

The Effect of Hurricane Sandy on Cardiovascular Events in New Jersey

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Background—Hurricane Sandy made landfall in New Jersey (NJ) on October 29, 2012. We studied the impact of this extreme weather event on the incidence of, and 30-day mortality from, cardiovascular (CV) events (CVEs), including myocardial infarctions (MI) and strokes, in NJ.

Methods and Results—Data were obtained from the MI data acquisition system (MIDAS), a database of all inpatient hospital discharges with CV diagnoses in NJ, including death certificates. Patients were grouped by their county of residence, and each county was categorized as either high- (41.5% of the NJ population) or low-impact area based on data from the Federal Emergency Management Agency and other sources. We utilized Poisson regression comparing the 2 weeks following Sandy landfall with the same weeks from the 5 previous years. In addition, we used CVE data from the 2 weeks previous in each year as to adjust for yearly changes. In the high-impact area, MI incidence increased by 22%, compared to previous years (attributable rate ratio [ARR], 1.22; 95% confidence interval [CI], 1.16, 1.28), with a 31% increase in 30-day mortality (ARR, 1.31; 95% CI, 1.22, 1.41). The incidence of stroke increased by 7% (ARR, 1.07; 95% CI, 1.03, 1.11), with no significant change in 30-day stroke mortality. There were no changes in incidence or 30-day mortality of MI or stroke in the low-impact area.

Conclusion—In the 2 weeks following Hurricane Sandy, there were increases in the incidence of, and 30-day mortality from, MI and in the incidence of stroke. (*J Am Heart Assoc.* 2014;3:e001354 doi: 10.1161/JAHA.114.001354)

Key Words: cardiovascular diseases • epidemiology • myocardial Infarction • stroke

Hurricane Sandy was one of the most destructive natural disasters to occur in New Jersey (NJ). On October 29, 2012, Hurricane Sandy made landfall in NJ, and by the next day, the state was designated as a major disaster area by President Obama. Nearly the entire state was affected to some extent, including extended power outages, major infrastructure damage, and disruption of transportation services.¹ The total cost of damages in NJ has been estimated at over \$37 billion.² Based on damage estimates alone, the effect of Sandy was unparalleled in NJ history.

Both the incidence of, and mortality from, cardiovascular (CV) events (CVEs), such as myocardial infarctions (MIs) and strokes, have been shown to significantly increase following

the onset of natural disasters.^{3–9} The incidence of CVEs may be increased for a prolonged period after the disaster.^{3,10,11} Psychosocial stress may play an important role in the etiology of these illnesses.^{5,8,9} In addition, owing to the disruption of transportation services, differences in transportation times to hospitals may affect survival from CVEs.¹² Changes in blood chemistry, such as increased fibrinogen levels, may also play a role, especially in MIs.¹³ Changes in these environmental and physiological factors may lead to an increased risk for CVE following a natural disaster.

Although a number of studies have looked at the acute effects of natural disasters, such as earthquakes, on CVEs, the research is scarce on the short-term effects of extreme weather events. In addition, there is little or no information on these events in densely populated areas in industrialized countries. NJ, one of the most densely populated areas in the United States, is an opportune setting to investigate the short-term effects of extreme weather events. The aim of this study was to examine changes in the incidence of, and mortality from, MIs and strokes specifically, and CVEs in general, during the 2 weeks following Hurricane Sandy in the high- and low-impact areas of NJ. This research may provide information to guide the utilization of emergency medical resources following the onset of extreme weather events, particularly in densely populated areas.

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Methods

We obtained data for the incidence of, and mortality from, MI, stroke, and CVEs from the MI data acquisition system (MIDAS) for the years 2007–2012. MIDAS is an administrative database containing hospital records of all patients discharged from nonfederal hospitals in NJ with a CV disease (CVD) diagnosis or invasive CV procedure. Information from death certificates is linked to the hospital discharge records. The accuracy of MIDAS for diagnosis of MI and stroke has been previously verified through an audit of a stratified random sample of charts.^{14,15} It was found that the diagnosis in MIDAS for MI and stroke were supported in 91% and 89% of cases, respectively. The current study was approved by the Robert Wood Johnson Medical School Institutional Review Board.

Data for the year Sandy occurred were categorized as follows: 2 weeks before Sandy (the “prestudy period”) and 2 weeks directly following Sandy making landfall in NJ (the “study period”). For each of the previous years, we utilized 2-week periods for the prestudy period and the study period. Starting days of each week of the years preceding Sandy were matched to the year of Sandy because day of the week is known to be associated with the incidence of, and death from, CVEs.¹⁶ The starting dates utilized for the prestudy period in each year were: October 15, 2007; October 13, 2008; October 19, 2009; October 18, 2010; October 17, 2011; and October 15, 2012.

Figure shows the rubric utilized to determine whether a patient had an incident event (eg, disease incidence of MI or

mortality incidence from MI) during a time period. Type A patients were admitted to the hospital for something other than an event of interest (ie, MI, stroke, or CVE) preceding the period and died from an event of interest (ie, death from MI, stroke, or CVE) while in the hospital during the period. These patients were counted as a death from the respective event during the period.

Type B patients were admitted to the hospital for an event of interest preceding the period and died from an event of interest while in the hospital during the period. As these patients had an event of interest preceding the period; they were not counted as a death from an event during the period. If the period when the incident event occurred was the prestudy period or the study period, the event was counted during that period. If the incident event occurred before the prestudy period, it was not counted in this analysis.

