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Lights out: Impact of the August 2003 power outage on mortality in New York, NY

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Abstract

Background—Little is known about how power outages affect health. We investigated mortality effects of the largest US blackout to date, August 14–15, 2003 in New York, NY.

Methods—We estimated mortality risk in New York, NY, using a generalized linear model with data from 1987–2005. We incorporated possible confounders, including weather and long-term and seasonal mortality trends.

Results—During the blackout, mortality increased for accidental deaths (122% [95% confidence interval = 28%–287%]) and non-accidental (i.e., disease-related) deaths (25% [12%–41%]), resulting in approximately 90 excess deaths. Increased mortality was not from deaths being advanced by a few days; rather, mortality risk remained slightly elevated through August 2003.

Discussion—To our knowledge, this is the first analysis of power outages and non-accidental mortality. Understanding the impact of power outages on human health is relevant, given that increased energy demand and climate change are likely to put added strain on power grids.

Power blackouts are likely to increase as growing energy use stresses aging power grids.[1] Climate change could also increase power outages,[2] and energy infrastructure may be targeted by national security threats.[1] However, we know little about how power outages affect health. Studies have reported increases in accidental deaths and injuries, including carbon monoxide (CO) poisoning,[3,4] food poisoning,[5] and hypothermia[3] during power outages, as well as increased respiratory hospitalizations.[6] Calls to emergency services[7] and poison control[8] can increase, although this may reflect the inability to contact primary health providers.[7] While one article showed graphically that mortality increased during the New York 2003 blackout,[6] to our knowledge, there has been no analysis of the effect of blackouts on total mortality, including non-accidental (i.e., disease-related) causes. Furthermore, estimated death tolls for disasters (e.g., hurricanes) generally include only directly attributable deaths (e.g., drowning),[9,10] even though disasters often also cause power outages. If outages affect mortality from non-traumatic causes, current fatality estimates for natural disasters could be underestimated, particularly for developed countries where disaster-related deaths are considered relatively rare.

We investigated mortality in New York, NY, during the largest blackout in US history (August 14–15, 2003).[11] This was the first citywide blackout of New York, NY, since 1977[7] and constituted a natural experiment—power was available until 4:11 pm on August 14, and

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then immediately unavailable throughout the community.[7] We compare population mortality on blackout days to days with power.

Methods

Data

Mortality data were obtained from the National Center for Health Statistics[12] through the National Morbidity, Mortality, and Air Pollution Study[13] for the New York, NY, community for 1987–2005. Data include daily mortality counts by age (<65, 65–74, <75 years) and cause of death: accidental, cardiovascular, respiratory, and non-cardiorespiratory (eTable1, http://links.lww.com).

Temperature and dew-point temperature data are from the National Climatic Data Center.[14] We used selected monitors operating over the entire study period (eTable 2 and eFigure 1, http://links.lww.com) and averaged daily data across all reporting monitors to estimate community-wide weather. We adjusted dew-point temperature by temperature, [15] as these variables were highly correlated (R^2=0.94).

Because pollution can affect mortality,[16] data for ozone (O_3), nitrogen dioxide (NO_2), sulfur dioxide (SO_2), particulate matter with aerodynamic diameter ≤10μm (PM_{10}), and CO were obtained for the months of August in 2001–2005 from the US Environmental Protection Agency's Air Quality System.[17] We included only those monitors reporting during August 14–16, 2003, excluding source-oriented monitors (eFigure 1 and eTable 3, http://links.lww.com).

Methods

We modeled daily mortality rates using a Poisson distribution with overdispersion, based on methods used to study health effects of air pollution and heatwaves.[13,15] We modeled blackout days using an indicator variable, and controlled for potential time-varying confounders including day-of-week, temperature, dew-point temperature, and long-term and seasonal mortality trends (details in the eAppendix, http://links.lww.com).We estimated the relative risk of mortality associated with the power outage, comparing mortality on blackout days to other days. We tested sensitivity of results using a model with temperature at lags ranging from same-day to four days previous. In this model, we included temperature lags using a distributed lag model with strata: same day and average of lags 1–4.[18]

To estimate number of deaths related to the blackout, we calculated baseline mortality on blackout days (the expected mortality had the blackout not occurred) and then estimated excess deaths associated with the blackout (relative risk associated with the blackout multiplied by expected mortality). Estimates of uncertainty for excess mortality incorporated uncertainty in the blackout's association with mortality and in baseline mortality. We estimated effects by age group and cause of death through stratified analysis.

