589	<0.0001	−0.0450	<0.0001
Sunday	0.2287	<0.0001	0.1597	<0.0001	0.1880	<0.0001	0.1701	<0.0001	0.2679	<0.0001	0.1591	<0.0001	0.0635	<0.0001	−0.0440	<0.0001	0.1062	<0.0001
Year Trend	−0.0408	<0.0001	0.0125	<0.0001	−0.0158	<0.0001	0.0162	<0.0001	0.0745	<0.0001	0.0695	<0.0001	−0.0507	<0.0001	−0.0034	0.5930	0.0136	0.0005

Analysis of Simple Effects for Interaction Terms in Models above:

	Storm Zone			Non-Storm Zone		
Model	**Risk[b]**	**95% CL**		**Risk[b]**	**95% CL**	
Outpatient – 1-Year Effect Period						
Mental Illness	0.8516	0.8345	0.869	0.8825	0.8670	0.8983
Females	0.9559	0.9472	0.9648	0.9448	0.9367	0.9528
Males	0.9461	0.9436	0.9487	0.9729	0.9674	0.9783
Age 45-64 years	0.9344	0.9321	0.9368	0.9430	0.9375	0.9486
Outpatient - 3-Month Effect Period						
Mental Illness	0.6813	0.6714	0.6914	0.722	0.7096	0.7347
Diabetes	0.8276	0.7721	0.8871	0.8673	0.8345	0.9013
ED Services - 1-Year Effect Period						
Mental Illness	1.0978	1.0701	1.1263	1.0321	1.0029	1.0622
Substance Abuse	0.9933	0.9677	1.0195	1.0244	0.9963	1.0532
Other Race/Ethnicity	0.9867	0.9706	1.0030	0.9647	0.9554	0.9742

[a]Abbreviations: CL, confidence limit; ED, emergency department; GEE, generalized estimating equation.

[b]Exponentiated least-squared mean differences between storm year and previous 2 years.

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TABLE 4

GEE Parameter Estimates and Analysis of Simple Effects for Pharmacy Models with Significant Storm Zone by Year Interactions[a]

Covariate	1-Year Effect Period																3-Month Effect Period	
	All Prescription Fills		Females		Males		Diabetes		Mental Illness		Age 45-64 Years		Age ≥65 Years		Other Race/Ethnicity		Age 45-64 Years	
	Estimate	*P*	Estimate	*P*	Estimate	*P*	Estimate	*P*	Estimate	*P*	Estimate	*P*	Estimate	*P*	Estimate	*P*	Estimate	*P*
Intercept	−125.6700	<0.0001	−128.472	<0.0001	−126.102	<0.0001	−359.533	<0.0001	−0.2070	0.9850	−197.371	<0.0001	−376.9540	<0.0001	−217.791	<0.0001	−154.906	<0.0001
Storm Zone Designation	0.0456	<0.0001	0.0474	<0.0001	0.0376	<0.0001	0.0359	<0.0001	0.1696	<0.0001	0.0581	<0.0001	−0.0173	0.1416	−0.0497	<0.0001	0.0554	<0.0001
Years: storm Year vs. Previous 2 Years	−0.0618	<0.0001	−0.0621	<0.0001	−0.0627	<0.0001	−0.1425	<0.0001	−0.0243	0.0199	−0.0899	<0.0001	−0.1547	<0.0001	−0.0834	<0.0001	−0.0329	0.0026
Storm Zone by Years	−0.0279	<0.0001	−0.0252	<0.0001	−0.0291	<0.0001	−0.0312	0.0066	−0.0341	0.0003	−0.0266	<0.0001	−0.0479	0.0065	−0.0286	0.0011	−0.0341	0.0005
Day																		
Monday	0.1494	<0.0001	0.1424	<0.0001	0.1600	<0.0001	0.1233	<0.0001	0.1478	<0.0001	0.1349	<0.0001	0.1222	<0.0001	0.1623	<0.0001	0.0969	<0.0001
Tuesday	0.0967	<0.0001	0.0892	<0.0001	0.1075	<0.0001	0.0733	<0.0001	0.1045	<0.0001	0.0841	<0.0001	0.0677	<0.0001	0.1004	<0.0001	0.0984	<0.0001
Wednesday	0.0550	<0.0001	0.0527	<0.0001	0.0583	<0.0001	0.0199	0.0437	0.0691	<0.0001	0.0452	<0.0001	0.0124	0.4120	0.0474	<0.0001	0.0064	0.4558
Friday	−0.5193	<0.0001	−0.5074	<0.0001	−0.5377	<0.0001	−0.3960	<0.0001	−0.644	<0.0001	−0.4939	<0.0001	−0.2980	<0.0001	−0.3143	<0.0001	−0.5092	<0.0001
Saturday	−1.1256	<0.0001	−1.1358	<0.0001	−1.1151	<0.0001	−1.0385	<0.0001	−1.1429	<0.0001	−1.1263	<0.0001	−0.9727	<0.0001	−0.8328	<0.0001	−1.1348	<0.0001
Sunday	0.1752	<0.0001	0.1629	<0.0001	0.1937	<0.0001	0.1859	<0.0001	0.1362	<0.0001	0.1662	<0.0001	0.1757	<0.0001	0.1918	<0.0001	0.1569	<0.0001
Year Trend	0.0612	<0.0001	0.0625	<0.0001	0.0611	<0.0001	0.1754	<0.0001	−0.0026	0.6387	0.0973	<0.0001	0.1863	<0.0001	0.1067	<0.0001	0.0763	<0.0001