Type C patients were admitted to the hospital for an event of interest during the period and died from either an event of interest or some other event while in the hospital during the period. These patients were counted as having an incident event of interest. If they died from an event of interest, they were also counted as a death from an event of interest.

Type D patients were admitted to the hospital for an event of interest during the period and were released from the hospital during the period. These patients were counted as having an incident event of interest.

Type E patients were admitted to the hospital for an event of interest during the period and died from either an event of

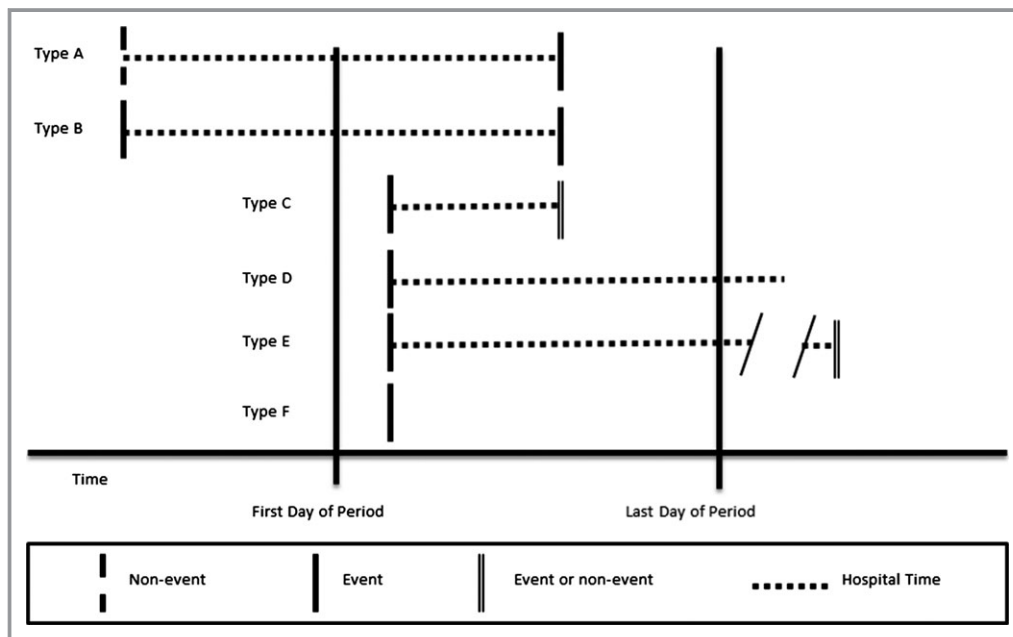


Figure. Rubric utilized to determine whether a patient had an incident event (eg, disease incidence of MI or mortality incidence from MI) during a time period where “period” is one of either the “prestudy period” or “study period.” MI indicates myocardial infarction.

interest or some other event within 30 days of discharge from the hospital either during or after the period. These patients were counted as having an incident event of interest. If they died from an event of interest, they were also counted as a death from an event of interest.

Type F patients died from an event of interest without hospital admission during the period. These patients were counted as a death from the event during the period.

Priority was given for admission (ie, a patient who was admitted during the prestudy period), and died while in the study period was counted as having an incident event in the prestudy period with a concomitant death from that event.

In MIDAS, diagnoses are recorded using International Classification of Diseases, Ninth Revision, Clinical Modification (ICD-9-CM) codes; cause of death is recorded using ICD-10-CM codes. Patients were determined to have been admitted as an inpatient to a hospital for MI if the ICD-9-CM primary discharge diagnosis code was 410.XX, where XX represent any numeric values between 0 and 99 (n=17 446). Patients were excluded if the final digit in the ICD-9-CM code was 2, indicating a subsequent episode of care (n=1327). Patients were determined to have died from MI if the ICD-10-CM code for cause of death was between I21.0 and I23.8 (n=10 012). Patients were determined to have been admitted for stroke if the ICD-9-CM primary discharge diagnosis code was 1 of the following: 362.3; 430.X; 431.X; 432.9; 433.01; 433.11; 433.21; 433.31; 433.81; 433.91; 434.01; 434.11; 434.9; 436.X; 435.X; or 997.02 (n=20 934). Patients were determined to have died from stroke if the ICD-10-CM code for cause of death was between I60.0 and I64.9 (n=3351). Patients were determined to be admitted for CVE if the ICD-9-CM primary discharge diagnosis code was between 390.00 and 459.99 (n=161 189). Patients were determined to have died from CVE if the ICD-10-CM code for cause of death was between I00.0 and I99.9 (n=20 766).

The relative impact of the storm on each NJ county was taken from the work of Hoopes Halpin, who utilized data from several federal and state sources.² In this analysis, a “community hardship index” was developed based on power loss, residential, commercial, and municipal damage, emergency shelters established, and gasoline shortage. Raw scores for each measure were converted to standardized z-scores based on state-wide averages. The measures were weighted based on the formula:

$$\begin{aligned} \text{Hardship index} = & \text{Power outage}(20\%) \\ & + (\text{Residential damage} \times \text{tax}\%) \\ & + \text{Commercial damage} \times \text{tax}\%(40\%) \\ & + \text{Municipal damage}(20\%) \\ & + \text{Shelter}(10\%) + \text{Gas}(10\%) \end{aligned}$$

where residential and commercial taxes were utilized to account for differing county compositions.