Separately, we considered changes in mortality rates through 31 August 2003, to investigate evidence of short-term mortality displacement.[19] Following methods used to study mortality displacement following heatwaves,[20] we fit a spline to a 29-day period centered on 15 August 2003. We placed knots more closely near the blackout, since effects likely change more quickly at times closer to the event.[21]

Since heatwaves can affect mortality beyond single days of heat,[15,22,23] we investigated whether the blackout coincided with a heatwave, defined as ≥2 consecutive days with temperatures ≥ 98^{th} percentile of year-round temperatures in New York, NY.[15,22]

Previous work using airborne measurements found decreased pollution in the Northeast during the blackout, possibly from power-plant shutdowns.[24] We compared ground-level measurements of O_3, NO_2, SO_2, PM_{10}, and CO during the blackout to distributions of typical levels for the area and season (August 2001–2002 and 2004–2005).

Results

During the blackout, total mortality rose 28%, resulting in approximately 90 excess deaths (Figure 1, Table 1). Effect estimates were almost identical using a more complex model that included temperature effects at longer lags (eTable 4, http://links.lww.com). Risk of accidental deaths increased most; however, excess deaths were primarily from non-accidental causes. While all ages were affected, those 65–74 years were particularly susceptible (Table 1). We found no evidence of short-term mortality displacement; rather, mortality remained slightly elevated through August 2003.

Temperatures were hot but not extreme for a typical August day in New York (eFigure 2, http://links.lww.com). Neither the 14th or 15th of August was a heatwave day, making adjustment for added heatwave effects unnecessary. Pollution monitors were interrupted during the blackout; we therefore could not analyze pollution for the afternoon of 14 August through the morning of 15 August 2003. However, there are data for the morning of 14 August and immediately following power restoration (15 August). We compared pollutant concentrations for all available data on 14–16 August, 2003 to distributions of typical levels (August 2001–2002, 2004–2005) (Figure 2).

Pollution remained at normal August levels for O_3 (Figure 2A) and PM_{10} (Figure 2E). SO_2 concentrations were high (top 75th percentile of usual values) on the morning of 16 August 2003 (Figure 2B). NO_2 was higher than usual the evening following power restoration (15 August 2003) (Figure 2C). CO was close to normal at one of two monitors, but exceptionally high during the afternoon of 15 August 2003 at a monitor in Manhattan (Figure 2D).

Discussion

Our results indicate that power outages can immediately and severely harm human health. We found a much higher mortality than reported by the New York City Department of Health and Mental Hygiene, which counted six deaths directly attributable to the blackout (the majority from CO poisoning).[25] Although an earlier study graphically depicted mortality rates during the blackout,[6] there has been no analysis of the effects of a blackout on disease-related mortality risk, or estimates of excess deaths associated with the August 2003 New York blackout. We found that most excess deaths during the blackout were from disease-related causes.

The conditions reported during the blackout help explain our mortality estimates. Some people were trapped in subways over an hour,[26] and firefighters performed an estimated 800 elevator rescues.[11] Residents of high-rise apartments were isolated[27] and lacked potable water.[25] Those who left higher floors had to descend many flights of stairs—one documented mortality was a heart attack after leaving a high-level office.[28]

The blackout also complicated the management of illness, which may help explain the range of causes of death. Most food sources and pharmacies were closed—a serious problem for diabetics and anyone low on prescription medicines.[28,29] Some power-operated home medical equipment (e.g., ventilators, oxygen conservers) could not be used.[30] Ambulances responded more slowly than usual,[7] and, because cellular phone service failed during part of the blackout,[31] it was difficult to contact emergency services. Four of the 75 hospitals in

New York, NY, lost power for part of the blackout,[27] and hospital emergency rooms with power were overcrowded with people seeking electricity for medical equipment.[27]