Analysis of Simple Effects for Interaction Terms in Models above:

Model	Storm Zone			Non-Storm Zone		
	Risk[b]	95% CL		Risk[b]	95% CL	
1-Year Effect Period						
All Prescription Fills	0.9141	0.8955	0.9331	0.9400	0.9249	0.9554
Females	0.9165	0.8876	0.9463	0.9398	0.9161	0.9642
Males	0.9122	0.8766	0.9493	0.9392	0.9114	0.9678
Diabetes	0.8406	0.7600	0.9297	0.8672	0.8025	0.9372
Mental Illness	0.9433	0.9222	0.9649	0.9760	0.9596	0.9927
Age 45-64 years	0.8900	0.8652	0.9156	0.914	0.8933	0.9352
Age ≥65 years	0.8167	0.7426	0.8980	0.8567	0.7866	0.9331
Other Race/ Ethnicity	0.8941	0.8508	0.9396	0.9200	0.8777	0.9643
3-Month Effect Period						
Age 45-64 years	0.9351	0.9135	0.9574	0.9676	0.9472	0.9884

[a]Abbreviations: CL, confidence limit; GEE, generalized estimating equation.

[b]Exponentiated least-squared mean differences between storm year and previous 2 years.

no differences by storm zone designation. It is also possible that immediate emergency response efforts, concentrated in areas most affected by the storm, may have mitigated reductions in utilization of health care services among those residing inside the storm zone, resulting in no differences in the patterns of utilization among Medicaid enrollees residing inside or outside of the storm zone. The reductions in outpatient, inpatient, and pharmacy utilization, and increases in mental health and substance-abuse-related ED utilization, though often greater in magnitude among Medicaid enrollees living inside the storm zone, frequently extended to areas designated as outside of the storm zone, with this pattern of results largely demonstrated over the 1-year effect period, as hypothesized. This is consistent with theory and previous investigations demonstrating that some of the greatest effects of such a natural disaster on health and health care services utilization occur over a period well beyond the initial storm impact. These long-term effects, combined with the absence of immediate effects, suggests that storm recovery, with its effect on health care services utilization, may have followed different paths in areas designated as inside or outside of the storm zone, perhaps due, at least in part, to governmental storm response efforts.

About the Authors

New York State Department of Health, Albany, New York (Dr Sharp, Dr Sun, Ms Ledneva, Mr Pantea), and State University of New York at Albany, School of Public Health, Albany, New York (Ms Lauper, Dr Lin).

Correspondence and reprint requests to Mark J. Sharp, PhD, Office of Quality and Patient Safety, New York State Department of Health, ESP Corning Tower Rm 1911, Albany, NY 12237 (e-mail: mark.sharp@health.ny.gov).

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Supplementary material

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