We utilized the index at the county level for our analyses. In the Hoopes Halpin report, NJ counties were grouped into quintiles based on scores from the formula above. We defined the high-impact area as those counties in the state with an index in the upper 2 quintiles given that these categories included only those counties with hardship indices significantly above the mean level for the state. The high-impact area encompassed 8 counties and a population of approximately 3.5 million people. The remaining 13 counties, with a population of approximately 5.1 million people, were considered the low-impact area. County-level census data from the NJ Department of Labor for the years of the study were utilized to determine incidence and mortality rates per 100 000 person-weeks to allow direct comparison between the high- and low-impact areas.¹⁷ Intercensal population estimates were used for all years other than 2010.

Statistical Analysis

Data for the changes in incidence, 30-day mortality, and case fatality rates between each of the 2 weeks in the study period and the average rates in the 2 weeks in the prestudy period were estimated for each year using Poisson regression with the GENMOD procedure in SAS (V9.3; SAS Institute Inc., Cary, NC). The main comparisons of interest in this study were the changes in incidence, 30-day mortality, and case fatality rates from the prestudy period to the study period during 2012, the year that Hurricane Sandy occurred, compared to the changes that occurred from the prestudy period to the study period in the 5 years preceding 2012. In the Poisson models, we estimated crude and adjusted differences and ratios of counts of events (eg, MIs). Crude measures were estimated through a model with the event count during the study period as the response variable and Sandy year versus non-Sandy year as the exposure. The adjusted model included the event count from the prestudy period as a covariate to account for yearly variations in event counts. Parameter estimates were determined utilizing generalized estimating equations with robust variances for repeated measures, the repeated measure being the 2 weekly counts from each year.¹⁸

Incidence was estimated as the following:

$$\text{Incidence}_{ij} = (\text{Count of hospital admissions} + \text{Out-of-hospital deaths})_{ij}$$

where incidence_{ij} =estimated incidence for study period j in year i.

Thirty-day mortality was estimated as the following:

$$\text{30-day mortality}_{ij} = \text{Count 30-day Mortality}_{ij}$$

where $\text{30-day mortality}_{ij}$ =estimated 30-day mortality for study period j in year i.

Incidence rate was estimated as the following:

$$\text{Incidence rate}_{ij} = \text{Incidence} / 100\,000 \text{ person-weeks}_{ij}$$

where incidence rate_{ij}=estimated rate for study period j in year i.

Thirty-day mortality rate was estimated as the following:

$$\text{30-day Mortality rate}_{ij} = \text{30-day Mortality} / 100\,000 \text{ person-weeks}_{ij}$$

where 30-day mortality rate_{ij}=estimated rate for study period j in year i.

Difference in incidence rate between the study period and the prestudy period was estimated as the following:

$$\text{Incidence rate difference}_i = \text{Incidence rate}_{\text{study period}(i)} - \text{Incidence rate}_{\text{pre-study period}(i)}$$

where incidence rate difference_i=estimate for year i.

Difference in 30-day mortality rate was estimated as the following:

$$\begin{aligned} \text{30-day mortality rate difference}_i &= \text{30-day mortality rate}_{\text{study period}(i)} \\ &- \text{30-day mortality rate}_{\text{pre-study period}(i)} \end{aligned}$$

where 30-day mortality rate difference_i=estimate for year i.

Case fatality ratio for each year was estimated as the following:

$$\text{Case fatality ratio}_i = \text{30-day mortality rate}_i / \text{Incidence rate}_i$$

where case fatality ratio_i=estimate for year i.

The difference in yearly rate difference for incidence and 30-day mortality (ie, the rate differences), on an additive scale, comparing 2012 to the previous 5 years, was estimated as the following:

$$\begin{aligned} \text{Difference in yearly rate difference} &= \text{Attributable rate difference (ARD)} \\ &= (\text{Yearly rate difference}_{2012}) \\ &- (\text{Yearly rate difference}_{2007-2011}) \end{aligned}$$

The difference in yearly case fatality rate difference comparing 2012 to the previous 5 years was estimated as the following:

$$\begin{aligned} \text{Difference in yearly case fatality rate difference} &= \text{Attributable case fatality rate difference (ACFRD)} \\ &= (\text{Yearly 30-day mortality rate difference}_{2012} / \text{Yearly incidence rate difference}_{2012}) \\ &- (\text{Yearly 30-day mortality rate difference}_{2007-2011} / \text{Yearly incidence rate difference}_{2007-2011}) \end{aligned}$$

The population attributable difference in the total number of cases for the 2 weeks in 2012 following Sandy, either

incident or 30-day mortality, was estimated as the following:

$$\begin{aligned} &\text{Population attributable risk per 2 weeks (PAR)} \\ &= \text{Difference in yearly incidence rate difference} \\ &\times (\text{Average area population}_{2012} / 100\,000 \text{ person-weeks}) \\ &\times 2 \text{ weeks} \end{aligned}$$

The ratio of yearly rate differences for incidence and 30-day mortality (ie, the rate differences), on a multiplicative scale, comparing 2012 to the previous 5 years, was estimated as the following:

$$\begin{aligned} \text{Ratio of yearly rate differences} &= \text{Attributable rate ratio (ARR)} \\ &= (\text{Rate difference}_{2012}) / (\text{Rate difference}_{2007-2011}) \end{aligned}$$

The ratio of yearly case fatality rate differences was estimated as the following:

$$\begin{aligned} \text{Ratio of yearly case fatality rate differences} &= \text{Attributable case fatality rate ratio (ACFRR)} \\ &= (\text{Yearly 30-day mortality rate difference}_{2012} / \text{Yearly incidence rate difference}_{2012}) \\ &/ (\text{Yearly 30-day mortality rate difference}_{2007-2011} / \text{Yearly incidence rate difference}_{2007-2011}) \end{aligned}$$

We calculated 95% confidence intervals (CIs) for all effect estimates.