Both heat and air pollution can affect mortality.[16,23] Our estimate of excess mortality during the blackout cannot be explained solely by heat. We controlled for temperature in the model, and the blackout did not coincide with a heatwave. However, increased exposure to heat during the power outage (i.e., lack of air conditioning, increased pedestrian traffic) could have aggravated the normal effects of heat. Because pollution monitors were interrupted, we were unable to fully analyze pollutant levels. However, we found elevated levels of some pollutants on the day following the blackout. While this blackout may have decreased pollution from long-range sources such as power generators in the Midwest,[24] local pollution sources were also affected, including traffic, public transportation, airlines, and generator use.[26,27,31] Unusually high pollution levels were likely caused by the blackout, and therefore were probably pathways rather than confounders in the relationship between the blackout and mortality.

Among US cities, New York, NY, may be particularly vulnerable because of its many high-rise buildings and substantial dependence on public transportation. Other power outages have lasted longer or been accompanied by more extreme weather.[3,4] Future research may determine if health effects observed during this blackout are found during other blackouts and in other communities. Our findings indicate that health impacts of power outages have been under-estimated, which has implications for emergency planning, as well as for assessment of the full impact of national disasters and other events related to blackouts.

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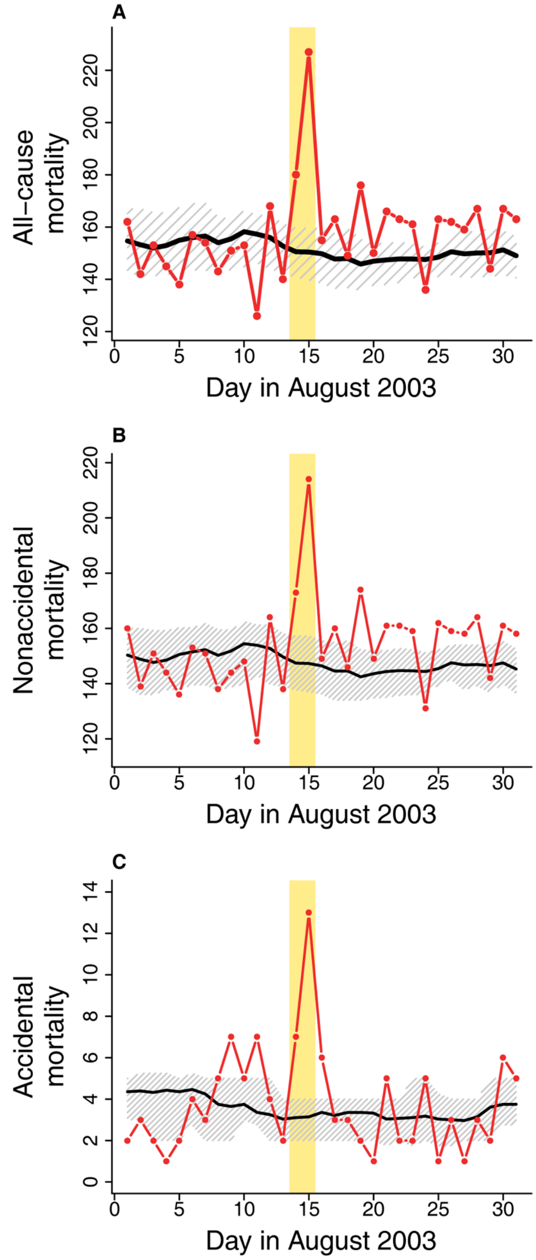
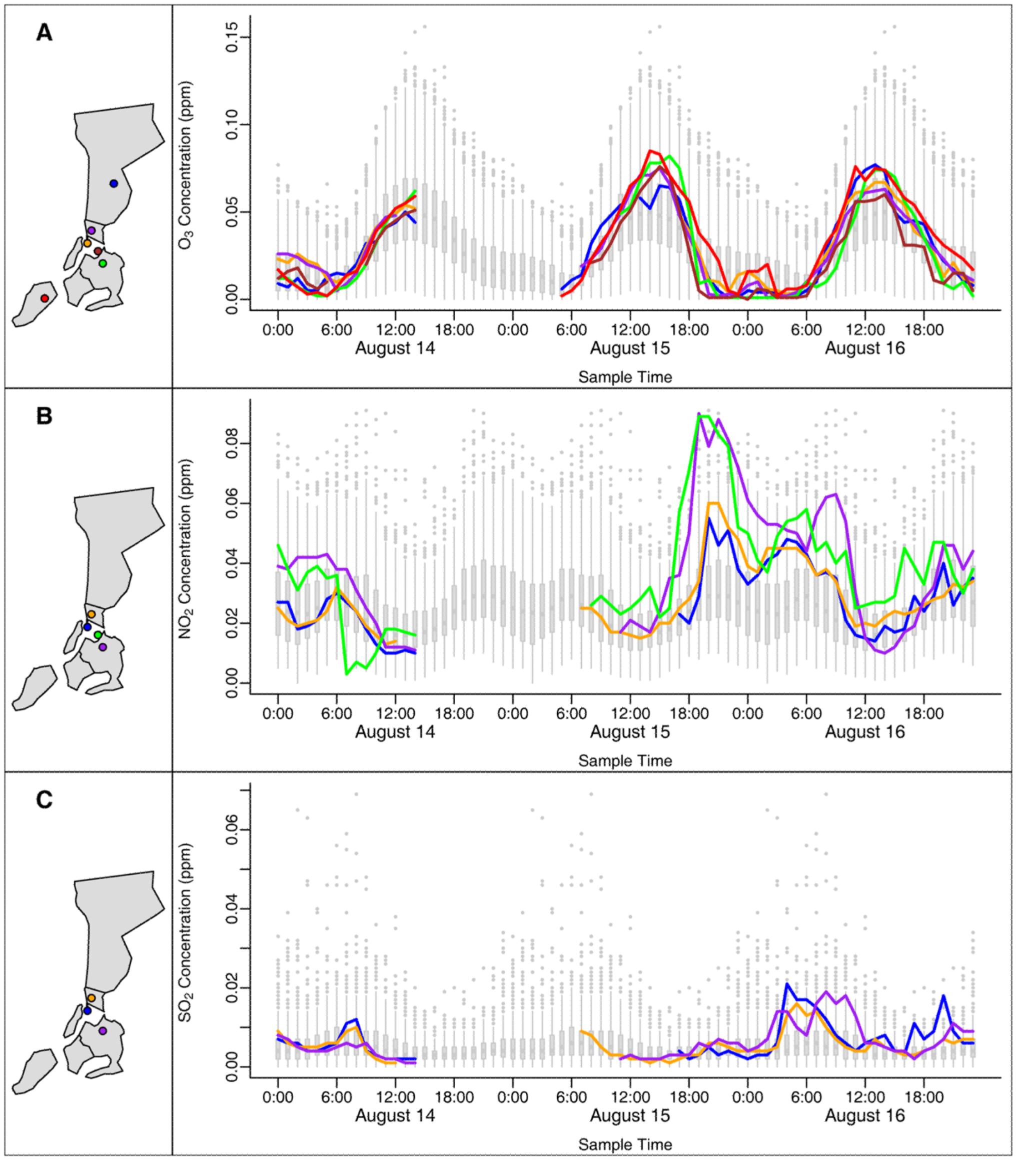


Figure 1.
Daily mortality counts during August 2003 (in red) compared with average August mortality rates for (A) all-cause mortality, (B) non-accidental mortality, and (C) accidental mortality. Shown for comparison are the mean (black line) and interquartile range (hatched area) of a seven-day moving average of mortality in August of the two proceeding (2001,2002) and two following years (2004,2005). Yellow highlights blackout dates.