Results

Effect on MI

We found a crude increase of approximately 21% in the incidence of MI in the high-impact area from the prestudy period to the study period following Sandy (Table 1). In the low-impact area, the crude increase was less than 1%. There was a 22% increase in the rate of MI in the study period following Sandy, compared to the study period in the previous 5 years after adjusting for the prestudy periods (attributable rate ratio [ARR], 1.22; 95% CI, 1.16, 1.28; Table 2). The rate of MI in the low-impact area was unchanged following Sandy, compared to the previous 5 years (ARR, 0.99; 95% CI, 0.98, 1.02; Table 3). We estimated that there were 125 additional cases of MI during the 2 weeks following Sandy than would have been expected based on the same time period in the previous 5 years (95% CI, 98, 152). The attributable rate difference (ARD) for incidence of MI from Sandy was 1.7 MIs per 100 000 person-weeks. The crude 30-day mortality rate from MI in the high-impact area for the 2-week study period increased approximately 33%, compared to the prestudy period. In the low-impact area, there was less than a 1% crude increase in 30-day mortality. Utilizing our model, we found a

Table 1. Demographic Information of Incidence of, and 30-Day Mortality From, AMI, Stroke, and CVE Patients During the Prestudy and Study Periods of the Year of Hurricane Sandy and the Previous 5 Years in the High- and Low-Impact Areas of NJ

| Year(s) of Study | All NJ* | | High-Impact Area† | | Low-Impact Area‡ | |
|------------------------------|-------------|-----------------------|-------------------|-----------------------|------------------|-----------------------|
| | 2012 | 2007–2011‡ Average | 2012 | 2007–2011‡ Average | 2012 | 2007–2011‡ Average |
| Total N | 8 864 590 | 8 729 068 | 3 677 069 | 3 630 314 | 5 187 521 | 5 098 754 |
| Incidence of MI | | | | | | |
| Prestudy period | | | | | | |
| N | 1411 | 1297.8 | 572 | 547.2 | 804 | 704.2 |
| Age (SD) | 73.7 (15.0) | 74.3 (14.7) | 74.5 (14.7) | 75.3 (14.5) | 73.2 (15.3) | 73.9 (14.8) |
| % Male | 53.8 | 52.7 | 53.0 | 54.1 | 53.9 | 51.1 |
| Study period | | | | | | |
| N | 1530 | 1304.8 | 692 | 546.6 | 806 | 712.4 |
| Age (SD) | 74.4 (14.7) | 74.2 (14.7) | 75.5 (14.2) | 75.2 (14.3) | 73.5 (15.1) | 73.8 (14.8) |
| % Male | 55.3 | 54.2 | 56.5 | 54.0 | 54.6 | 53.9 |
| 30-day mortality from MI | | | | | | |
| Prestudy period | | | | | | |
| N | 555 | 539.4 | 224 | 236.2 | 317 | 280.6 |
| Age (SD) | 79.1 (14.0) | 79.7 (12.8) | 79.7 (13.3) | 80.4 (12.4) | 78.9 (14.2) | 79.5 (13.0) |
| % Male | 49.0 | 50.2 | 47.8 | 52.0 | 49.2 | 48.4 |
| Study period | | | | | | |
| N | 628 | 558.6 | 298 | 244.6 | 321 | 290.2 |
| Age (SD) | 80.0 (12.6) | 79.1 (13.2) | 80.5 (11.9) | 80.0 (12.4) | 79.5 (13.3) | 79.0 (13.3) |
| % Male | 51.9 | 51.1 | 54.0 | 50.7 | 50.8 | 50.9 |
| Incidence of stroke | | | | | | |
| Prestudy period | | | | | | |
| N | 1245 | 1225.4 | 509 | 501.8 | 706 | 688.2 |
| Age (SD) | 71.6 (15.7) | 71.5 (15.8) | 72.2 (15.7) | 73.0 (15.3) | 71.4 (15.6) | 70.6 (16.0) |
| % Male | 44.8 | 44.2 | 45.8 | 44.4 | 43.3 | 43.6 |
| Study period | | | | | | |
| N | 1260 | 1216.4 | 542 | 498.2 | 684 | 689.6 |
| Age (SD) | 72.6 (15.8) | 71.5 (15.8) | 74.7 (15.5) | 72.6 (15.5) | 71.0 (15.9) | 70.8 (15.9) |
| % Male | 45.1 | 45.0 | 45.8 | 45.6 | 44.7 | 44.2 |
| 30-day mortality from stroke | | | | | | |
| Prestudy period | | | | | | |
| N | 184 | 182.8 | 74 | 76.6 | 107 | 100.6 |
| Age (SD) | 80.0 (12.7) | 77.8 (14.4) | 78.6 (13.2) | 79.2 (13.0) | 81.0 (12.4) | 76.9 (15.2) |
| % Male | 39.1 | 43.3 | 41.9 | 43.6 | 37.4 | 42.7 |
| Study period | | | | | | |
| N | 189 | 183.6 | 83 | 77 | 100 | 103.2 |
| Age (SD) | 78.0 (14.1) | 78.9 (13.6) | 80.1 (15.8) | 79.5 (13.0) | 76.3 (12.3) | 78.3 (14.2) |
| % Male | 43.4 | 40.5 | 41.0 | 42.1 | 47.0 | 39.2 |
| Incidence of CVEs | | | | | | |
| Prestudy period | | | | | | |
| N | 9883 | 9764.2 | 4227 | 3999 | 5396 | 5473.2 |

Continued

Table 1. Continued

| Year(s) of Study | All NJ* | | High-Impact Area [†] | | Low-Impact Area [†] | |
|----------------------------|-------------|-----------------------------------|-------------------------------|-----------------------------------|------------------------------|-----------------------------------|
| | 2012 | 2007–2011 [‡] Average | 2012 | 2007–2011 [‡] Average | 2012 | 2007–2011 [‡] Average |
| Age (SD) | 67.7 (17.1) | 67.9 (17.0) | 68.7 (16.6) | 69.3 (16.7) | 66.9 (17.4) | 66.9 (17.3) |
| % Male | 50.5 | 50.7 | 48.4 | 52.0 | 49.6 | 49.7 |
| Study period | | | | | | |
| N | 9409 | 9717.6 | 3966 | 4041 | 5203 | 5412 |
| Age (SD) | 68.7 (17.2) | 67.9 (17.0) | 70.6 (16.7) | 69.3 (16.6) | 67.4 (17.5) | 66.9 (17.2) |
| % Male | 50.9 | 51.0 | 48.6 | 52.2 | 50.6 | 50.1 |
| 30-day mortality from CVEs | | | | | | |
| Prestudy period | | | | | | |
| N | 1114 | 1127.4 | 475 | 478.6 | 612 | 606.4 |
| Age (SD) | 79.0 (15.6) | 78.7 (14.7) | 79.7 (13.8) | 79.8 (14.1) | 78.4 (15.3) | 77.9 (15.2) |
| % Male | 46.7 | 47.1 | 44.0 | 48.4 | 48.9 | 46.1 |
| Study period | | | | | | |
| N | 1314 | 1144.4 | 603 | 490.6 | 683 | 612.8 |
| Age (SD) | 78.6 (15.2) | 78.4 (14.9) | 79.6 (14.2) | 79.5 (14.1) | 77.7 (15.2) | 77.4 (15.5) |
| % Male | 50.3 | 47.7 | 49.4 | 47.7 | 51 | 47.6 |

AMI indicates acute myocardial infarction; CVE, cardiovascular event; MI, myocardial infarction; NJ, New Jersey.

*All incidence/mortality in NJ.

[†]NJ residents only.

[‡]Five-year mean values.

31% increase in the 30-day mortality rate from MI in the study period following Sandy, compared to the study period in the previous 5 years after adjusting for the prestudy periods (ARR, 1.31; 95% CI, 1.22, 1.41). We estimated that there were 69 more deaths from MI during the 2 weeks following Sandy than would have been expected (95% CI, 50, 87). Sandy appeared to add nearly 1 extra death (ARD, 0.9; 95% CI, 0.7, 1.2) per 100 000 person-weeks from MI. We also estimated a 7% increase in the case fatality rate (attributable case fatality rate ratio [ACFRR], 1.07; 95% CI, 1.01, 1.14).

Effect on Stroke

We found a crude increase of approximately 6% in the incidence of stroke in the high-impact area from the prestudy period to the study period (Table 1). In the low-impact area, there was a crude decrease of approximately 3%. There was a 7% increase in the rate of stroke (ARR, 1.07; 95% CI, 1.03, 1.11) following Sandy in the high-impact area. The rate of stroke in the low-impact area was unchanged (ARR, 0.97; 95% CI, 0.90, 1.03). We estimated that there were 35 cases of stroke during the 2 weeks following Sandy in the high-impact area, more than would have been expected (95% CI, 16, 56). This corresponds to a rate increase of approximately 7% (ARR,

1.07; 95% CI, 1.03, 1.11) and an ARD of 0.5 strokes per 100 000 person-weeks from Sandy (95% CI, 0.2, 0.8). We observed no significant change in either 30-day mortality or case fatality rate from strokes in either the high- or low-impact areas following Sandy.