A
B
C
O_3 Concentration (ppm)
NO_2 Concentration (ppm)
SO_2 Concentration (ppm)
0:00
6:00
12:00
18:00
August 14
August 15
August 16
Sample Time

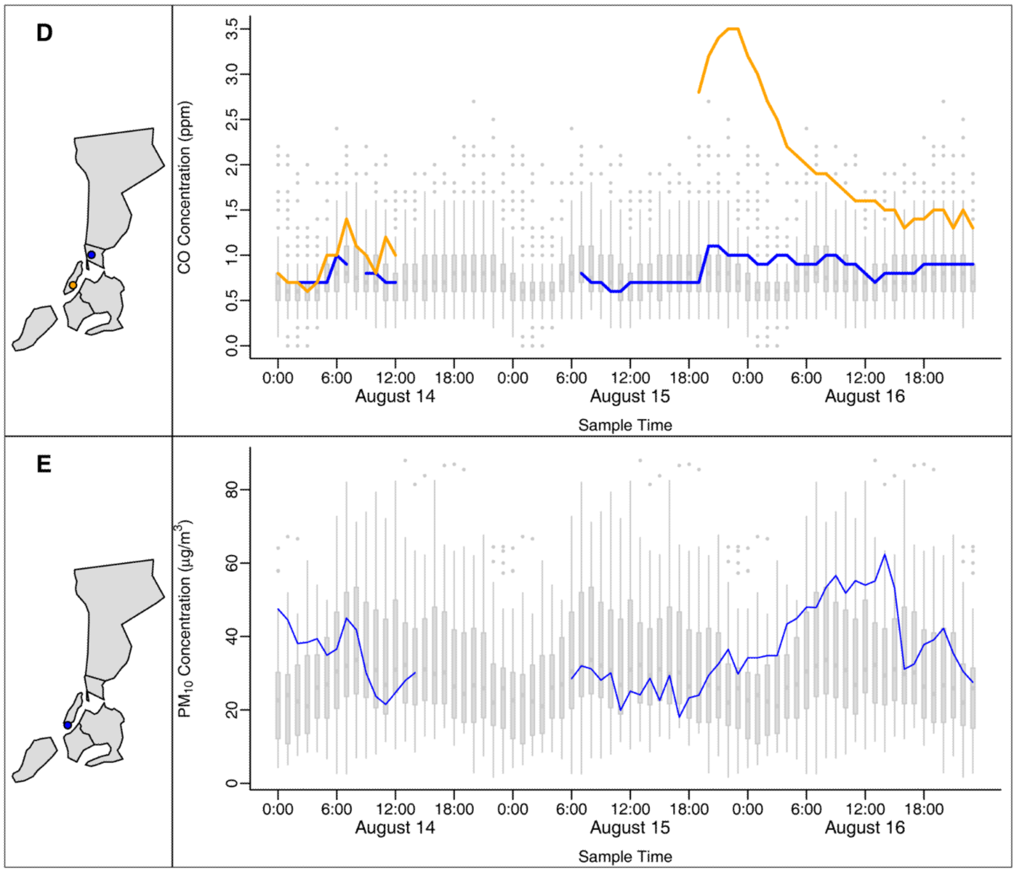


Figure 2.
Concentrations of pollutants immediately following the blackout for (A) O_3; (B) NO_2; (C) SO_2; (D) CO; and (E) PM_{10}. Gray boxes show boxplots of hourly distributions for August of the two proceeding (2001, 2002) and two following (2004, 2005) years. The color of each line corresponds to the monitor of the same color shown on the accompanying map. Two extreme outliers are removed in figure (C); these did not occur during the power outage.

Table 1

Effects of the August 14–15, 2003, blackout on mortality risk in New York, NY, by age and cause of death.

	Baseline mortality: estimated mortality for the blackout period, had the blackout not occurred No. deaths	Percent increase in mortality comparing the black period to other periods (95% confidence interval)	Excess mortality during the blackout period No. deaths (95% confidence interval)[a]
All ages	319	28 (15 to 44)	90 (46 to 138)
Age (years)			
<65	91	30 (6 to 59)	27 (6 to 53)
65–74	53	44 (14 to 82)	24 (8 to 43)
≥75	175	23 (6 to 42)	39 (10 to 73)
Cause of death			
All non-accidental	309	25 (12 to 41)	78 (37 to 125)
Cardiovascular	148	26 (7 to 48)	38 (10 to 71)
Respiratory	21	12 (−27 to 69)	3 (−6 to 15)
Non-cardiorespiratory	140	27 (8 to 48)	37 (11 to 66)
Accidental	10	122 (28 to 287)	12 (3 to 27)

[a]Confidence intervals of excess mortality incorporate uncertainty in estimates of baseline mortality and of the risk associated with the blackout.