Effect on CVEs

The crude incidence for any CVD diagnosis decreased by approximately 6% during the 2 weeks following Sandy in the high-impact area and by approximately 4% in the low-impact area (Table 1). We found an 8% decrease (ARR, 0.92; 95% CI, 0.90, 0.95) in the rate of CVE in the high-impact area following Sandy after adjusting for changes in the previous 5 years. In the low-impact area, we found an adjusted 2% decrease (ARR, 0.98; 95% CI, 0.96, 0.99). The crude mortality rate increased by approximately 27% and 10% in the high- and low-impact areas, respectively. We found an adjusted 22% increase in 30-day mortality rate from CVEs (ARR, 1.22; 95% CI, 1.15, 1.30) and a concomitant 32% increase in the case fatality rate from CVE (ACFRR, 1.32; 95% CI, 1.24, 1.41) in the high-impact area. In the low-impact area, we found an adjusted 14% increase in the 30-day mortality rate (ARR, 1.14; 95% CI, 1.07, 1.21) and a 16% increase in the case

Table 2. Effect Estimates of Hurricane Sandy on Incidence of, 30-Day Mortality From, and Case Fatality From AMI, Stroke, and All CV Admissions in the High-Impact Areas of NJ

| | Crude Attributable Rate* | Adjusted Attributable Rate [†] | Population Attributable Rate [‡] | P Value | Crude ARR | Adjusted ARR [‡] | P Value |
|--------------------|--------------------------|---|---|---------|-------------------|---------------------------|---------|
| MI | | | | | | | |
| Incidence | 1.93 (1.57, 2.28) | 1.69 (1.33, 2.05) | 125 (98, 152) | <0.0001 | 1.26 (1.20, 1.32) | 1.22 (1.16, 1.28) | <0.0001 |
| 30-day mortality | 0.73 (0.48, 0.98) | 0.93 (0.67, 1.17) | 69 (50, 87) | <0.0001 | 1.24 (1.15, 1.33) | 1.31 (1.22, 1.41) | <0.0001 |
| Case fatality rate | −0.01 (−0.03, 0.01) | 0.026 (−0.003, 0.055) | — | 0.1 | 0.97 (0.93, 1.01) | 1.07 (1.01, 1.14) | 0.03 |
| Stroke | | | | | | | |
| Incidence | 0.51 (−0.22, 1.23) | 0.48 (0.21, 0.75) | 36 (16, 56) | 0.0004 | 1.07 (0.97, 1.19) | 1.07 (1.03, 1.11) | 0.0005 |
| 30-day mortality | 0.07 (0.01, 0.13) | 0.08 (−0.03, 0.18) | 6 (−2, 13) | 0.1 | 1.07 (1.00, 1.14) | 1.10 (0.99, 1.21) | 0.06 |
| Case fatality rate | −0.01 (−0.02, 0.01) | −0.0002 (−0.021, 0.021) | — | >0.9 | 0.99 (0.97, 1.01) | 1.02 (0.90, 1.17) | 0.70 |
| CVE | | | | | | | |
| Incidence | −1.78 (−6.22, 2.65) | −4.43 (−6.06, −2.80) | −328 (−448, −207) | <0.0001 | 0.97 (0.89, 1.05) | 0.92 (0.90, 0.95) | <0.0001 |
| 30-day mortality | 1.39 (0.83, 1.95) | 1.30 (0.94, 1.66) | 96 (70, 123) | <0.0001 | 1.23 (1.12, 1.35) | 1.22 (1.15, 1.30) | <0.0001 |
| Case fatality rate | 0.03 (0.02, 0.04) | 0.033 (0.027, 0.040) | — | <0.0001 | 1.28 (1.20, 1.36) | 1.32 (1.24, 1.41) | <0.0001 |

AMI indicates acute myocardial infarction; ARR, attributable rate ratio; CV, cardiovascular; CVE, cardiovascular event; MI, myocardial infarction; NJ, New Jersey.

*Attributable rate—rate per 100 000 person-weeks.

[†]Adjusted for prestudy period.

[‡]Population attributable rate—population attributable change in the total number of cases for the 2 weeks in 2012 following Sandy in high-impact area.

fatality rate (ACFRR, 1.16; 95% CI, 1.09, 1.24). We estimated that death from CVEs increased by 96 cases more than expected in the high-impact area (95% CI, 70, 123) and by 72 cases more than expected in the low-impact area (95% CI, 35, 108).

In 2012, total mortality in the high-impact area increased from 1069 deaths in the 2 weeks before Sandy to 1287 in the 2 weeks after Sandy made landfall. The fraction of deaths resulting from CVEs increased slightly in the prestudy period (44.4%) compared to the study period (46.8%).

To gain a better understanding of possible causes of the mortality-rate changes in the high-impact area, we examined changes for in- and out-of-hospital 30-day mortality rates following Sandy (Table 4). In the high-impact area, the in-hospital mortality rate from MI increased by 41% following Sandy (ARR, 1.41; 95% CI, 1.26, 1.58); the out-of-hospital mortality rate increased by 25% (ARR, 1.25; 95% CI, 1.14, 1.37). For overall CVEs, the in-hospital mortality rate increased by 31% (ARR, 1.31; 95% CI, 1.19, 1.44) and the out-of-hospital mortality rate increased by 18% (ARR, 1.18; 95% CI, 1.08, 1.30).

In a sensitivity analysis to test the methodology used in this study, we examined MI incidence and mortality in the high-impact area for alternative time periods during 2012 and compared them to the same time period in the previous 5 years. We saw no significant differences in MI incidence or mortality when we utilized data from 2, 4, or 6 months preceding Sandy, adjusted for the preceding 2 weeks and compared to the previous 5 years (data not shown). For example, when we examined an alternative study period 2 months before Sandy, August 27–September 9, we found no change in the incidence of, or mortality from, MI in 2012, as compared to similar periods in 2007–2011.

Discussion

We found evidence suggesting that, in the high-impact area of NJ, Hurricane Sandy increased the incidence of MIs by 22%, increased the 30-day mortality from MI by 31%, and increased the rate of stroke by 7%. We found no effect on the 30-day mortality rate from stroke. We saw no change in the rates of MI or stroke in the low-impact area of NJ following Hurricane

Table 3. Effect Estimates of Hurricane Sandy on Incidence of, 30-Day Mortality From, and Case Fatality From AMI, Stroke, and All CV Admissions in the Low-Impact Areas of NJ

| | Crude Attributable Rate* | Adjusted Attributable Rate [†] | Population Attributable Rate [‡] | P Value | Crude ARR | Adjusted ARR [†] | P Value |
|--------------------|--------------------------|---|---|---------|-------------------|---------------------------|---------|
| MI | | | | | | | |
| Incidence | 0.81 (0.49, 1.13) | -0.02 (-0.18, 0.13) | -2 (-19, 14) | 0.8 | 1.12 (1.07, 1.17) | 0.99 (0.98, 1.02) | 0.8 |
| 30-day mortality | 0.28 (0.10, 0.46) | -0.01 (-0.08, 0.06) | -1 (-8, 6) | 0.7 | 1.12 (1.05, 1.19) | 0.99 (0.97, 1.02) | 0.7 |
| Case fatality rate | -0.01 (-0.02, 0.01) | -0.004 (-0.008, 0.0003) | — | 0.07 | 0.98 (0.96, 1.01) | 0.99 (0.98, 1.00) | 0.10 |
| Stroke | | | | | | | |
| Incidence | -0.18 (-0.60, 0.24) | -0.24 (-0.67, 0.18) | -25 (-70, 19) | 0.3 | 0.97 (0.91, 1.04) | 0.97 (0.90, 1.03) | 0.3 |
| 30-day mortality | -0.06 (-0.12, 0.01) | -0.12 (-0.29, 0.04) | -12 (-30, 4) | 0.1 | 0.94 (0.88, 1.00) | 0.91 (0.76, 1.08) | 0.3 |
| Case fatality rate | -0.005 (-0.011, 0.001) | -0.013 (-0.031, 0.006) | — | 0.20 | 0.97 (0.93, 1.01) | 0.94 (0.81, 1.07) | 0.3 |
| CVE | | | | | | | |
| Incidence | -2.83 (-7.00, 1.34) | -1.23 (-2.05, -0.42) | -128 (-213, -44) | 0.003 | 0.95 (0.87, 1.03) | 0.98 (0.96, 0.99) | 0.004 |
| 30-day mortality | 0.67 (0.16, 1.19) | 0.69 (0.34, 1.04) | 72 (35, 108) | <0.0001 | 1.13 (1.02, 1.24) | 1.14 (1.07, 1.21) | <0.0001 |
| Case fatality rate | 0.02 (0.01, 0.03) | 0.017 (0.010, 0.024) | — | <0.0001 | 1.19 (1.13, 1.26) | 1.16 (1.09, 1.24) | <0.0001 |

AMI indicates acute myocardial infarction; ARR, attributable rate ratio; CV, cardiovascular; CVE, cardiovascular event; MI, myocardial infarction; NJ, New Jersey.

*Attributable rate—rate per 100 000 person-weeks.

[†]Adjusted for prestudy period.

[‡]Population attributable rate—population attributable change in the total number of cases for the 2 weeks in 2012 following Sandy in high-impact area.

Sandy. To the best of our knowledge, this is the first study that has reported on the short-term effects of MI and stroke following an extreme weather event.

The mechanism by which Hurricane Sandy could increase the risk of MI and stroke is not known, but others have attributed higher incidence rates of severe CVEs during natural

Table 4. Effect Estimates of Hurricane Sandy on 30-Day Mortality From AMI, Stroke, and CVEs in the High-Impact Area of NJ Stratified by In- and Out-of-Hospital Death

| | Attributable Rate* | P Value | ARR | P Value |
|-----------------|---------------------|---------|-------------------|---------|
| MI | | | | |
| Out of hospital | 0.48 (0.30, 0.66) | <0.0001 | 1.25 (1.14, 1.37) | <0.0001 |
| In hospital | 0.44 (0.32, 0.56) | <0.0001 | 1.41 (1.26, 1.58) | <0.0001 |
| Stroke | | | | |
| Out of hospital | 0.10 (0.03, 0.18) | 0.005 | 1.22 (1.07, 1.40) | 0.002 |
| In hospital | -0.04 (-0.10, 0.02) | 0.2 | 0.96 (0.84, 1.09) | 0.5 |
| CVE | | | | |
| Out of hospital | 0.77 (0.42, 1.12) | <0.0001 | 1.18 (1.08, 1.30) | 0.0002 |
| In hospital | 0.52 (0.37, 0.67) | <0.0001 | 1.31 (1.19, 1.44) | <0.0001 |

AMI indicates acute myocardial infarction; ARR, attributable rate ratio; CVE, cardiovascular event; MI, myocardial infarction; NJ, New Jersey.

*Attributable rate—rate of death per 100 000 person-weeks.

disasters or extreme weather events to increased stress,^{19–22} increased physical activity,²³ blood rheology,¹³ decreased attention or ability to maintain medical needs,²⁴ and lack of sufficient emergency services.²⁵ Nakamura et al., for example, attributed the approximate 4-fold increase in MI rate following the Great East Japan earthquake to strong psychosocial stress.²² Emotional stress has been linked to platelet activation and increased risk of acute coronary syndrome.²⁶ Delayed emergency medical care may have been responsible for many deaths following the 1999 Athens earthquake.²⁵ It is likely that an interaction between these factors played a major role in morbidity and mortality following these events.

There were several factors that may have caused significant delays in treatment of MIs and strokes following Sandy. During the 2 weeks following Sandy, NJ experienced significant power outages throughout the hardest hit parts of the state. Many roads were blocked for significant periods of time as a result of fallen trees, and gasoline was in short supply.² Telephone service was unavailable for many days after the storm. In addition, emergency medical services were stretched to their limits with higher call volumes, particularly from injuries occurring from the effects of the storm or the clean-up effort, exacerbating the situation.^{27,28} The delays likely caused patients to arrive at the hospital later in the course of their MI or stroke than would have normally been the case. Delays in treatment may have contributed to the higher rates of in-hospital deaths for MI given that greater myocardial damage may have occurred before medical treatment was initiated.

The changes we observed in our measures of overall CVE in both the high- and low-impact areas—decreased incidence and increased mortality—may indicate that following Sandy certain types of hospital admissions for CVE, which could have been postponed without significant health outcomes (eg, elective procedures), were delayed. The most serious CVE admissions (ie, those with higher mortality risk) likely continued leading to the higher rate of mortality. Given that medical facilities develop emergency preparedness plans for future events, strategies to repurpose underutilized resources from a reduction in elective procedures should be taken into consideration.

There are other environmental factors that have been associated with increases in incidence of and mortality from MI besides extreme weather events. Influenza outbreaks have been shown to increase the incidence of MI, especially in the elderly.²⁹ In NJ during the 2 weeks following Sandy, there was, however, no significant increase in influenza cases, as compared to previous years. The rates for MI incidence and mortality in 2012 significantly exceeded that of 2009 when the influenza pandemic occurred.³⁰ Large increases and decreases in ambient temperature have also been shown to cause increases in the risk of MI.³¹ During the 2 weeks

following Sandy, the average temperature was around 2.5°C lower than the mean temperature from the same periods in the previous 5 years.³² For comparison, Madrigano et al. found that a 1-day decrease in temperature of 6.6°C was associated with an 8% to 15% increased risk of MI.³¹ Many researchers have found an association between increases in air pollution and higher risk of MI incidence.^{33–35} We examined the levels of ambient fine particulate pollution, PM_{2.5}, in NJ during our study periods utilizing US Environmental Protection Agency data.³⁶ We found a slight decrease in the levels of this pollutant in the 2 weeks following Sandy, compared to both the preceding 2 weeks and the same period in the previous 5 years. It appears that these 3 important environmental factors likely did not play a significant role in the changes in incidence and mortality from MI following Sandy.

There were several limitations to this study. Given that the incidence data were based on administrative records of hospital admissions, there is the possibility that miscoding of the primary diagnoses may have occurred. However, the probability of miscoding for MI and stroke is likely very low given that studies have found the sensitivity and specificity for these 2 diagnoses in administrative records to be near or above 90%.^{37,38} The mortality records, however, especially for out-of-hospital deaths, may also have significant misclassification for cause of death. In 1 study, it was found that CVD was overestimated as a cause of death by as much as 25% overall and 50% in older individuals.³⁹ We found that the rate of diagnosis of CV death in the high-impact area showed minimal change from the 2 weeks before Sandy to the 2 weeks after Sandy in spite of an increase in overall death. This may indicate that there was not a differential misclassification of CV death following Sandy. We also assumed that all residents within the high- and low-impact areas were impacted equally, which is unlikely. This assumption would have also biased the results toward the null. Our rationale to include in the high-impact area only the NJ counties estimated to be significantly above the mean impact for NJ following Sandy may have reduced exposure misclassification. The data available in the MIDAS data set are limited to diagnoses and demographic information and do not include more-detailed data, such as the results from laboratory tests. More-detailed studies, for example, those examining individual patient medical records, would greatly improve the ability to more precisely ascertain the causes of morbidity and mortality following Sandy.

There were several strengths to this study. We used a previously published, multifactorial report to determine the high- and low-impact areas in NJ. Limiting our high-exposure area to only those counties significantly above the mean for the state likely reduced the probability of exposure misclassification in this ecological study. We leveraged verified data sources to determine how extreme weather events influence CV outcomes. Focusing on MI and stroke,

conditions with high diagnostic sensitivity and specificity, reduced the likelihood of outcome misclassification. In addition, we found that our methods were robust to sensitivity analysis by testing against other time periods.

We observed a significant increase in the incidence of MIs and strokes and mortality from MIs in the most severely affected areas of NJ similar to the reported effects of natural disasters in other industrialized countries. Overall, Sandy likely added 125 cases of MI and nearly 70 additional deaths. It also likely contributed 36 additional strokes in the most severely hit areas. As the frequency of these types of events increase, the medical community, in conjunction with disaster preparedness planners, needs to be aware of how the volume and severity of health events change. These include all aspects of medicine, but particularly the elements of emergency medicine, from emergency medical services in the field to emergency department staffs in the hospital.

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Disclosures

None.

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